THE UNIVERSITY OF CALGARY

Significance of Mixed Carbonate-Siliciclastic Sedimentation in the Mississippian Banff Formation, Greater Cessford Area, Southeastern Alberta

by

Alice G. Goldthorpe

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY AND GEOPHYSICS

CALGARY, ALBERTA

JUNE, 1997

© Alice G. Goldthorpe 1997

National Library of Canada
Acquisitions and Bibliographic Services
395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale du Canada
Acquisitions et services bibliographiques
395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-24663-9

Canada

ABSTRACT

The Lower Mississippian Banff Formation consists of a shallowing- and coarsening-upward succession of carbonates and fine-grained siliciclastics deposited on a southwestward-deepening ramp in southeastern Alberta. This study divides the Banff Formation into six cyclic units, each of which is a correlatable lithologic assemblage interpreted from associations of different log signatures. Differential sedimentation has generated piles of sediment with highly variable shape, thickness and areal extent in all but the uppermost unit, which is characterized by broad, evenly-spaced sediment belts. The ramp profile appears to have changed over time from a shallowly sloping surface during deposition of Units 1 and 2 to a surface with a slightly inflected or curved profile during deposition of Units 3-6. A medial siliciclastics belt separates two carbonate belts in Units 3 to 6 and is interpreted as a series of bottom current deposits distributed along a slight inflection on the inner ramp.

ACKNOWLEDGMENTS

First and foremost, I wish to thank my supervisor, Dr. John Hopkins, both for proposing the project and for his patient supervision throughout its duration. I am also grateful to Crestar Energy for their financial support of my work at the Alberta Energy and Utilities Board Core Storage Facility. Special thanks go to the Canadian Society of Petroleum Geologists, the Canadian Well Logging Society, and the University of Calgary for their financial support during my graduate studies. I also would like to thank Brian Fong for his invaluable assistance with computer equipment, and Deb Glatiotis for assistance with the SEM, XRD, and the equipment in room 142. Thanks also to Mickey Horvath for preparing the thin sections used in this study, and to Rick Larush for assistance with the photography.

TABLE OF CONTENTS

APPROVAL PAGE ii
ABSTRACT iii
ACKNOWLEDGMENTS iv
TABLE OF CONTENTS v
LIST OF FIGURES x
LIST OF PLATES xiii
LIST OF TABLES xiv

CHAPTER 1: INTRODUCTION 1
1.1 PURPOSE 1
1.2 CARBONATE RAMPS AND SEQUENCE STRATIGRAPHY 4
1.3 PREVIOUS WORK 5
1.4 METHODS 11
1.4.1 Subsurface Analysis 11
1.4.2 Core Work 13
1.4.2.1 Logged Cores 13
1.4.2.2 Petrophysical Data 13
1.4.3 Petrography 15
1.4.3.1 Thin Sections 15
1.4.3.2 Scanning Electron Microscope 15
1.4.3.3 X-Ray Diffraction 15
1.4.4 Mini Permeameter 16
1.4.5 Classification Schemes 16
1.5 TERMINOLOGY 17
1.6 STRATIGRAPHY 18
1.7 TECTONIC SETTING 20
1.8 SEDIMENTOLOGY 21
1.9 PALEOGEOGRAPHIC SETTING AND CLIMATE 22

CHAPTER 2: CORRELATION OF UNITS IN THE BANFF FORMATION 25
2.1 RAMP GEOMETRY 25
2.1.1 Introduction 25
2.1.2 Global Ramps 25
2.1.3 Mississippian Ramps 27
2.1.4 Banff and Lodgepole Formations 28
2.1.5 Discussion 30
2.2 METHODS 33

2.2.1 Introduction 33
2.2.2 Geophysical Well Logs 33
2.2.3 Identification and Recognition of Units 34
2.2.4 Formation Scale Mapping 37
2.2.5 Mapping of Banff Formation Units 54
2.3 DISCUSSION OF FORMATION SCALE MAPPING 67
2.4 UNIT DESCRIPTIONS AND GEOMETRY 75
2.4.1 Introduction 75
2.4.2 Unit 1 76
2.4.3 Unit 2 77
2.4.4 Unit 3 78
2.4.5 Unit 4 79
2.4.6 Unit 5 81
2.4.7 Unit 6 82
2.5 SUMMARY 83

CHAPTER 3: SEDIMENTOLOGY 87
3.1 INTRODUCTION 87
3.2 LITHOFACIES 89
3.2.1 Shale 89
3.2.1.1 Description 89
3.2.1.2 Thickness and Distribution 89
3.2.1.3 Depositional Environment 92
3.2.2 Bioturbated Mudstone 93
3.2.2.1 Subfacies Bioturbated Mudstone 93
3.2.2.1.1 Description 93
3.2.2.1.2 Thickness and Distribution 93
3.2.2.1.3 Depositional Environment 98
3.2.2.2 Subfacies Bioturbated Silty Mudstone 98
3.2.2.2.1 Description 98
3.2.2.2.2 Thickness and Distribution 99
3.2.2.2.3 Depositional Environment 106
3.2.3 Dolomitic/Calcareous Quartzose Siltstone/Sandstone . 106
3.2.3.1 Description 106
3.2.3.2 Thickness and Distribution 112
3.2.3.3 Depositional Environment 112
3.2.4 Pelleted Mudstone to Packstone 116
3.2.4.1 Description 116
3.2.4.2 Thickness and Distribution 118
3.2.4.3 Depositional Environment 118

3.2.5 Crinoidal Bioclastic Wackestone to Packstone 119
3.2.5.1 Description 119
3.2.5.2 Thickness and Distribution 125
3.2.5.3 Depositional Environment 125
3.2.6 Crinoidal Bioclastic Grainstone 127
3.2.6.1 Description 127
3.2.6.2 Thickness and Distribution 131
3.2.6.3 Depositional Environment 131
3.3 FACIES ASSOCIATIONS 132
3.3.1 Introduction 132
3.3.2 Unit 1 133
3.3.3 Unit 2 133
3.3.4 Unit 3 133
3.3.5 Unit 4 134
3.3.6 Unit 5 134
3.3.7 Unit 6 135

CHAPTER 4: CARBONATE-SILICICLASTIC MIXTURES AND A RAMP MODEL FOR THE BANFF FORMATION 136
4.1 INTRODUCTION 136
4.2 COMPARISON WITH REGIONAL BANFF FORMATION 137
4.2.1 Regional Banff Formation and Established Ramp Models 137
4.2.2 Greater Cessford Area 140
4.3 CARBONATE-SILICICLASTIC MIXTURES 142
4.3.1 Introduction 142
4.3.2 Punctuated Mixing 143
4.3.3 Facies Mixing 144
4.3.4 In Situ Mixing 144
4.3.5 Source Mixing 144
4.3.6 Selected Examples 145
4.3.6.1 Introduction 145
4.3.6.2 Modern Mixed Carbonate-Siliciclastic Shelves 146
4.3.6.3 Mixed Carbonate-Siliciclastic Sedimentation in the Western Canada Sedimentary Basin 148
4.3.7 Banff Formation in the Greater Cessford Area 149
4.4 SOURCE OF SILICICLASTIC SEDIMENT 151
4.4.1 Introduction and Background 151
4.4.2 Source of Siliciclastic Sediments in the Banff

Formation 153
4.5 STRUCTURAL INFLUENCES ON RAMP SEDIMENTATION 154
4.6 BANFF FORMATION RAMP MODEL FOR THE GREATER CESSFORD AREA 157
4.6.1 Introduction 157
4.6.2 Climate 158
4.6.3 Depositional Environments 158
4.6.3.1 Units 1 and 2 158
4.6.3.2 Units 3-6 160
4.6.4 Siliciclastic Sediments 160
4.6.4.1 Distribution of Siliciclastic Sediments 160
4.6.4.2 Sediment Movement Mechanisms and Bottom Currents 162
4.7 SUMMARY 164

CHAPTER 5: DIAGENESIS 165
5.1 INTRODUCTION 165
5.2 BIOLOGICAL DIAGENESIS 165
5.3 CEMENTS 166
5.3.1 Syntaxial Overgrowth Calcite Cement 166
5.3.2 Isopachous Bladed Calcite Cement 166
5.3.3 Equant Finely to Coarsely Crystalline Calcite Cement 167
5.3.4 Blocky Dolomite Cement 170
5.3.5 Quartz Cement 170
5.4 DISSOLUTION 171
5.5 REPLACEMENT 171
5.5.1 Dolomite Replacement 171
5.5.2 Silica Replacement 171
5.5.3 Hematite Replacement 172
5.5.4 Pyrite Replacement 173
5.5.5 Hydrocarbon Replacement 173
5.6 NEOMORPHISM 173
5.7 STYLOLITES AND OTHER PRESSURE SOLUTION FEATURES 176
5.8 PHYSICAL COMPACTION 176
5.9 PARAGENETIC SEQUENCE 177
5.10 SEDIMENTATION AND DIAGENESIS ASSOCIATED WITH THE POST-MISSISSIPPIAN UNCONFORMITY 177
5.10.1 Introduction 177

5.10.2 Sub-Unconformity Banff Formation Residual Deposits 179
5.10.3 Detrital Formation 182
5.10.4 Ellerslie Formation 183
5.10.5 Diagenesis 183
5.11 SUMMARY 184

CHAPTER 6: PETROLEUM GEOLOGY 185
6.1 INTRODUCTION 185
6.2 EXISTING PRODUCTION 186
6.3 POROSITY AND PERMEABILITY DEVELOPMENT 191
6.4 SUMMARY 197

CHAPTER 7: SUMMARY AND CONCLUSIONS 198

REFERENCES 203

APPENDIX A: GEOPHYSICAL WELL LOG TOPS DATABASE 221
APPENDIX B: UNIT WELL LOG DATABASE 258
APPENDIX C: LIST OF CORES EXAMINED 263
APPENDIX D: CORE DESCRIPTIONS 266
APPENDIX E: THIN SECTION DESCRIPTIONS 319
APPENDIX F: X-RAY DIFFRACTION DATA 366
APPENDIX G: SAMPLE DETAILS 368
APPENDIX H: CORES EXAMINED-CYCLIC BREAKDOWN 373

LIST OF FIGURES

Figure 1.1: Study Area Location Map 2
Figure 1.2: Stratigraphic Nomenclature in Southeastern Alberta 3
Figure 1.3 (a): Western and Eastern Domains of the Banff Formation 9
Figure 1.3 (b): Depositional Environment Summary Diagram of the Eastern and Western Domains 9
Figure 1.4: Banff and Exshaw Formation Penetrations 12
Figure 1.5: Banff Formation Cores Examined 14
Figure 1.6: Tectonic Elements of Western North America during the Carboniferous 19
Figure 2.1 (a): Rich's Model 26
Figure 2.1 (b): Grosmont Formation Cross-Section 26
Figure 2.2: Type Log 14-35-025-15W4 35
Figure 2.3: Type Log 12-20-021-14W4 36
Figure 2.4: Base Map for Cross-Sections A-A' and B-B' 38
Figure 2.5 (a): Cross-Section A-A'-Stratigraphic 39
Figure 2.5 (b): Cross-Section A-A'-Structural 40
Figure 2.6 (a): Cross-Section B-B'-Stratigraphic 41
Figure 2.6 (b): Cross-Section B-B'-Structural 42
Figure 2.7 (a): Stettler Formation Structure Map 43
Figure 2.7 (b): Stettler Formation Trend Map 43
Figure 2.8: Stettler Formation Block Diagram 44
Figure 2.9 (a): Big Valley Formation Structure Map 45
Figure 2.9 (b): Big Valley Formation Trend Map 45
Figure 2.10: Big Valley Formation Block Diagram 46
Figure 2.11 (a): Exshaw Formation Structure Map 47
Figure 2.11 (b): Exshaw Formation Trend Map 47
Figure 2.12: Exshaw Formation Block Diagram 48
Figure 2.13 (a): Banff Formation Structure Map 49
Figure 2.13 (b): Banff Formation Trend Map 49
Figure 2.14: Banff Formation Block Diagram 50
Figure 2.15 (a): Mannville Formation Structure Map 51
Figure 2.15 (b): Mannville Formation Trend Map 51
Figure 2.16: Mannville Formation to Big Valley Formation Isopach Map 52
Figure 2.17 (a): Mannville Formation to Banff Formation Isopach Map 53
Figure 2.17 (b): Banff Formation to Big Valley Formation Isopach Map 53
Figure 2.18: Base Map for Cross-Sections C-C', D-D', E-E' and F-F' 55
Figure 2.19: Cross-Section C-C'-Stratigraphic 56
Figure 2.20: Cross-Section D-D'-Stratigraphic 57

Figure 2.21: Cross-Section E-E'-Stratigraphic 58
Figure 2.22: Cross-Section F-F'-Stratigraphic 59
Figure 2.23 (a): Isopach Map of Units 1-3 60
Figure 2.23 (b): Isopach Map of Units 4-6 60
Figure 2.24 (a): Unit 1 Isopach Map 61
Figure 2.24 (b): Unit 1 Shale Percentage Map 61
Figure 2.25 (a): Unit 2 Isopach Map 62
Figure 2.25 (b): Unit 2 Shale Percentage Map 62
Figure 2.26 (a): Unit 3 Isopach Map 63
Figure 2.26 (b): Unit 3 Shale Percentage Map 63
Figure 2.27 (a): Unit 4 Isopach Map 64
Figure 2.27 (b): Unit 4 Shale Percentage Map 64
Figure 2.28 (a): Unit 5 Isopach Map 65
Figure 2.28 (b): Unit 5 Shale Percentage Map 65
Figure 2.29 (a): Unit 6 Isopach Map 66
Figure 2.29 (b): Unit 6 Shale Percentage Map 66
Figure 2.30 (a): Unit 1 Neutron-Density Porosity Log Cross-Plot 68
Figure 2.30 (b): Unit 1 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 68
Figure 2.31 (a): Unit 2 Neutron-Density Porosity Log Cross-Plot 69
Figure 2.31 (b): Unit 2 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 69
Figure 2.32 (a): Unit 3 Neutron-Density Porosity Log Cross-Plot 70
Figure 2.32 (b): Unit 3 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 70
Figure 2.33 (a): Unit 4 Neutron-Density Porosity Log Cross-Plot 71
Figure 2.33 (b): Unit 4 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 71
Figure 2.34 (a): Unit 5 Neutron-Density Porosity Log Cross-Plot 72
Figure 2.34 (b): Unit 5 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 72
Figure 2.35 (a): Unit 6 Neutron-Density Porosity Log Cross-Plot 73
Figure 2.35 (b): Unit 6 Neutron minus Density Porosity versus Gamma Ray Log Cross-Plot 73
Figure 3.1: Environmental subdivisions of a carbonate ramp 88
Figure 3.2 (a): 16-06-025-08W4 Type Log 94
Figure 3.2 (b): 02/16-14-025-12W4 Type Log 94
Figure 3.2 (c): 02/16-22-025-12W4 Type Log 95
Figure 3.2 (d): 14-35-025-15W4 Type Log 95
Figure 3.2 (e): 06-22-026-16W4 Type Log 96

Figure 3.2 (f): 06-18-027-15W4 Type Log 96
Figure 3.2 (g): 16-28-030-16W4 Type Log 97
Figure 3.2 (h): 16-04-031-11W4 Type Log 97
Figure 3.3: Upper Dolomitic Quartzose Siltstone Isopach Map 113
Figure 3.4: Base Map for Cross-Sections G-G' and H-H' 114
Figure 3.5: Cross-Section G-G' and H-H'-Stratigraphic 115
Figure 4.1: Comparison of Regional Banff Formation Model with the Greater Cessford Area 138
Figure 4.2: Source and Transport of Clastics in Units 3-6 155
Figure 4.3: Block Diagram for Unit 2 159
Figure 4.4: Block Diagram for Units 3-6 161
Figure 5.1: Paragenetic Sequence 178
Figure 6.1: Banff Formation Producing Wells 187
Figure 6.2: Banff Formation Producing Fields 188
Figure 6.3 (a): Units 2 and 3 Quartzose Siltstone/Sandstone Porosity-Maximum Permeability Cross-Plot 192
Figure 6.3 (b): Unit 6 Dolomitic Quartzose Siltstone Porosity-Maximum Permeability Cross-Plot 192
Figure 6.4 (a): Crinoidal Bioclastic Grainstone Porosity-Maximum Permeability Cross-Plot 193
Figure 6.4 (b): Crinoidal Bioclastic Grainstone and Quartzose Siltstone/Sandstone Composite Porosity-Maximum Permeability Cross-Plot 193
Figure 6.5 (a): Unit 6 Dolomitic Quartzose Siltstone Porosity-Permeability Cross-Plot 194
Figure 6.5 (b): Crinoidal Bioclastic Grainstone Porosity-Permeability Cross-Plot . 194

LIST OF PLATES

Plate 1: Shale and Bioturbated Silty Mudstone Lithofacies - Core Photographs 91
Plate 2: Lithologic Contacts - Core Photographs 101
Plate 3: Bioturbated Silty Mudstone, Pelleted Mudstone to Packstone and Crinoidal Bioclastic Wackestone to Packstone Lithofacies - Thin Section Photomicrographs 103
Plate 4: Bioturbated Silty Mudstone and Dolomitic Quartzose Siltstone Lithofacies - Scanning Electron Microscope Photomicrographs 105
Plate 5: Dolomitic Quartzose Siltstone and Crinoidal Bioclastic Wackestone to Packstone Lithofacies - Core Photographs 108
Plate 6: Dolomitic Quartzose Siltstone Lithofacies - Thin Section Photomicrographs 111
Plate 7: Crinoidal Bioclastic Packstone and Crinoidal Bioclastic Grainstone Lithofacies - Core Photographs 121
Plate 8: Crinoidal Bioclastic Packstone and Crinoidal Bioclastic Grainstone Lithofacies - Scanning Electron Microscope Photomicrographs 124
Plate 9: Crinoidal Bioclastic Grainstone Lithofacies - Thin Section Photomicrographs 129
Plate 10: Diagenetic Features - Thin Section Photomicrographs 169
Plate 11: Diagenetic Features - Thin Section Photomicrographs 175
Plate 12: Transition Zone, Detrital and Ellerslie Formations - Core Photographs .. 181

LIST OF TABLES

Table 2.1: Summary of Unit Characteristics 84
Table 6.1: Summary of Banff Formation Producing Fields - Oil Data 189
Table 6.2: Summary of Banff Formation Producing Fields - Gas Data 190

CHAPTER 1: INTRODUCTION

1.1 PURPOSE

The Lower Mississippian (uppermost Famennian to upper Tournaisian) Banff Formation consists of a shallowing-upward succession of carbonates extending from southwestern Manitoba to southeastern British Columbia through to the southwestern part of the District of Mackenzie. The Banff Formation outcrops in the Canadian Rockies and is present in the subsurface in Alberta, Saskatchewan and Manitoba. In the latter two provinces, the Lodgepole Formation is the Banff Formation equivalent.

The Greater Cessford Area is defined in this study as Townships 21-31 and Ranges 7-16 west of the 4th Meridian in southeastern Alberta, Canada (Figure 1.1). This area was selected because of the presence of a distinctive siltstone unit (informally known as the Banff sandstone) within the Banff Formation as indicated by preliminary core description and computer database searches.

The Upper Devonian Wabamun Group consists of shelf carbonates (predominantly dolomite) with varying amounts of anhydrite and salt of the Big Valley and Stettler Formations (Figure 1.2). The shales and siltstones of the Exshaw Formation unconformably overlie the Wabamun Group carbonates, and are in turn unconformably overlain by carbonates and siliciclastics of the Banff Formation. Skeletal grainstones and cherty packstones of the Pekisko Formation overlie the Banff Formation in the southwest portion of the study area. In contrast, the Pekisko Formation has been truncated and breccias of the Detrital Formation deposited on the upper Banff Formation surface in the remainder of the study area.

The purposes of this research are to: (1) establish units and correlate them across the ramp, (2) determine the distribution and character of the siltstone unit, (3) identify the sedimentologic relationships and propose a depositional model, (4) establish paleogeographic depositional environments through Banff time, (5) ascertain the

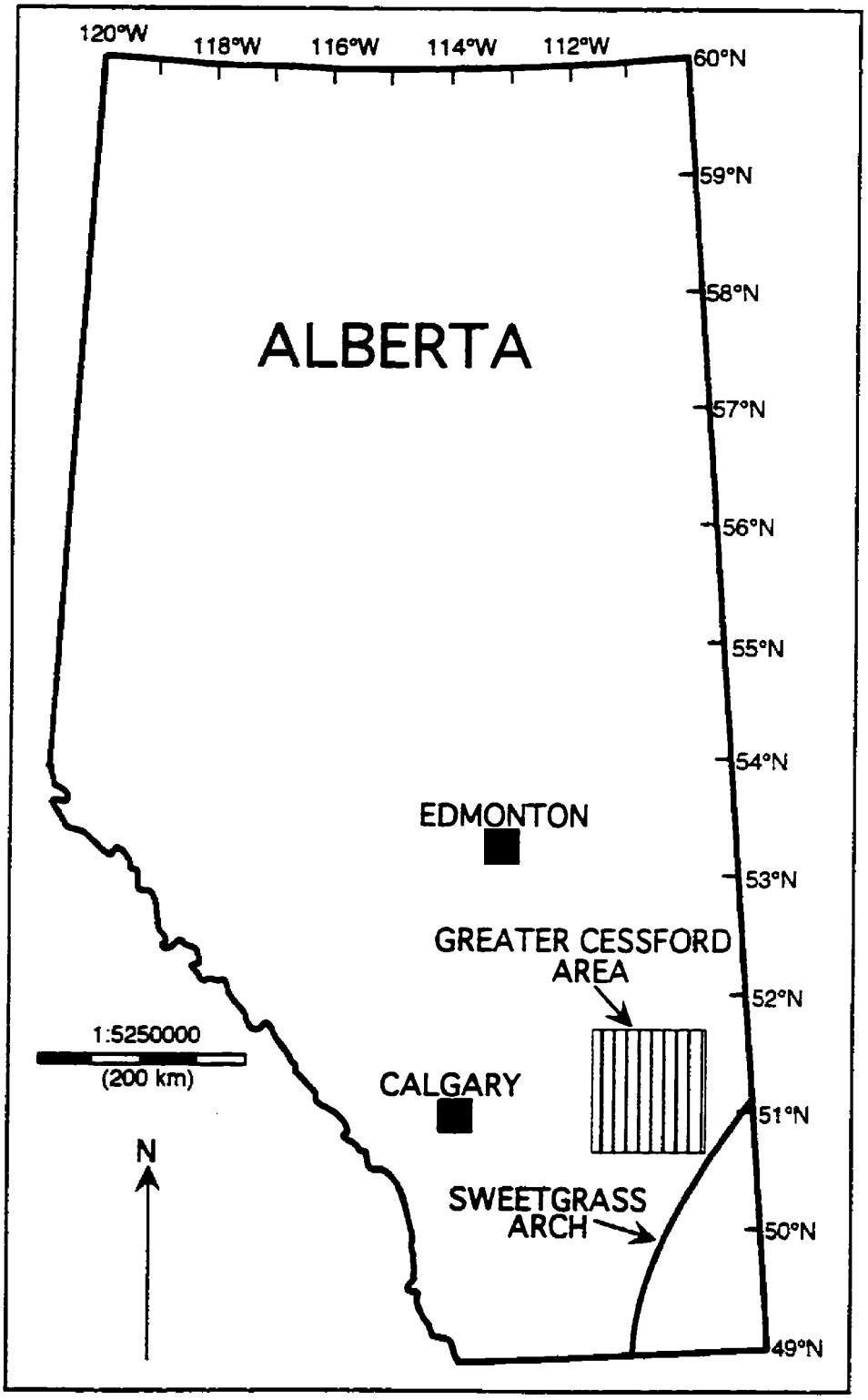


Figure 1.1. Location of the Greater Cessford Area in southeastern Alberta.

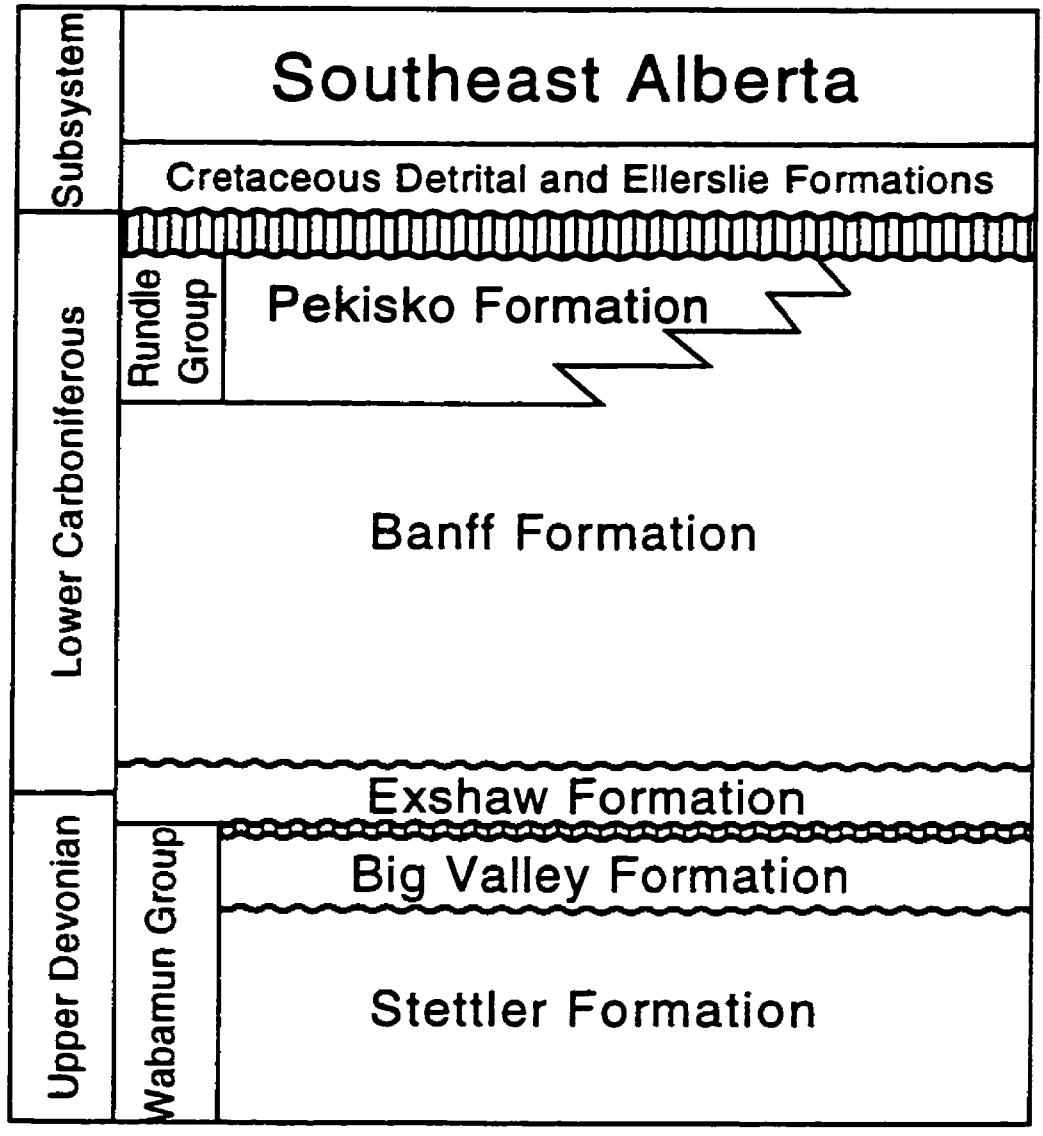


Figure 1.2. Stratigraphic nomenclature in southeastern Alberta (after Wonfor and Andrichuk 1956).

changing geometry of the carbonate ramp over time, (6) suggest possible controls on stratigraphic and sedimentologic relationships, (7) determine the paragenetic sequence, and (8) identify potential reservoir characteristics and reservoir forming processes.

1.2 CARBONATE RAMPS AND SEQUENCE STRATIGRAPHY

A carbonate ramp is a gently sloping depositional surface which passes gradually offshore from a shallow, wave-agitated setting into a deeper water, lower energy environment (Ahr 1973). Carbonate ramps are common in all geological periods but are especially dominant at times when reef-constructing organisms were absent or inhibited as in the Mississippian (Read 1982; Wright and Faulkner 1990). Burchette and Wright (1992) documented carbonate ramps in most types of sedimentary basins but noticed that they are best developed where subsidence is flexural and gradients are slight over large areas as in foreland and cratonic-interior basins, and along passive margins. Large ramps on passive margins commonly form linear sediment prisms trending for hundreds of kilometres along the basin margin.

Sequence stratigraphy integrates time and relative sea level changes to track the migration of facies (Sarg 1988). The Exxon sequence stratigraphic model and accompanying systems tract diagrams summarize the expected stratal patterns and geometries of siliciclastic depositional sequences that form in passive margin depositional basins (Haq et al. 1987; Vail 1987; Posamentier and Vail 1988). This work was largely based on seismic data. Handford and Loucks (1993) questioned the use of the Exxon model in carbonate environments due to the strong environmental controls over carbonate sedimentation and the diverse way in which carbonates respond to sea level changes.

Sequence geometries and stratigraphies are very difficult to determine from seismic data without using special processing on extensive, thin, featureless carbonate ramps. Burchette and Wright (1992) recognized that it is often necessary to determine

ramp sequence stratigraphies and geometries from widely spaced vertical sections using regional sedimentological, biostratigraphic and seismic data.

The prevailing approach to ramp geometry correlation has been based on models developed in passive margin settings using widely spaced data sets often tens of kilometres or more apart. The present work attempts to correlate units using closely spaced wells (1-5 kilometres apart) in a passive margin ramp setting.

1.3 PREVIOUS WORK

Published works on the subsurface Banff Formation are few in number (Moore 1958; Macauley et al. 1964; Martin 1967a, b, 1969; Richards 1989; Richards et al. 1993, 1994). The first published description of the Banff Formation was by McConnell (1887) who applied the term to a succession of Late Devonian and Triassic limestones and shales in the Bow Valley. He divided the Banff Formation into four parts; the Lower Banff limestone, Lower Banff shale, Upper Banff limestone and Upper Banff shale. Allan (1913) studied the Banff Formation in the Bow Valley and confirmed the nomenclature of McConnell (1887).

Kindle (1924) established the type locality of the Banff and overlying Rundle Formations at the north end of Mount Rundle and refined the Banff Formation to include only the dark argillaceous, more recessive limestones at the base of McConnell's (1887) Banff Formation. Kindle (1924) named the overlying massive, more resistant limestones the Rundle Formation.

Warren (1927) divided the type Banff Formation section into three members. Lower and upper shaly members under- and overlie the more resistant calcareous beds of the middle member respectively. In a later study (Warren 1937), he separated the black shales at the base of the Banff Formation from the overlying sediments and assigned them to the Exshaw Formation. Clark (1949) included overlying silty limestones as part of the Exshaw Formation. In addition, he recognized a 40 metre thick

fossiliferous member of the Banff Formation, which was later named the "Clark's member" by Beales (1950). Beales (1950) re-examined the same section as Warren (1927, 1937) and refined the upper, middle and lower member classification by suggesting different thicknesses for the three members.

The first detailed study of the type section was by Harker and McLaren (1958) who measured approximately 10 metres of each of the black shales and of the siltstones. Later investigations by Macqueen and Sandberg (1970) concluded that the black shale measurements were accurate but that the siltstone was almost four times as thick as previously recorded. Macqueen and Sandberg (1970) proposed that a thin dark fissile shale overlying the siltstone represents a disconformable contact between the Exshaw and Banff Formations.

Douglas (1953) and Douglas and Harker (1958) recognized the presence of the Exshaw, Banff and Rundle Formations in the Mount Head map area. The Rundle Formation was changed to the Rundle Group comprised of the Livingstone, Mount Head and Etherington Formations. The Livingstone Formation was further divided into the Pekisko (lower) and Turner Valley (upper) Members respectively. Gallup (1951) had previously termed the dark coloured limestones at the base of the Turner Valley Member the Shunda Formation. The Pekisko and Turner Valley Members were upgraded to formations by Penner (1958). The Livingstone, Pekisko and Turner Valley Formations consist of grain-supported carbonates.

The Middle and Upper Members of the Banff Formation in the Bow Valley were considered to be lateral equivalents of the subsurface Pekisko and Shunda Formations by Moore (1958). Nelson and Rudy (1959), Nelson (1961), Green (1962) and Middleton (1963) all correlated the subsurface Pekisko and Shunda Formations with various levels of the Banff Formation in outcrop. Macqueen and Bamber (1967; Macqueen et al. 1972) used stratigraphic, lithologic, paleoenvironmental and macrofaunal evidence to show that the Pekisko, Shunda and Turner Valley Formations

are the lateral equivalents of the Livingstone Formation. The successions including the Banff, Pekisko, Shunda and Turner Valley Formations comprise the eastern facies, and the Banff and Livingstone Formations constitute the western facies in southwestern Alberta. Macqueen and Bamber (1967) found no evidence to suggest that the Shunda Formation should be correlated with the upper member of the type Banff Formation. Further stratigraphic work by Oswald (1968) and Mamet and Mason (1968), as well as microfaunal data presented by Petryk, Mamet and Macqueen (1979) further supported Macqueen and Bamber's (1967) conclusions. More recent work by Richards (1989; Richards et al. 1993) suggests that the Pekisko Formation of south and southwestern Alberta is in fact equivalent to the upper part of the Banff Formation.

Cycles in the Banff Formation were first recognized by Spreng (1953), who defined six cycle types based on different repetitive patterns of limestone and shale in outcrops within Banff National Park. Ethier (1970) expressed the cyclical bedded successions of open marine limestones and shales of the Banff Formation in the southern Canadian Rockies in terms of mathematical probabilities. A method of assessing the similarity between pairs of transition probability matrices was not found to be useful for correlating individual beds in the Banff Formation. She established that the upper two-thirds of the Banff Formation consisted of siliceous limestone grading up into wackestones which are in turn overlain by packstones and grainstones. This coarsening-upward succession is capped by a mudstone unit.

Macqueen and Bamber (1974) studied the stratigraphy, biostratigraphy and sedimentology of the Lower Carboniferous at a thrust-faulted anticline within the Foothills. Here, the Banff Formation consists of argillaceous carbonate rocks and calcareous and/or dolomitic shales.

A paleoecological study of the Banff Formation was undertaken by Hanneman (1977) at Ram Mountain. Sedimentological and paleontological evidence was used to establish the paleoenvironments of the upper Banff as grading from shallow subtidal

conditions in the lower portion of the section to an intertidal depositional environment higher in the section. In addition, four faunal units were recognized on the basis of a dominant brachiopod species.

Bamber et al. (1980, 1981, 1984) furthered their previous work (Macqueen and Bamber 1967, 1974; Macqueen et al. 1972) by showing that an eastern belt of thick, platform carbonates and detrital clastics grade laterally into a western belt of thin, basinal shale across a transitional platform margin with a very low depositional slope.

Chatellier (1983, 1988, 1992) confirmed the presence of an eastern facies in the subsurface and a western facies restricted to the Front Ranges (Figure 1.3a). The eastern facies consists of rhythmic argillaceous to cherty limestones and crinoidal grainstones overlain by fossiliferous argillaceous limestones. Crinoidal packstones and dolomitic to silty limestones cap the succession. The western facies consists of rhythmically bedded argillaceous limestones overlain by black cherty lime mudstones and crinoidal lime grainstones overlain by fossiliferous and argillaceous limestones. Chatellier (1983) recognized three shallowing-upward "mesosequences" in the eastern facies which collectively form a "megasequence". In contrast, only two "mesosequences" were identified in the western facies (Figure 1.3b).

Chatellier (1983) interpreted the Banff Formation as a very extensive, westward-prograding, homoclinal carbonate ramp. He used Rich's model (1951) to divide the ramp into three parts: the fondoform (deep floor), clinoform (sloping floor) and undaform (zone of wave action). The first mesosequence of the eastern facies and the entire western facies was deposited on an open marine outer ramp with basin, slope, deep marine, and barrier shoal depositional environments encompassing the fondoform, clinoform and the base of the undaform. The second and third mesosequences were deposited on a restricted marine inner ramp consisting of subtidal, intertidal and supratidal depositional environments all of which are part of the undaform.

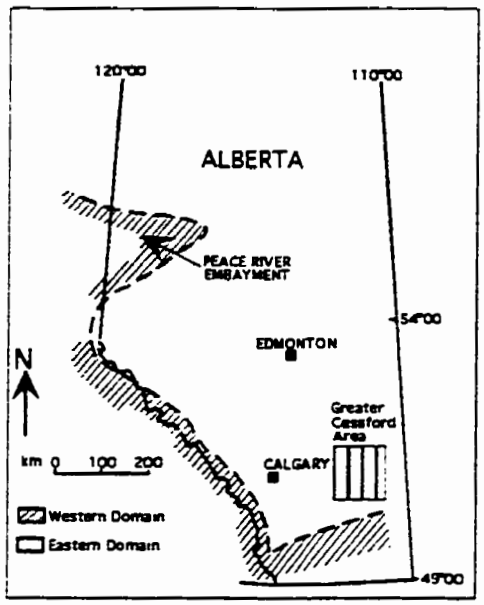


Figure 1.3 (a). The Western and Eastern Domains of the Banff Formation (after Chatellier 1988).

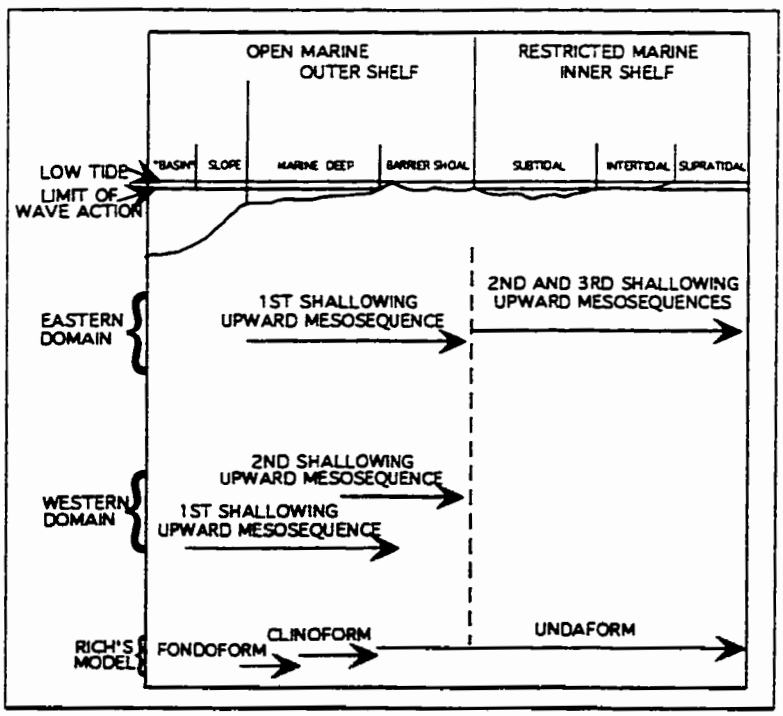


Figure 1.3 (b). Summary diagram of the eastern and western domains (after Chatellier 1983, 1988).

An extensive investigation of Lower Carboniferous brachiopods from the Banff Formation was undertaken by Carter (1987). He documented 87 brachiopod species from the eastern Cordillera of Alberta and British Columbia and derived three brachiopod biostratigraphic zones for the Banff Formation. The brachiopods of the Banff Formation were compared to the standard section of the Mississippian System in the mid-continent and to the correlative Lodgepole Formation in the Cordilleran region of the western United States. Of the species described, the majority are either identical to or have close affinity with, Banff Formation specimens. This suggests that marine communication may have existed between the mid-continent and the northern Cordilleran region at some time during the early Mississippian.

O'Connell (1990) studied the anomalously thick Banff Formation succession in the Peace River Embayment to determine the configuration of the basin. The shallower water facies of the middle and upper Banff Formation show little thickness variation, indicating that the main phase of basin formation and infilling occurred during the Lower Banff. Through a series of stratigraphic cross-sections and isopach maps, O'Connell (1990) illustrated that the lower Banff Formation consists of slope and basin carbonate and shale deposited in two separate embayments. The two embayments formed as a result of burial of the Peace River Arch structure and continued differential subsidence of structures at the northern margin of the Arch.

Stoakes (1992) documented two transgressive-regressive cycles of sedimentation in the uppermost Wabamun Group, and Exshaw, Banff, Pekisko and Shunda Formations. The first cycle commenced with distal upper ramp sedimentation in the uppermost Wabamun Group and terminated with the progradation of ramp deposits in the lower part of the Pekisko Formation. The second cycle commenced with the backstepping of Pekisko Formation carbonate ramps and terminated with the progradation and basin-filling of the Shunda Formation. Stoakes (1992) suggests that

each Mississippian cycle represents increased reflooding of the Western Canada Sedimentary Basin and thus may be part of a much larger depositional phase.

The most recent summary of the Banff Formation is from the Geological Atlas of the Western Canada Sedimentary Basin (Richards et al. 1994). The Atlas expands on the extensive sedimentology, stratigraphy and tectonic work of Richards (1989) and Richards et al. (1993). The Atlas includes a series of regional cross-sections, isopach and structure maps, paleodepositional models, oil and gas pool accumulations, and discussion of the tectonic setting and lithostratigraphy of the Banff assemblage in Western Canada. The Banff assemblage includes carbonates and fine-grained siliciclastics of the Bakken, Exshaw, Lodgepole, Banff and Yohin Formations.

1.4 METHODS

1.4.1 Subsurface Analysis

A total of 3,549 wells penetrate the Banff Formation in the Greater Cessford Area. Most wells terminate in the top 20 metres and only 320 of these wells penetrate the entire Banff Formation section through to the top of the Exshaw Formation (Figure 1.4a, b). Almost 2,400 wells were examined for this study in order to obtain a minimum sample density of one data point in each Section where available. The top of each of the Banff, Exshaw, Big Valley and Stettler Formations was picked (Figure 1.2). In addition, the top and base of a variably calcareous or dolomitic quartzose siltstone were identified. The subsurface tops database is presented in Appendix A.

One third of the wells which penetrate the entire Banff Formation section were selected for more detailed analysis based on log quality and geographical distribution. Unit boundary tops and shale/silt percentage were determined for these wells and are presented in Appendix B.

The GeoGraphix Exploration System (GeoGraphix Inc.) was used to manipulate and contour the larger formation tops database because of its ability to handle larger

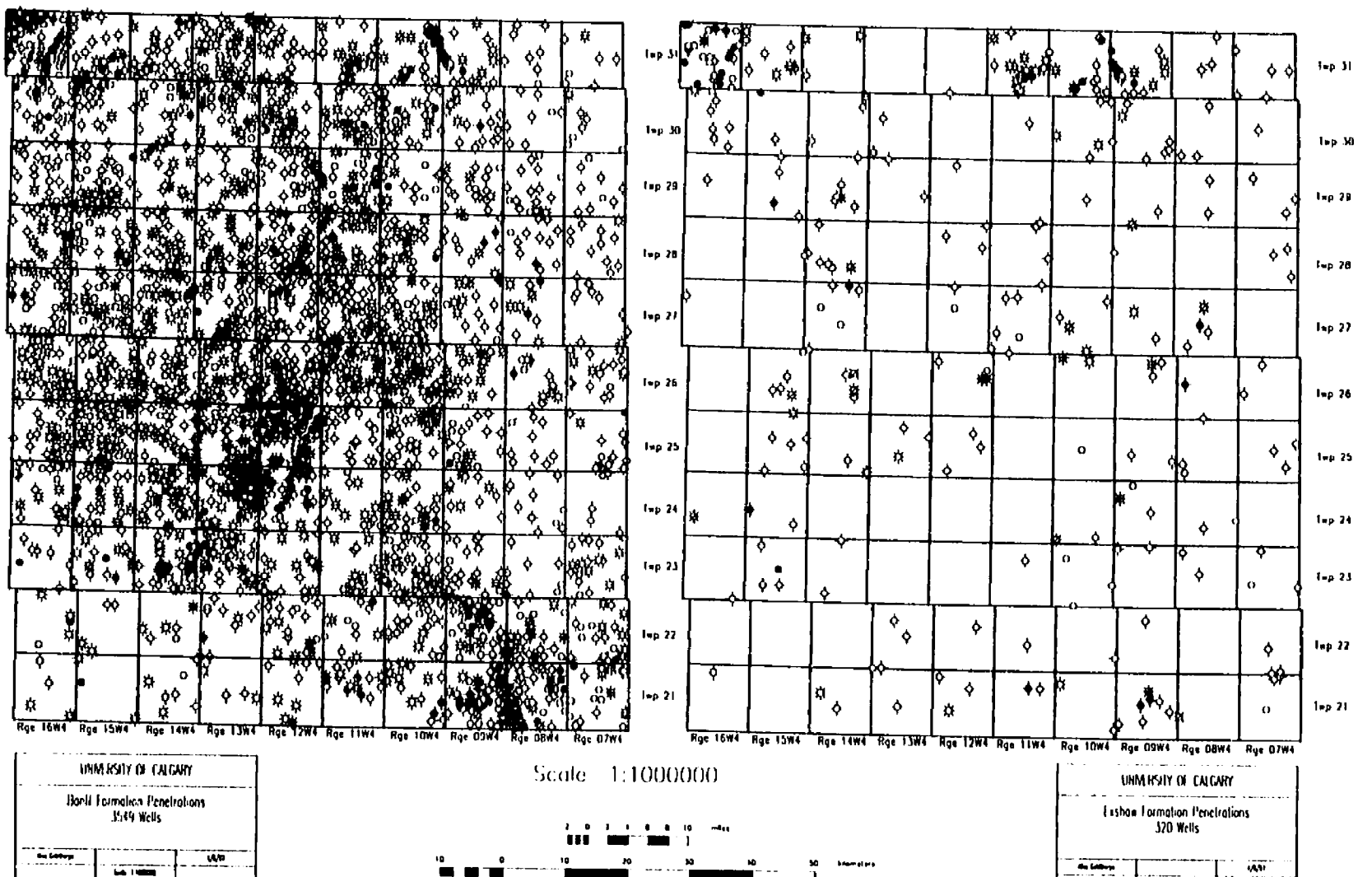


Figure 1.4 (a) and (b). Banff (a) and Exshaw (b) Formation well penetrations in the Greater Cessford Area.

datasets. Individual units of the Banff Formation were mapped using MCad Contour (Aupperle Services and Contracting Limited).

Four different logs (gamma ray, density, neutron, PEF) were digitized for representative wells using the DigiRule RAT (Digi-Rule Inc.). A variety of log cross-plots (neutron versus density porosity, neutron minus density porosity versus gamma ray) were generated in order to identify the various lithofacies as well as graphically illustrate porosity and permeability relationships.

1.4.2 Core Work

1.4.2.1 Logged Cores

Of the 47 cores longer than 3 metres in the Greater Cessford Area, 39 were logged at the Alberta Energy and Utilities Board core storage facility (Figure 1.5; Appendix C). An additional 6 cores were logged adjacent to the western limit of the study area for a total of 675 metres of logged core. Thirty-four of these cores are >10 metres long and 8 are >20 metres long. The majority of these cores are from the upper part of the Banff Formation. Several cores are representative of the middle and lower sections. Seven of these cores are through reservoir rocks which produce from the Banff Formation. Appendix D contains detailed core descriptions as well as porosity and permeability data where available.

1.4.2.2 Petrophysical Data

Porosity-permeability cross-plots were generated using Alberta Energy and Utilities Board commercial data from core analyses retrieved using DigiTech (DigiTech Information Services). Maximum permeability values were plotted against porosity to delineate the petrophysical porosity and permeability characteristics of potential reservoir lithofacies.

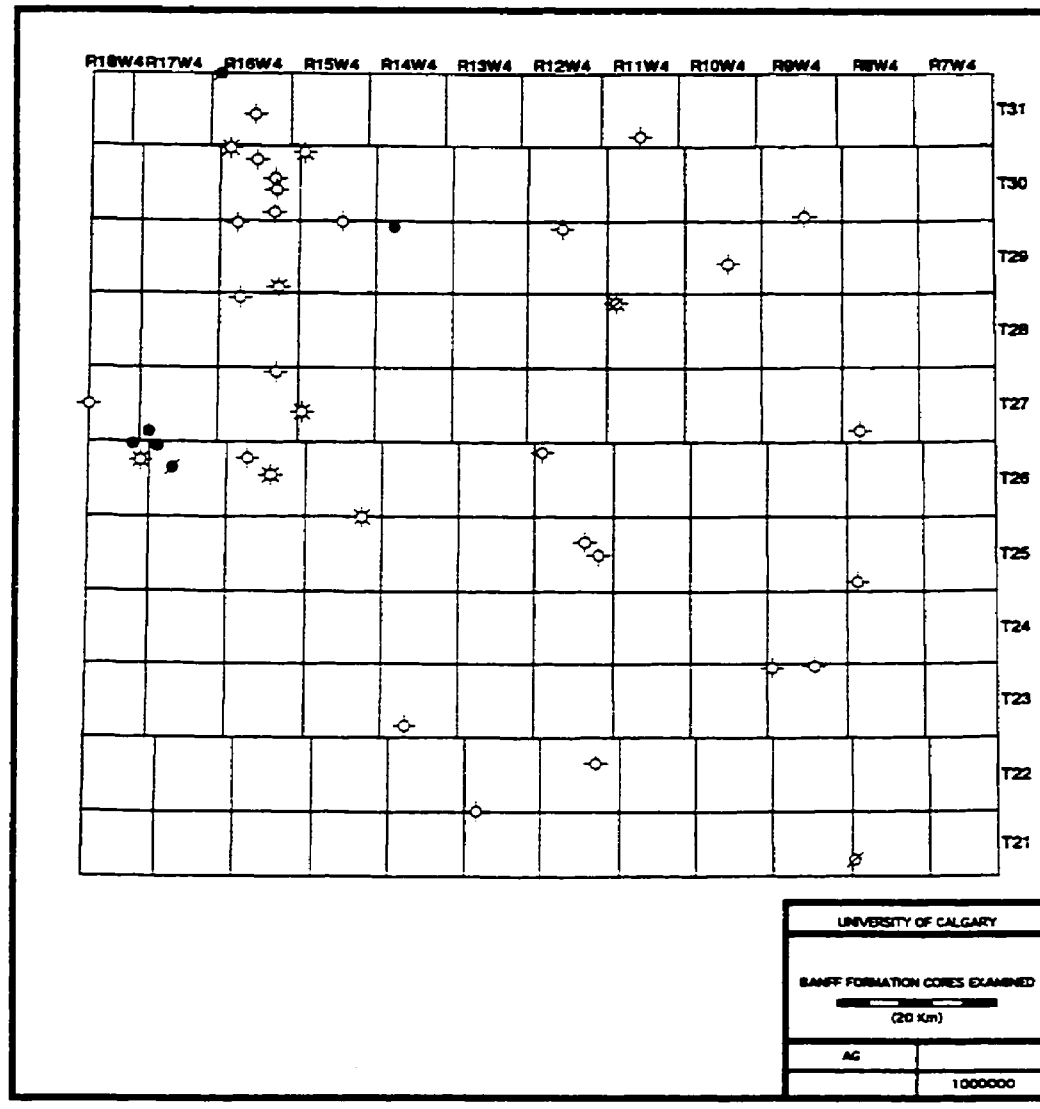


Figure 1.5. Map of the cores examined.

1.4.3 Petrography

1.4.3.1 Thin Sections

A total of 65 petrographic thin sections were cut from core samples. Blue dye epoxy was used to impregnate the slides. Half the area of each thin section was stained for carbonates with Alizarin Red-S and K-ferricyanide (Miller 1988). Standard transmitted light microscopy techniques were used to examine the thin sections. Mineralogy, grain size, sorting, skeletal components, cements and other characteristics were described in order to elucidate porosity and permeability relationships and the degree of diagenetic alteration. Appendix E contains detailed thin section descriptions.

1.4.3.2 Scanning Electron Microscope

A Cambridge Stereoscan 250 Scanning Electron Microscope with a Kevex Energy Dispersion Spectrometer was used to examine 12 samples in order to ascertain the three dimensional pore and pore throat geometries, cement evolution, and replacement fabrics. The samples were hammered from the core sample in order to obtain a fresh surface. The cut samples were attached to scanning electron microscope specimen plugs and a thin coat of Silpaint applied in order to provide an electrical ground from the sample to the plug. The samples were subsequently coated in gold in an Edwards S150B Vacuum Sputter Coater (Rutherford 1984; Trewin 1988).

1.4.3.3 X-Ray Diffraction

The purpose of the X-ray diffraction analyses is to determine mineralogical composition. X-ray techniques were used to distinguish between calcite and dolomite, and determine the presence and percentage of detrital clays. Mineralogical composition determined from X-ray diffraction analysis was compared with visual estimates from thin section work.

Thirty-five samples were selected and crushed into a very fine powder using a mortar and pestle. These samples were placed into a cavity mount holder and analyzed on a Scintag X-ray diffractometer. Standard conditions as laid out in the Department of

Geology and Geophysics X-ray diffraction manual (Glatiotis 1994) were adhered to. The starting and stopping angles were 4° and 74° respectively.

The data were manipulated using the computer program "Jade" (Materials Data, Incorporated) to highlight and measure the peaks in terms of 2θ, convert these values into d-spacings, and ultimately identify the minerals. Over 30 mineral pattern matches were attempted for all the samples analyzed. The mineralogical compositions (weight percentage) of the whole rock samples were calculated from peak intensities based on established d-spacings for individual minerals and are presented in Appendix F (Bayliss 1986; Bayliss et al. 1986; Hardy 1988; Moore and Reynolds Jr. 1989).

1.4.4 Mini permeameter

The core analysis stopped at the top of the siltstone unit in well 14-35-025-15W4. Nondestructive mini permeameter tests were conducted on 2.3 metres of siltstone to obtain the range of matrix permeability values and to quantify the impact of depositional and diagenetic effects on permeability (Georgi and Jones 1992; Jones 1992). In addition, profile permeability data can be correlated with wireline log data and core descriptions to further elucidate the nature of individual lithofacies and improve log correlation from well to well (Georgi et al. 1993). Permeability tests were conducted on the sand blasted, slabbed core at the Western Atlas core labs, Calgary.

1.4.5 Classification Schemes

Dunham's (1962) carbonate rock classification scheme was used for petrographic analyses. Rocks with less than 50% siliciclastic grains are classified as silty carbonates and rocks with more than 50% siliciclastic grains are classified as calcareous or dolomitic siltstones.

Mount (1985) proposed a new classification scheme for mixed siliciclastic and carbonate sediments. He defined a tetrahedron whose subdivision produces eight general classes of mixed sediment. The apices of the tetrahedron are (1) siliciclastic sand (sand sized quartz, feldspar, etc.), (2) mud (mixtures of silt and clay), (3) allochems (carbonate

grains such as bioclasts, peloids >20 micrometres in size), and (4) carbonate mud or micrite (<20 micrometres in size). The name of a class reflects the dominant grain type and the most abundant antithetic component. A rock that contains >50% siliciclastic material, of which most is sand sized, and contains secondary allochems, is called an allochemic sandstone. Micritic sandstone, allochemic and micritic mudstone, sandy or muddy allochem limestone, and sandy or muddy micrite are the other rock classifications. This scheme has not, however, been widely accepted in the established literature so the more traditional rock names of Dunham's (1962) classification scheme are used throughout this study.

1.5 TERMINOLOGY

Carbonate platforms can be grouped into two major categories: (1) carbonate shelves and (2) carbonate ramps. These terms are briefly defined below to avoid the confusion associated with conflicting classification schemes in the literature (Ahr 1973; Ginsburg and James 1974; Wilson 1975; Read 1982). The terms used in this study will follow the conventions of Burchette and Wright's (1992) extensive paper on carbonate ramp depositional systems.

A carbonate platform is a three-dimensional carbonate buildup with a subhorizontal top but with no implications as to the profile. A carbonate shelf is a carbonate body with a subhorizontal top and relatively abrupt margins. Carbonate ramps are gently sloping carbonate bodies that lack an obvious break in slope. Shallow, high energy, wave-agitated deposits of the nearshore zone pass downslope into deeper water, low-energy deposits (Burchette and Wright 1992).

Carbonate ramps may be further subdivided on the basis of profile into "homoclinal ramps" and "distally steepened ramps". Homoclinal ramps have relatively uniform, gentle slopes (1 to a few metres/kilometre) into the basin and generally lack significant gravity flow deposits and slumps. In contrast, distally steepened ramps have

a major break in slope and abundant slumps, slope breccias and turbidites. However, distally steepened ramps differ from shelves in that the major break in slope occurs many kilometres seaward of the transition from wave-agitated lime sand to subwave-base muds. The major break in slope on shelves occurs in this transition zone. Carbonate ramps commonly evolve into carbonate shelves as a result of high carbonate production on the developing shelf edge and sediment starvation of the off-shelf environments (Read 1982, 1985; Burchette and Wright 1992).

1.6 STRATIGRAPHY

The Lower Carboniferous Banff Formation is part of Sloss' (1963) upper Kaskaskia sequence. Two third-order sequences (the Exshaw/Bakken and Banff/Lodgepole) constitute the second-order, transgressive-regressive sequence termed the Banff assemblage (Richards 1989). The overlying Pekisko/Shunda, where developed, is a third-order sequence as well.

The Banff assemblage consists of carbonates and siliciclastics of the Bakken, Exshaw, Lodgepole, Banff and Yohin Formations. The axis of the Mesozoic expression of the Sweetgrass Arch is an arbitrary nomenclatural boundary that divides the assemblage into two successions (Figure 1.6). The Bakken and Lodgepole Formations were deposited east of the arch on the cratonic platform and in the Williston Basin. The Exshaw, Banff and Yohin Formations were deposited west of the arch and extend into the southwestern District of Mackenzie (Richards et al. 1994).

The Banff Formation unconformably overlies the Exshaw Formation and is variably conformably overlain by the Pekisko Formation or unconformably overlain by the Detrital Formation. The Lodgepole Formation unconformably overlies the widespread organic shale facies of the Bakken Formation and is conformably overlain by the Mission Canyon Formation limestones and its equivalents (Peterson 1988).

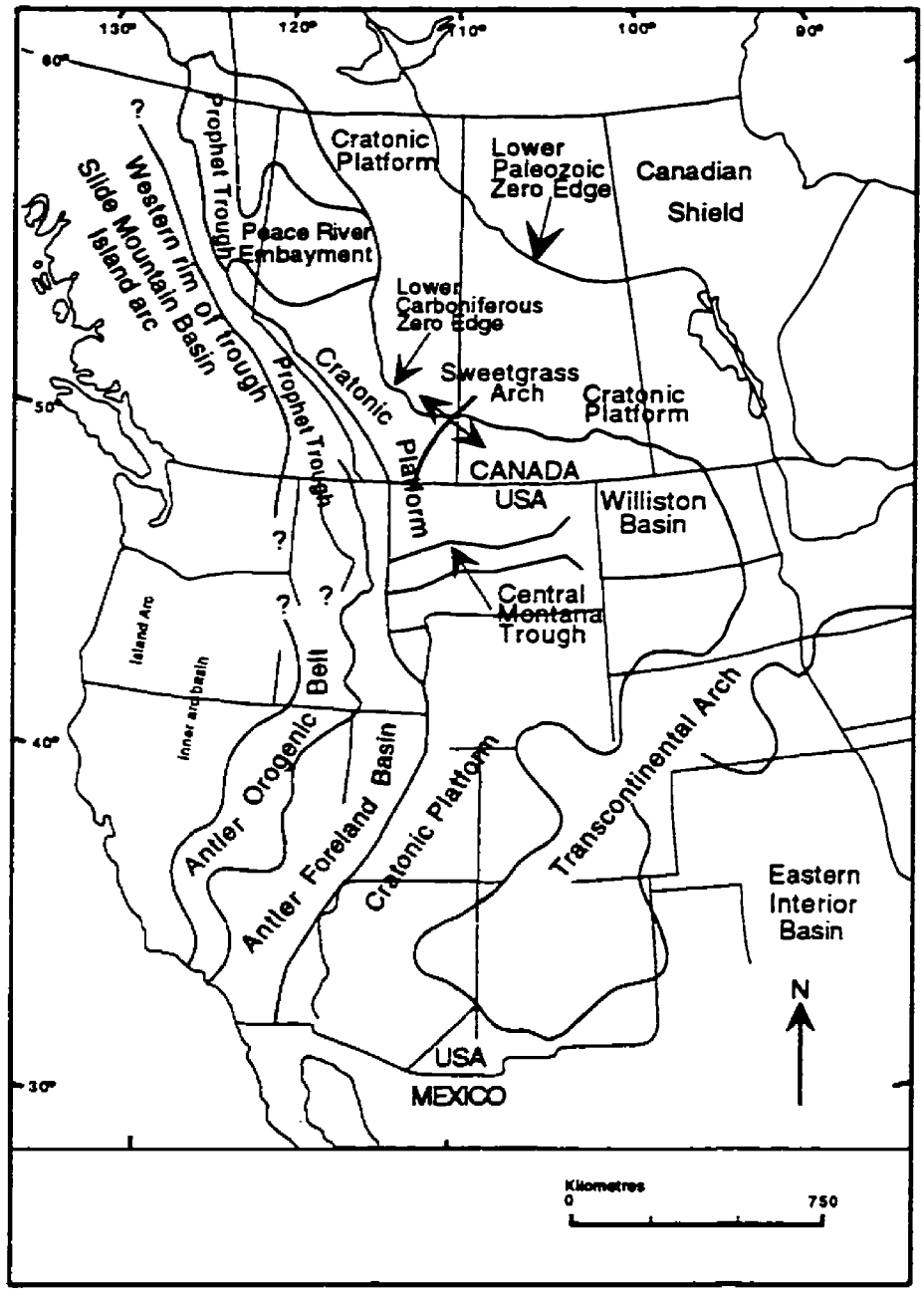


Figure 1.6: Principal tectonic elements of western North America during the Carboniferous (after Richards et al. 1994).

1.7 TECTONIC SETTING

The Banff Formation was deposited on the downwarped and downfaulted western margin of the ancestral North American plate. The principal tectonic elements in the Western Canada Sedimentary Basin during the Carboniferous were the Prophet Trough, the Peace River Embayment, the cratonic platform, the Williston Basin and the Yukon Fold Belt (Figure 1.6).

The Prophet Trough formed during the latest Devonian to Early Carboniferous and remained into the Late Cretaceous. The trough was connected to the Antler Foreland Basin in the western United States and extended up into the southern Yukon. An orogenic belt and a broad hinge zone were the western and eastern boundaries of the trough respectively. The hinge was a foreland peripheral bulge along most of its length during the late Famennian and Tournaisian (Richards 1989; Richards et al. 1994).

The Peace River Embayment was a fault-controlled re-entrant into the western cratonic platform, opening into the Prophet Trough. Several broad arches and the Williston Basin comprised the western cratonic platform. The Williston Basin was well developed during most of the Carboniferous but regional epeirogenic uplift and erosion occurred during the mid-Carboniferous (Richards et al. 1993, 1994).

During the Tournaisian an extensive seaway extended between southeastern Alberta and Wyoming. This seaway connected a large embayment which included the Williston basin to the Prophet Trough and the Antler Foreland Basin. The Williston Basin became a topographical basin concurrent with the development of a broad, northeast-trending uplift across the seaway in southeastern Alberta. Richards et al. (1994) modified the term "Madison Shelf" introduced by Sando et al. (1990) to describe the shelf areas that formed between southern Alberta and Manitoba in the seaway connecting the Williston Basin and Prophet Trough.

The Lodgepole Formation ramp in the northwestern United States was bordered in the east by the Transcontinental Arch and in the west by the Antler foredeep and

orogenic highlands. During Lower Mississippian time, the ramp was dissected by the Central Montana Trough which was the marine connection between the Antler foredeep and the Williston Basin (Figure 1.6).

The axis of the proto Sweetgrass Arch is interpreted to be approximately coincident with that of its present-day expression during the Carboniferous (Richards et al. 1994). The Sweetgrass Arch was not a positive feature in southeastern Alberta until Early Visean time, postdating deposition of the Banff and Lodgepole Formations (Podruski 1988; Richards 1989).

A principal phase of tectonism commenced during the latest Devonian and continued into the late Tournaisian and early Visean. This phase followed broad Famennian epeirogenic uplift that is recorded by the unconformity at the base of the Big Valley Formation (Richards et al. 1994). Marked regional subsidence resulted dominantly from intraplate compressive stress, but also from block faulting and tectonic loading during the Antler Orogeny of the western United States and the Cariboo Orogeny of eastern British Columbia. The major tectonic elements on Figure 1.6 were established during this phase of tectonism (Richards 1989; Bond and Kominz 1991; Smith et al. 1993).

Moderate subsidence rates and basinward progradation of shallow-water carbonates during the late Tournaisian and early Visean mark the transition between the compressional regime of the Tournaisian and the dominantly extensional tectonics of the Visean (Richards et al. 1994).

1.8 SEDIMENTOLOGY

Hays (1985) and Richards and Higgins (1988) documented the deposition of fine-grained siliciclastics of the Bakken and Exshaw Formations in euxinic-basin to shallow-neritic environments during the late Famennian and earliest Tournaisian time. Black shales of the lower Exshaw Formation record the culmination of a regional

transgression that commenced with the deposition of the underlying Famennian Big Valley Formation. Most of the Exshaw Formation was subaerially eroded during regional shallowing in the early Tournaisian creating an unconformity between the Exshaw Formation and the overlying Banff Formation. Shallow marine sandstone, siltstone and ooid grainstones in the middle Bakken record shallowing (Richards et al. 1993, 1994).

Basal black shales of the Banff Formation mark the start of a second transgression. The establishment of distal-ramp and slope environments in the middle and upper Banff Formation chronicle the continuation of this transgression (Richards et al. 1994). Waulsortian mounds developed in the Williston Basin and Central Montana Trough at this time (Smith 1977; Precht and Shepard 1988).

Regional shallowing and progradation of slope and distal ramp to supratidal carbonates and siliciclastics record regional shallowing following the early Tournaisian transgression. Restricted-shelf lithofacies of the Banff Formation record the end of the regression on the stable cratonic platform. In contrast, the regression culminated with sedimentation of the overlying Rundle Assemblage on the unstable craton in Southern Alberta and in most of the Williston Basin and Prophet Trough. Progradation and shallowing during the regression were interrupted by a regional transgression and deposition of deep water slope sediments in the southern Prophet Trough (Richards et al. 1993, 1994).

1.9 PALEOGEOGRAPHIC SETTING AND CLIMATE

One or a combination of paleomagnetic, paleoclimatic, paleobiogeographic and tectonic data have been used by numerous authors to reconstruct the position of North America during the Tournaisian stage (Scotese et al. 1979; Scotese 1984; Van der Voo 1988; Witzke and Heckel 1988; Ziegler 1988; Golonka et al. 1994; Metcalfe 1994). Paleomagnetic data is most often used to constrain continental blocks to specific

latitudes (Scotese 1984) while longitudinal placement is inferred from tectonic and historic evidence (Witze and Heckel 1988). Secondary remagnetization, if unrecognized, can severely thwart plate reconstruction, as can tectonic rotations and displaced terranes (Scotese 1984).

As a result, the location of the Greater Cessford Area during Tournaisian time is only broadly constrained to have been between 10° south and 25° north latitude (Scotese 1984; Van der Zwan et al. 1985; Van der Voo 1988; Witzke and Heckel 1988; Ziegler 1988; Golonka et al. 1994; Metcalfe 1994). Alberta was located on the western edge of the North American continental land mass immediately preceding the amalgamation of the supercontinent Pangea.

Parrish (1982) qualitatively modeled paleoatmospheric circulation on paleogeographic reconstructions for the Late Cambrian through to the Late Permian. Her work was guided by modern atmospheric circulation patterns and principles and the interpreted paleogeographic settings of Scotese et al. (1979) for each stage. The Greater Cessford Area lies within the northeast trades and equatorial easterlies belts. Dry offshore prevailing winds would have been the norm during the winter months. Dominant paleowinds were to the south. Winter high pressure cells and a large summer low pressure cell over northern Laurussia constituted a tropical monsoonal circulational system (Parrish 1982, 1993; Bardossy 1994; Francis 1994). Strong monsoonal storms may have occurred all year round, but were particularly frequent during the summer.

Rowley et al. (1985) suggest that monsoonal conditions would make the equatorial region dryer by deflecting rainfall north and south of the equator into a low pressure cell in the southern hemisphere. In a study conducted in Great Britain, Wright (1990) confirmed the presence of a monsoonal system during the Tournaisian. He suggests the presence of a semi-arid climate with seasonal rainfall interrupted by more humid phases.

The Persian Gulf lies between latitudes 24° and 30.30° north which is the northern limit of the estimated position of the Greater Cessford Area during the Tournaisian. An arid, sub-tropical, essentially continental climate with high summer temperatures and frequent strong winds, stimulate the formation of evaporitic minerals and the delivery of eolian dust to the basin in the Persian Gulf. Average annual rainfall is less than 5 centimetres a year (Purser and Seibold 1973).

There is a marked seasonality to the climate of the Persian Gulf. Strong winds and dust storms with temperatures between 45-50°C are common in the winter months, with calmer winds and temperatures around 20°C in the summer (Purser and Seibold 1973). Coastal environments are swept by waves and surface currents because the prevailing winds blow down the axis of the gulf. Extremely high evaporation rates due to frequent winds, high temperatures, and low precipitation cause abnormal salinities throughout most of the basin. Fluviatile influx is limited to a single delta and to the mountainous Iranian coast where terrigenous sediments contrast with the carbonates forming in the shallow seas in front of the low deserts of Arabia.

Comparison with modern environments indicates that most of the Western Canada Sedimentary Basin would have been dominated by arid to semi-arid tropical and subtropical desert climates, with more humid climates in the northwest during the Tournaisian (Richards 1989). The Greater Cessford Area likely had an arid to semi-arid tropical desert climate with seasonally fluctuating temperatures, winds, rainfall and storm activity.

CHAPTER 2: CORRELATION OF UNITS IN THE BANFF FORMATION

2.1 RAMP GEOMETRY

2.1.1 Introduction

The prevailing approach to establishing ramp geometry and stratigraphy has been the construction of a number of regional cross-sections across entire ramp systems. These cross-sections span hundreds of kilometres and use wells or outcrop sections which are often tens of kilometres or more apart (Chatellier 1983, 1988, 1992; Wright 1986, 1987; Elrick and Read 1991; Chen and Webster 1994; etc.). Individual ramp units 15-150 metres thick are commonly interpreted as third-order cycles (1-10 million years duration). These are correlated as clinoforming packages of approximately uniform thickness which prograde into the basin (Figure 2.1). No detailed correlations of ramp units <15 metres thick and interpreted as fourth- or fifth-order cycles (0.01-0.5 million years duration) were found in the published literature.

2.1.2 Global Ramps

Ahr (1973) described carbonate ramp sediments as wedge-shaped deposits that thicken seaward. He suggested that facies patterns across ramps are distributed in concentric facies belts that follow bathymetric contours.

Various scales of cycles have been recognized on carbonate ramps around the world and throughout the geologic record (Wright 1986, 1987; Ross and Ross 1988; Wright and Faulkner 1990). Cyclicity on Carboniferous ramps is reported with greater frequency than in any other geologic period. These units generally coarsen- and shallow-upward and vary from metre- to decimetre-scale in thickness. Units are stacked in distinctive patterns to form a series of depositional sequences.

Thomas (1984) recognized several 1-10 metre-thick shallowing-upward cycles of lime mudstone overlain by shallow water grainstones deposited in the shoreface-foreshore in the Triassic rocks of Germany. An emergence horizon with minor

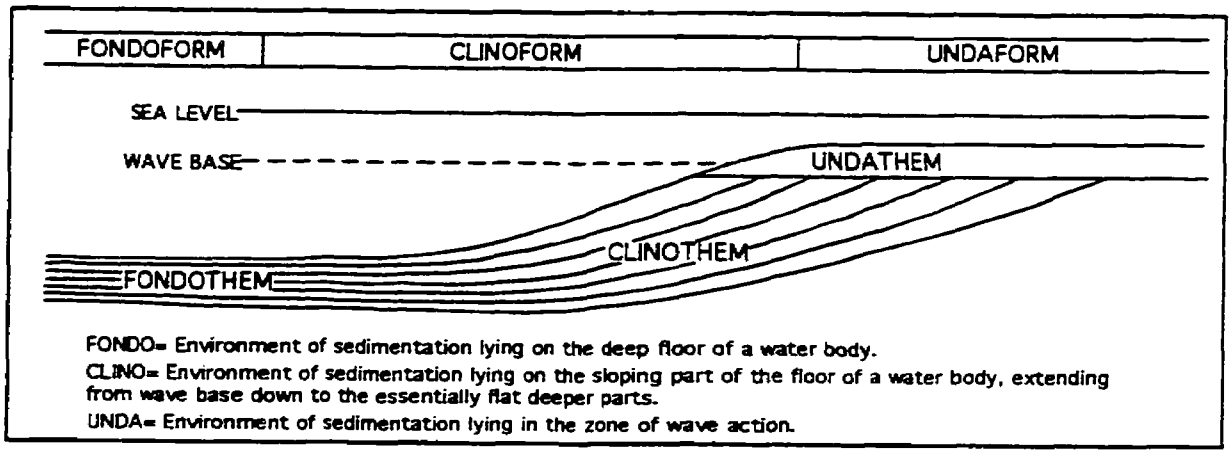


Figure 2.1a: Rich's Model (1951) was used as the basis for Chatellier's (1983) interpretation.

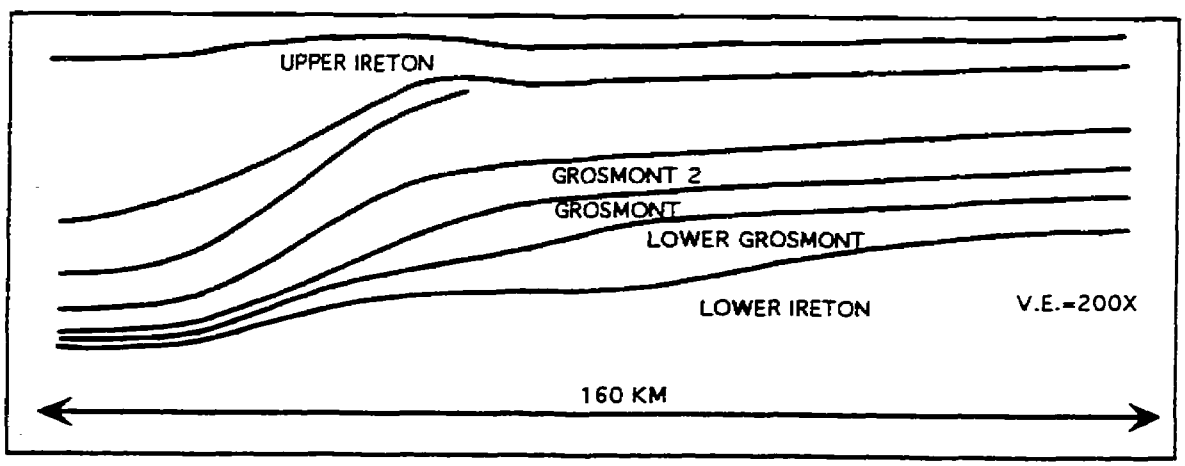


Figure 2.1 (b). A cross-section through the Frasnian Grosmont Formation, a carbonate ramp in the Western Canada Sedimentary Basin. Note that with large vertical exaggeration, the ramp exhibits subtle shingled clinoforms. Slope angle and slope height show cumulative increase upwards through the sequence. Vertical thickness of the Grosmont Formation is approximately 200 metres (after Cutler, 1983).

paleokarst, dolomite or an evaporite bed commonly capped the sequence. The same types of cycles were documented in the Middle Triassic of the Catalan Basin in Eastern Spain (Calvet et al. 1990; Tucker et al. 1993).

Burchette and Wright (1992) presented a series of highly schematic cross-sections through passive margin sedimentary basins showing the location and character of associated carbonate ramps. Relatively uniform subsidence rates accompany the rift to drift transition that decreases exponentially as the passive margin matures. This regime is characterized by large areas with very gradual slopes over the old rift shoulders. This favours the development of carbonate ramps hundreds of kilometres wide and potentially thousands of kilometres long. Burchette and Wright (1992) relied on seismic data to illustrate a series of low-angle sigmoidal or shingled clinoforming packages of approximately equal thickness, prograding into the basin.

2.1.3 Mississippian Ramps

Ross and Ross (1988) recognized eleven transgressive-regressive depositional sequences in the Tournaisian and Visean strata of Great Britain. Identification of transgressive-regressive depositional sequences on the craton relied on finding and tracing unconformities, establishing age relationships of strata, and determining depositional environments and facies changes. The Tournaisian deposits of Great Britain are predominantly shallow water carbonates consisting of a diverse array of carbonate-producing organisms.

A carbonate ramp has been described by Wright (1986, 1987) who examined the evolution and distribution of carbonate successions on a very broad scale in the Carboniferous Limestone Province in southwestern Britain. The ramp consists of a southward-thickening wedge of limestone and dolomites >1500 metres thick in the most southerly outcrops. He constructed a cross-section covering approximately 80 kilometres and correlated a series of facies belts across the ancient ramp system. Wright (1986, 1987) used outcrop sections and previously published works as his data sources.

The number of outcrops examined is never explicitly stated but appears to be approximately five. Differential subsidence and sea-level changes resulted in distinctive facies associations that can be placed into three geomorphotectonic settings termed the inner, mid- and outer ramp.

The inner ramp is dominated by shoal and back-shoal sediments that include oolitic grainstones and peritidal limestones arranged into metre-scale, transgressive-regressive units. The peritidal limestones are stacked into asymmetrical, shallowing- and coarsening-upward, metre- to decimetre-scale cycles. The mid-ramp is dominated by bioclastic limestones that are commonly stacked into decimetre-scale, shallowing- and coarsening-upward units that consist of up to four individual sand bodies. Regressive phases consist of oolitic grainstones usually capped by paleokarstic surfaces. The outer ramp consists of a thick sequence of muddy bioclastic limestones and major Waulsortian reef-mounds. None of the shallowing phases or cyclicity observed in the inner and mid-ramp zones can be detected in the outer ramp sequence (Wright 1986, 1987).

2.1.4 Banff and Lodgepole Formations

Several scales of cyclicity have been recognized by various authors in the Banff and Lodgepole Formations (Chatellier 1983, 1988, 1992; O'Connell 1990; Elrick and Read 1991; Elrick et al. 1991; Chen and Webster 1994; Richards et al. 1994).

Chatellier (1983) constructed a series of cross-sections through the Banff Formation from the Interior Plains to the Front Ranges of the Rocky Mountains in south-central and southwestern Alberta using both field and subsurface observations. Data points were typically located between 25 and 60 kilometres apart. Seismic data from northeast British Columbia and northwest Alberta was used to characterize the Banff Formation as a sigmoidal, progradational carbonate ramp consisting of clinoforming sediment packages (Chatellier 1983, 1988).

Chatellier (1983, 1988) recognized three scales of cyclicity. He divided the Banff Formation into three coarsening- and shallowing-upward mesosequences

(approximately 5-50 metres thick, more typically 25-50 metres thick), which, together with the Exshaw Formation form a megasequence (approximately 150 metres thick) (Figure 1.3). The underlying Devonian Wabamun-Palliser Formations and overlying Mississippian Rundle Group are the preceding and succeeding megasequences respectively. Locally, thinner, metre-scale cycles were recognized. Some of these cycles repeat the same succession of lithologies, while others grade upward into more restricted sediments.

Elrick and Read (1991) and Elrick et al. (1991) studied the Lodgepole and lower Madison Formations (20-225 metres thick) in Wyoming, Western Montana and Eastern Idaho on a broad, laterally extensive, storm-dominated, pericratonic carbonate ramp (>700 kilometres wide and >1600 kilometres long). Outcrop exposures located between 20 and 150 kilometres apart were correlated to create a series of regional sections.

The authors recognized three types of metre-scale cyclicity that stacked to form three depositional sequences. The first type of metre-scale cycle consists of peritidal cycles of very shallow subtidal sediments overlain by algal-laminated tidal flat deposits that are rarely capped by paleosol/breccia layers. Secondly, shallow subtidal cycles consist of stacked ooid grainstone shoal deposits or deeper subtidal sediments that are capped by ooid-skeletal grainstones. Deep subtidal cycles of limestone-argillite overlain by storm-deposited limestone and capped by hummocky stratified to massive skeletal-ooid grainstone are the third type of fifth-order cycle. Deep subtidal cycles pass downslope into rhythmically interbedded limestone and argillite with local mud mounds. No upward-shallowing cycles occur within the ramp-slope facies.

Similarly, Chen and Webster (1994) studied the Lodgepole/lower Madison/Henderson Canyon Formations in Central Wyoming, Eastern Idaho and Northeastern Utah. Using three widely-spaced outcrop sections (135 and 375 kilometres apart respectively) and previous work, the authors divided the ramp into seven facies associations. These are foreslope, offshore skeletal-peloidal bank, deep

ramp, middle ramp, foreshoal subtidal, shoal and peritidal-lagoonal associations. Cyclicity on any scale is not discussed in any detail.

Regional cross-sections were constructed using one well approximately every 30 kilometres in the Geological Atlas of the Western Canada Sedimentary Basin (Richards et al. 1994). Again, cyclicity of any scale was not the focus of this publication.

In contrast to the regional studies discussed above, O'Connell (1990) studied the Banff Formation on a more local scale in the Peace River embayment in north-central Alberta and northeast British Columbia. Although the study area was still very large (300 kilometres by 300 kilometres), his cross-sections were constructed from wells spaced between one and three ranges apart (10-30 kilometres). He divided the Banff Formation into three informal members and recognized informal stratigraphic units within each of the three larger members.

Isopach maps (O'Connell 1990, Figures 6 and 10) of two shale units and two carbonate units in the lower Banff Formation illustrated that sediments in these units were not distributed as concentric bands of increasing sediment thickness. Instead, sediments were deposited in irregularly distributed piles 5-120 metres thick. Similarly, cross-sections (O'Connell 1990, Figures 7-9, 11) illustrate the dramatic thickness changes in the units as well as changing log character over the study area.

2.1.5 Discussion

Ross and Ross (1988) recognized eleven transgressive-regressive sequences that lasted between 1.2 and 4 million years, typically about 2 million years (third-order). These sequences are believed to be synchronous depositional events that resulted from eustatic sea-level changes. A depositional sequence may contain four or five cyclothems or partial cyclothems within it.

Wright (1986, 1987) attributes the transgressive events on the Carboniferous Limestone Province ramp to eustatic changes as a result of major early Carboniferous sea level rise. In contrast, regressive phases may have been purely progradational in

origin, although some may have been related to localized tectonic base-level changes. Progradations may correspond to phases of reduced sea level or stillstand.

The focus of Chatellier's (1983, 1988, 1992) work was the mesosequence which is a third- or fourth-order cycle. The first regressive mesosequence consists of open marine basin, slope and barrier shoal sediments. Although global sea level rose at this time, carbonate production kept pace with or exceeded subsidence. The second and third mesosequences are restricted marine, inner ramp, subtidal, intertidal and supratidal sediments. Chatellier (1983) attributed this cyclicity to a sea level fall or cessation of subsidence, or uplift on the craton. Fifth-order, metre-scale cyclicity was briefly mentioned but not analyzed in any detail.

Elrick and Read (1991) recognized three types of fifth-order cyclicity that stacked to form third- to fourth-order depositional sequences but did not attempt to correlate these small-scale cycles across the ramp system. Average cycle durations calculated along the outer ramp range from 30-110 thousand years These cycles likely formed in response to Milankovitch-type sea-level oscillations with amplitudes of at least 20-25 metres, superimposed on long-term (third- to fourth-order) sea-level fluctuations.

Regional transgressive-regressive facies trends and metre-scale stacking patterns define three third- to fourth-order depositional sequences. Shallow and deep subtidal cycles form the ramp margin wedge which developed during long term sea level lowstand. The transgressive systems tract onlapped the ramp during sea level rise and is dominated by thick, deep and shallow subtidal cycles. Peritidal cycles are restricted to the inner ramp. Similarly, the highstand systems tract developed during long term sea level highstand and fall and consists of shallow subtidal cycles overlain by peritidal cycles on the inner ramp and shallow and deep subtidal cycles on the ramp-slope (Elrick and Read 1991).

O'Connell (1990) mapped the Lower Banff and Pekisko Formations in the Peace River Embayment to determine the basin configurations. The shallower water facies of the middle and upper Banff Formation show little thickness variation, indicating that the main phase of basin formation and infilling occurred during the Lower Banff.

Although cyclicity was not the focus of this work and therefore not discussed in any detail, the lower shale and carbonate units are interpreted as third- to fourth-order cycles. O'Connell (1990) attributed the sediment piling to differential subsidence, and divided the sediments into a northern (north-south trending, north of Township 90) and southern domain (west-east trending, south of Township 90). The development and orientation of the Lower Carboniferous Peace River Embayment and subsequent depositional patterns is attributed to progressive burial of the Peace River Arch and the continued differential subsidence along the trend of a northern boundary fault.

Although seismic data may provide a good regional overview of the geometry of depositional sequences, the vertical resolution is not usually adequate to recognize and correlate smaller-scale cycles. A general rule is that two reflecting horizons must be a minimum of one quarter of a wavelength apart if they are to be resolvable on seismic (Harris and Langan 1997). In a shallow, loosely consolidated sandstone or mudstone, the vertical resolution is approximately 7.5 metres. In contrast, the thinnest unit resolvable in a deep, Paleozoic carbonate section is about 75 metres thick (Miall 1990). The maximum vertical seismic resolution of 3D surface seismic images is 40 metres (Harris and Langan 1997).

Most of the work done on carbonate ramp cyclicity to date has involved the correlation of large-scale, low-order units or cycles across immense geographic areas using fairly limited outcrop and subsurface data. Although fourth- and fifth-order cycles have been identified on carbonate ramps around the world, there has been no previous attempt to correlate them. Seismic data has been used to derive the geometry of low-order cycles on a regional-scale.

2.2 METHODS

2.2.1 Introduction

The Banff Formation is divided into six cyclic units in this study in order to investigate the changing geometry of smaller-scale successions in a modestly sized study area. This is in contrast to the majority of previous work that has a regional perspective and focuses on formation-scale units. The present study attempts to correlate the six units across the study area and determine the changing distribution (areal and thickness) and character (log profile and lithology) of each unit.

The geometry of each unit is a function of predepositional topography, the geomorphology of the depositional environment, and its post-depositional history (Selley 1985). The approach of this study was to map the geometry of each unit using borehole data.

2.2.2 Geophysical Well Logs

Geophysical well logs are the single most important data source for this study, and particularly for this section, which involves the division of the Banff Formation into six component units. Units are correlatable lithologic assemblages interpreted from associations of different log signatures. The gamma ray, PEF, caliper, and neutron and density porosity logs are the dominant geophysical well logs utilized for stratigraphic correlation and lithologic interpretation.

Gamma ray logs are used as vertical profiles of grain size. The gamma ray log measures the natural radioactivity of the rocks which is essentially related to the amount of clay minerals present. Thus, the gamma ray reading tends to increase in proportion to the amount of clay minerals present in the sediment, and the amount of clay increases with decreasing particle size (Brock 1984). No radioactive minerals having the potential to yield a misleading gamma ray response, like mica or glauconite, are observed in either the cores or thin sections.

The effects of caving on log response are monitored by observing the caliper log(s) where present. The PEF log, in combination with the gamma ray and neutron-density porosity logs, is used to determine lithology where available. The neutron and density porosity logs are used to determine porosity and lithology in combination with the gamma ray and PEF logs. The amount of departure between the neutron and density porosity logs run on a limestone scale is especially useful for distinguishing dolomite from limestone. In a low porosity limestone lithology, the neutron and density porosity logs track parallel to each other. In contrast, the neutron and density logs are separated in a dolomite lithology (Asquith 1982, 1985; Schlumberger 1995).

2.2.3 Identification and Recognition of Units

No "typical" or "standard" succession exists for the Banff Formation in the study area. Closely spaced wells have quite different log signatures, however six units can be distinguished by distinct shifts in the gamma ray log (Figures 2.2-2.3). Six units, each comprised of one or several shallowing- and coarsening-upward cycles are recognized in the Banff Formation. As will be discussed below, the six units vary greatly in lithology, geographical distribution and thickness across the Greater Cessford Area.

The upper and lower boundaries of the Banff Formation are readily determined by changes in the gamma ray log. The base of the Banff Formation is identified by a decrease from high radiation values associated with the black shales of the Exshaw Formation. The top of the Banff Formation is determined by the shift of the gamma ray log to either: (1) lower radiation values which correspond to the Pekisko Formation (composed of crinoidal and bryozoan packstones and grainstones); or (2) higher radiation values which correspond to the shales and mudstones of the Banff Formation transition zone and Detrital Formation.

Two type logs illustrate the unit divisions for this study (Figures 2.2-2.3). Six peaks or breaks occur in the gamma ray log with corresponding peaks in the porosity

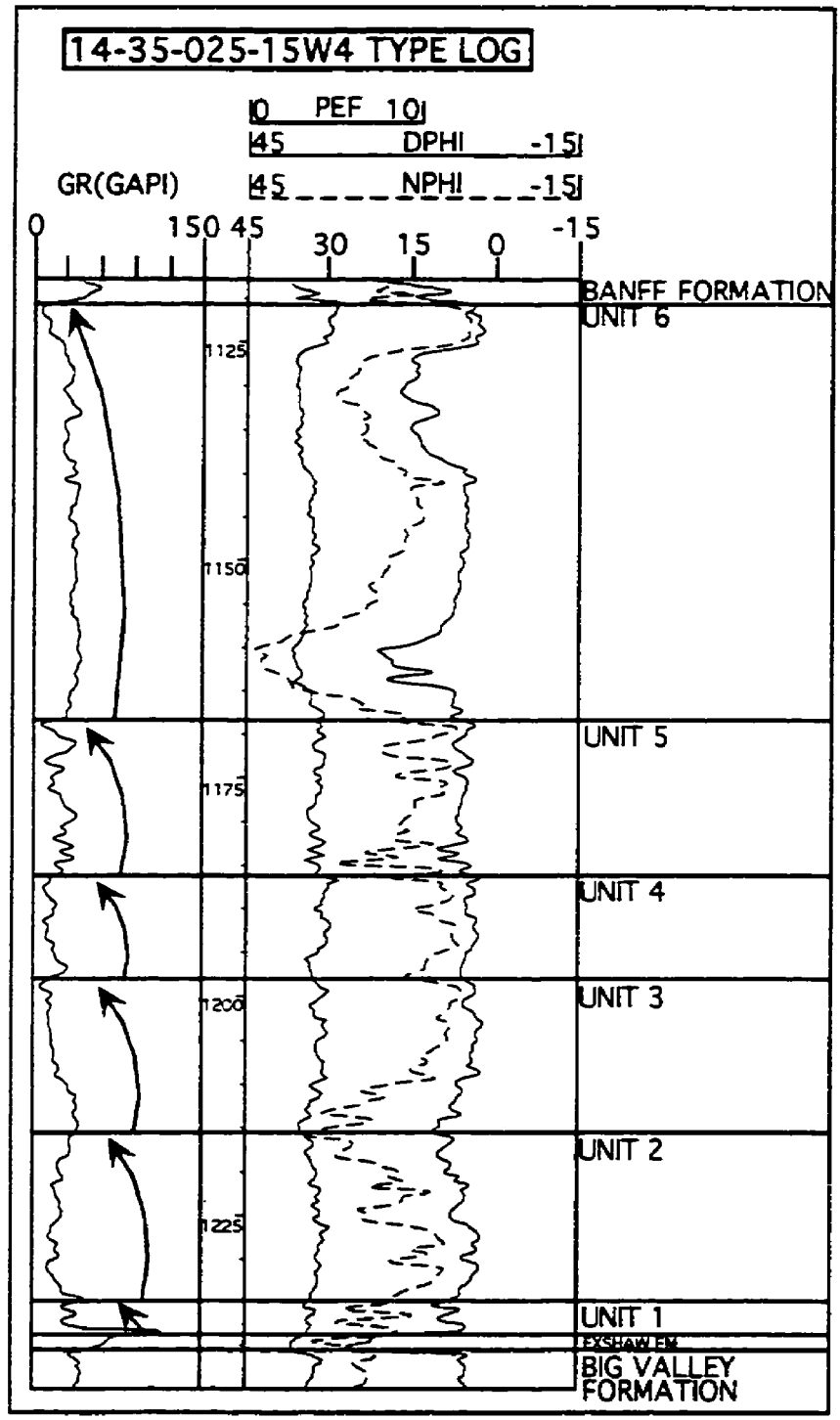


Figure 2.2. The type log for 14-35-025-15W4 illustrates the divsion of the Banff Formation into six units.

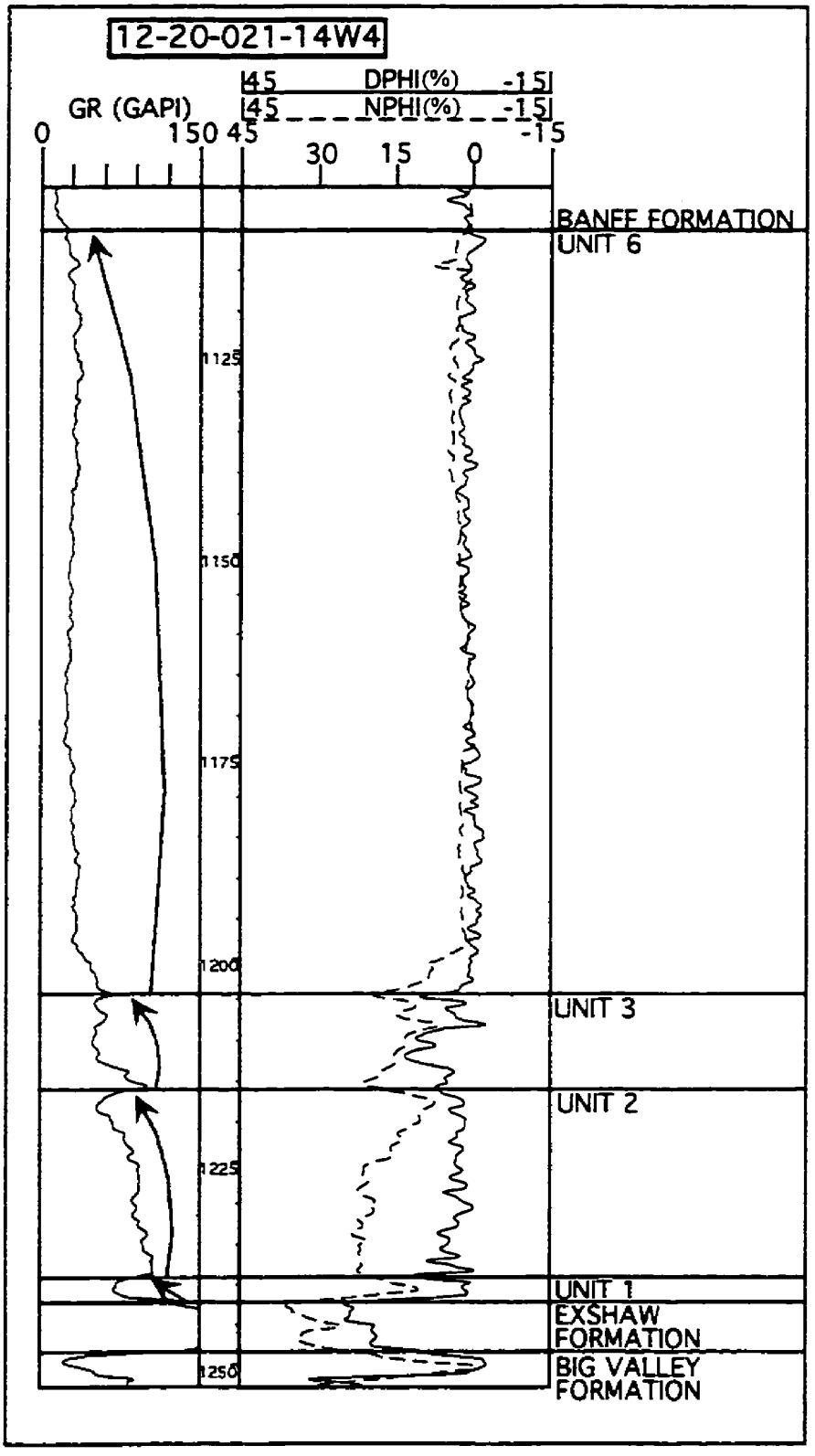


Figure 2.3. Units 4 and 5 cannot be differentiated from Unit 6 in the type log from 12-20-021-14W4.

logs within the Banff Formation. The unit boundaries generally consist of sediments with higher gamma radiation compared to adjacent (under- and overlying) rocks. These are typically shale and/or shaly carbonate rocks. Unit boundaries are identified by combining the occurrence of high gamma ray peaks with log-to-log correlation. These breaks or unit boundaries are correlatable throughout the Greater Cessford Area subsurface although upper units are truncated by the post-Mississippian unconformity towards the northeast portion of the study area (Figure 2.4-2.6). Unit 6 directly overlies Units 1-3 in the southwest portion of the study area (Figure 2.3-2.5). Here, Units 4 and 5 were not deposited or cannot be differentiated from cycle 6.

Although the units vary greatly in character across the study area and in closely-spaced wells, they generally consist of a shalier lower section which coarsens-upward into cleaner carbonates and/or quartzose siltstones and sandstones. This is evident by the gamma ray log response decreasing-upward. Even the more massive units slightly coarsen- and clean-upward.

2.2.4 Formation-Scale Mapping

Structure and trend maps, as well as block diagrams of the Stettler, Big Valley, Exshaw and Banff Formations (Figures 2.7-2.14) were generated using the Formation Tops Database (Appendix A). A structure and trend map were also constructed for the Mannville Formation (Figure 2.15) based on board tops for the smaller unit database (Appendix B). Using the same smaller database, isopach maps were generated for the Mannville to Big Valley Formations interval, Mannville to Banff Formations interval, and Banff to Big Valley Formations interval (Figures 2.16-2.17).

The large number of wells which only penetrate into the uppermost part of the Banff Formation is reflected in the far greater number of control points for the Banff Formation maps than those of the underlying formations. The purpose of examining such a great number of logs was to identify and map a calcareous and/or dolomitic quartzose siltstone unit which will be discussed in greater detail in Chapters 3

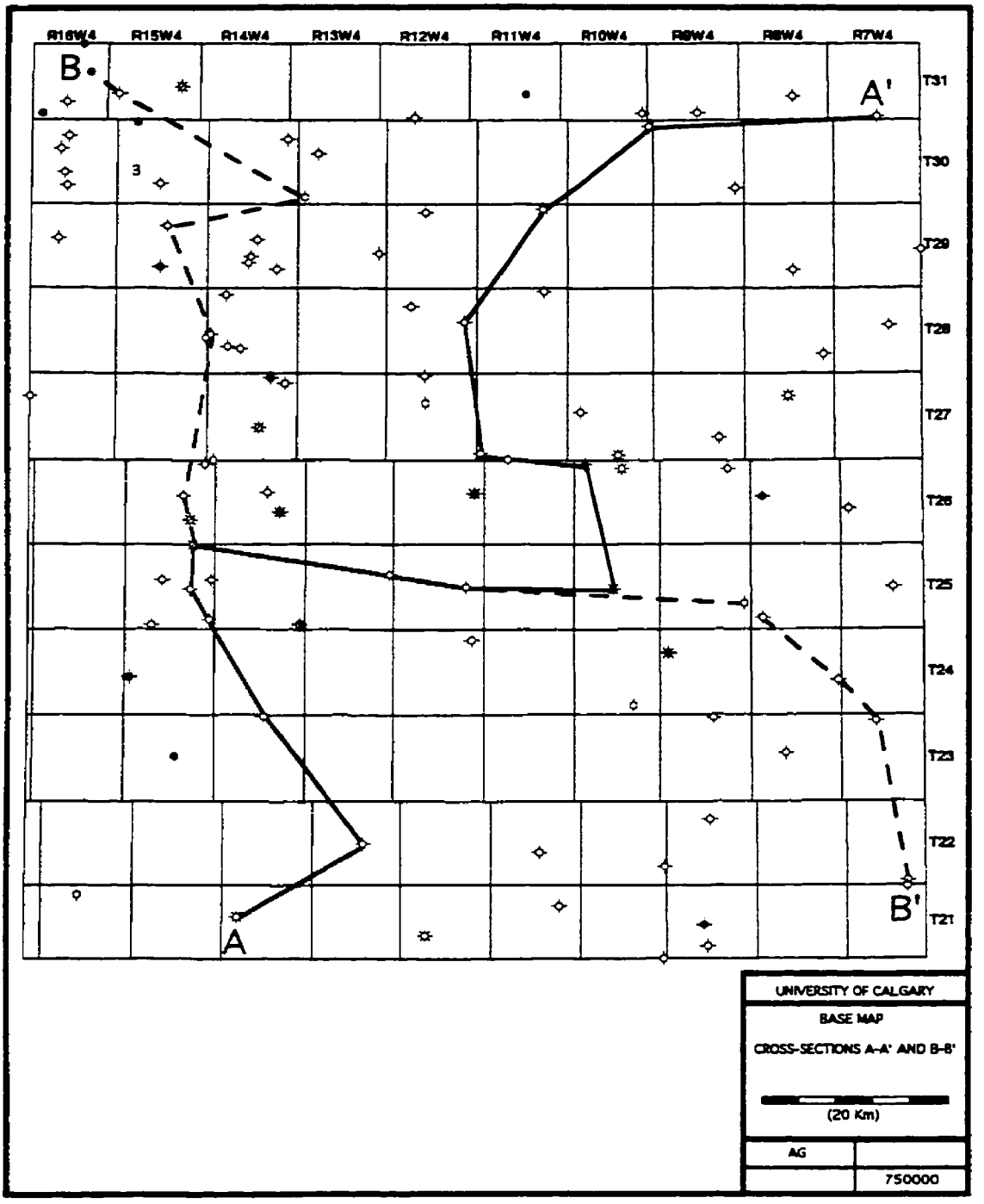


Figure 2.4. Base map for cross-sections A-A' and B-B' illustrated in Figures 2.5-2.6.

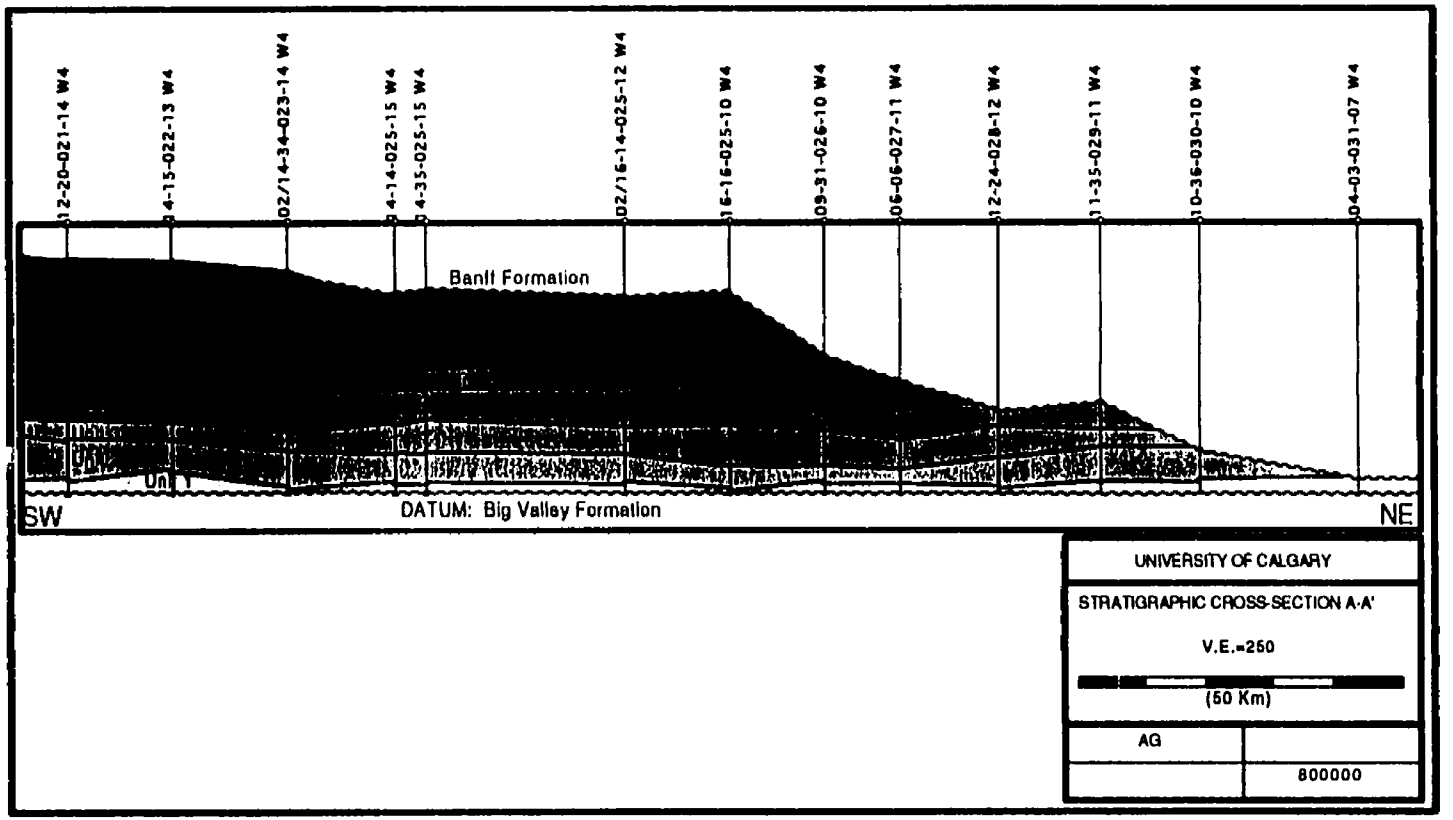


Figure 2.5 (a). Stratigraphic cross-section illustrates the general geometry of each of the six units. Units 4 and 5 cannot be differentiated from Unit 6 in the southwest quadrant of the Greater Cessford Area.

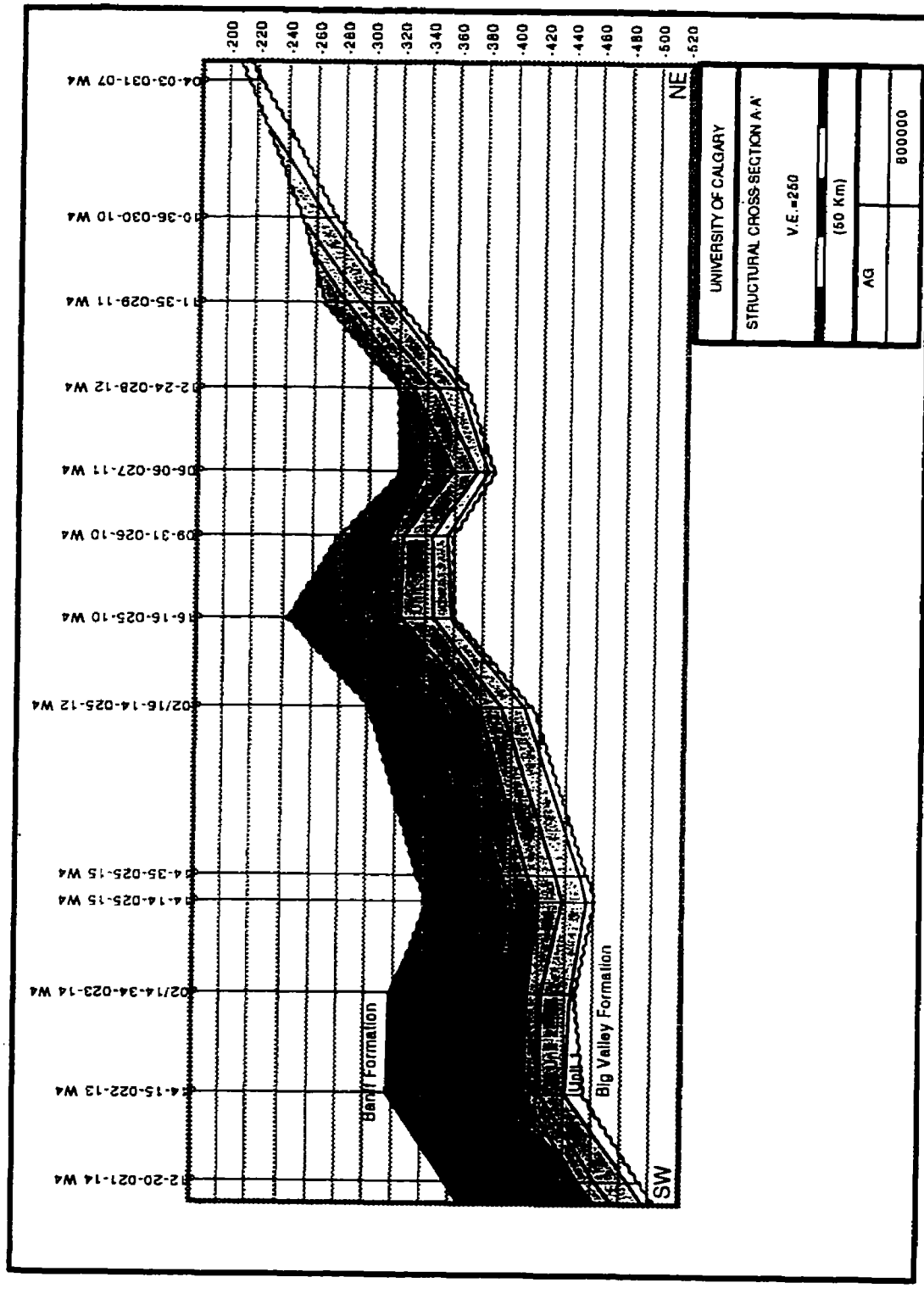


Figure 2.5 (b). Structural cross-section using the identical well locations as in Figure 2.5 (a).

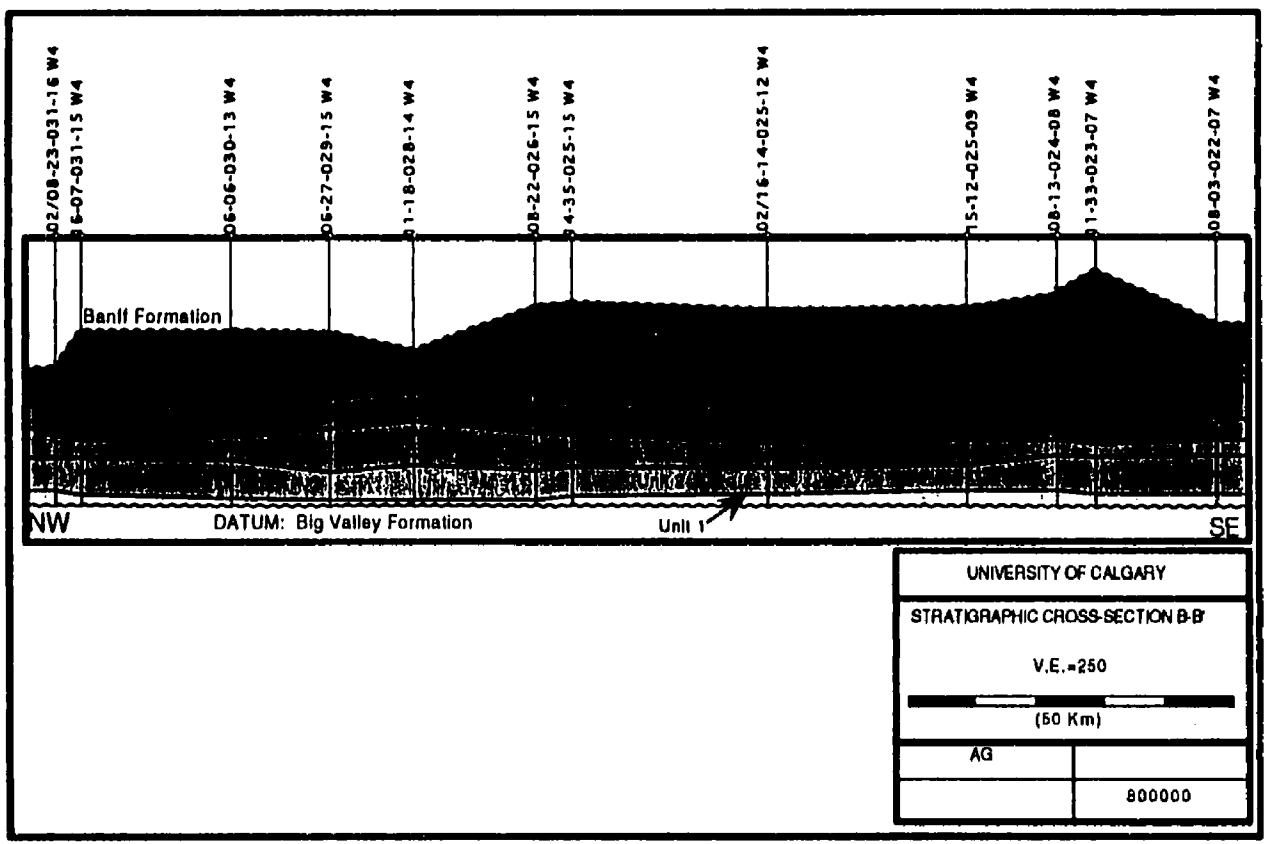


Figure 2.6 (a). Cross-section B-B' runs between the northwest and southeast quadrants of the Greater Cessford Area (Figure 2.4). The Devonian Big Valley Formation is the datum.

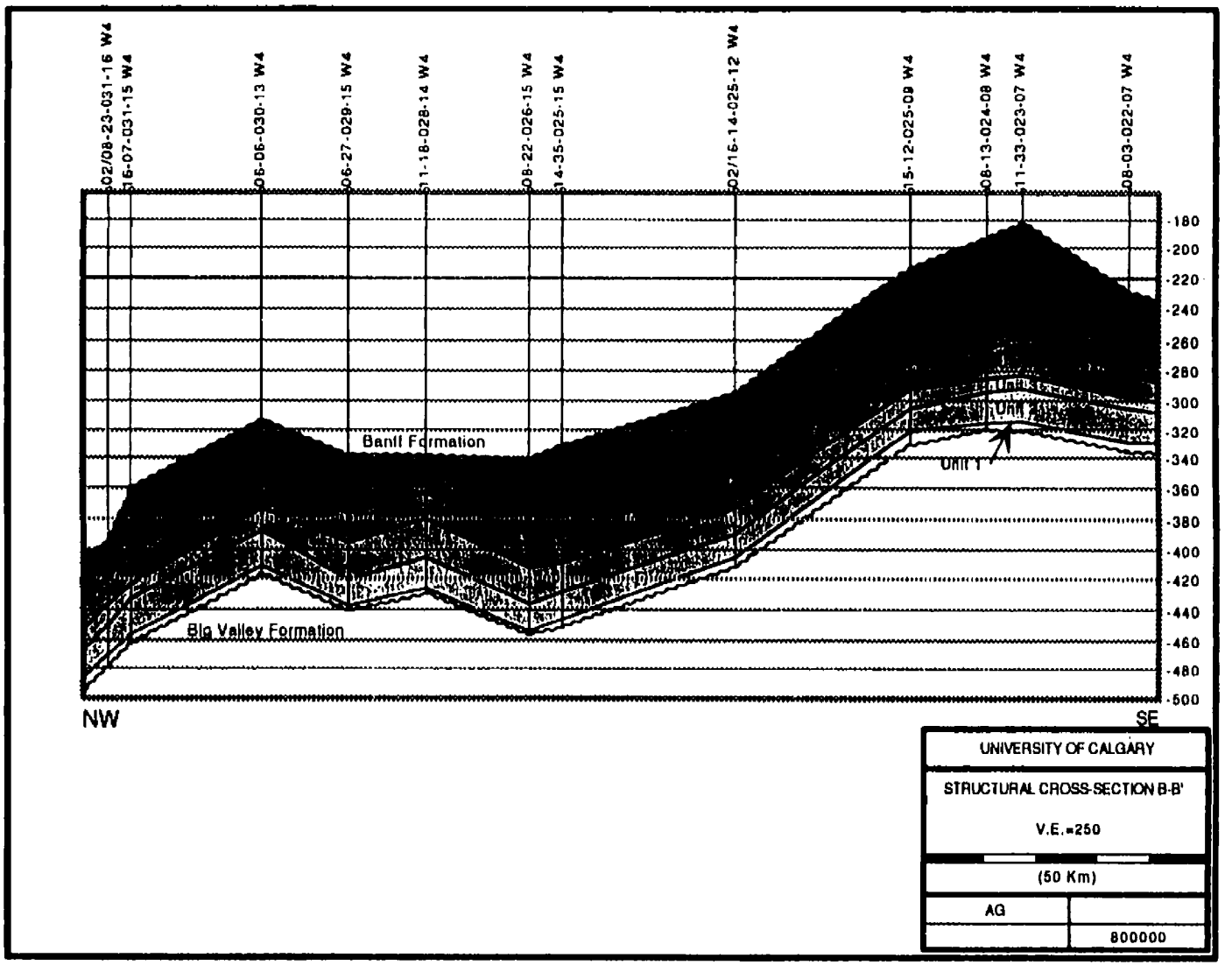


Figure 2.6 (b). Structural cross-section B-B'. Well locations are illustrated on Figure 2.4.

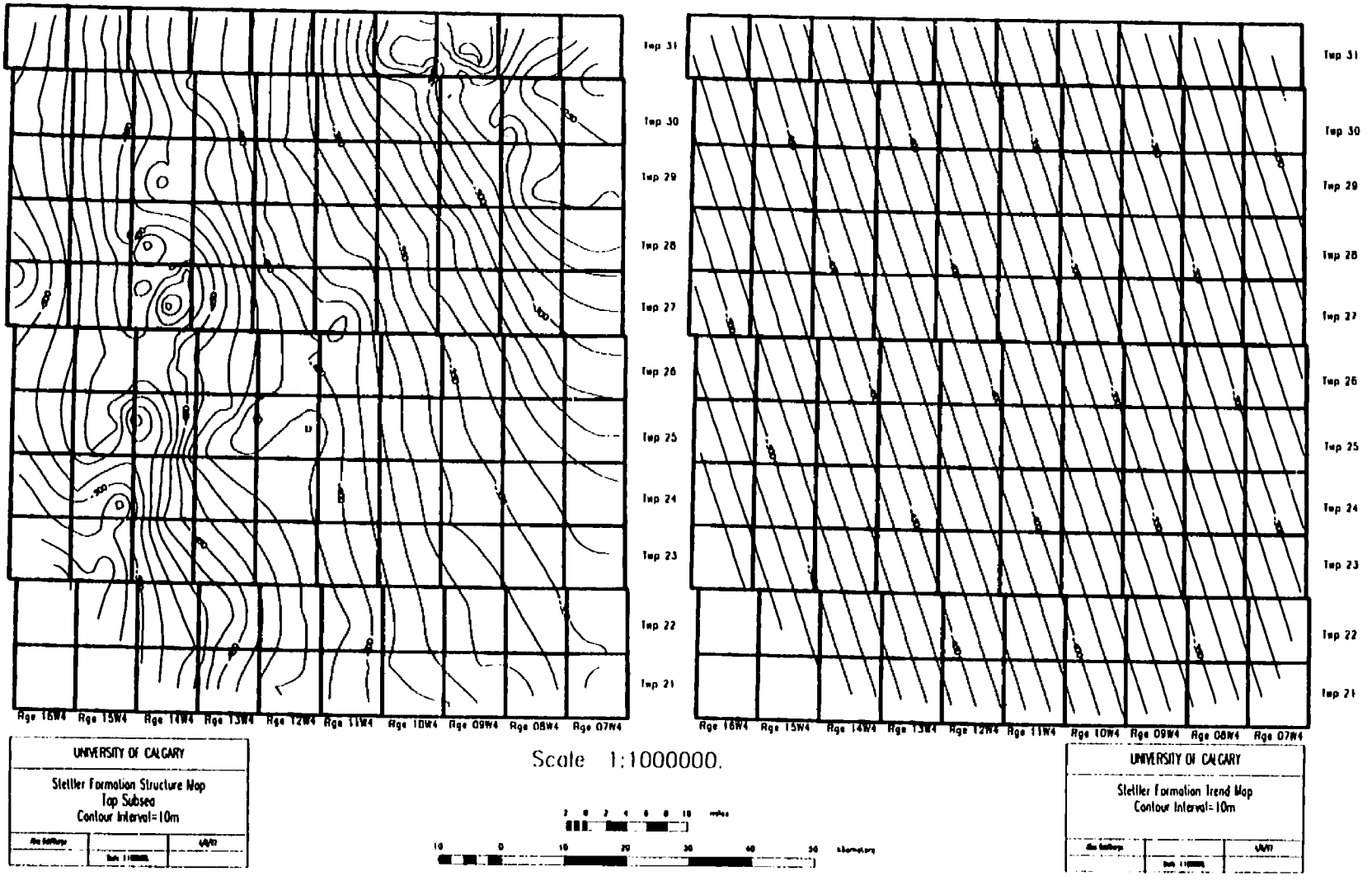


Figure 2.7 (a) and (b). Structure and trend maps on the upper surface of the Stettler Formation.

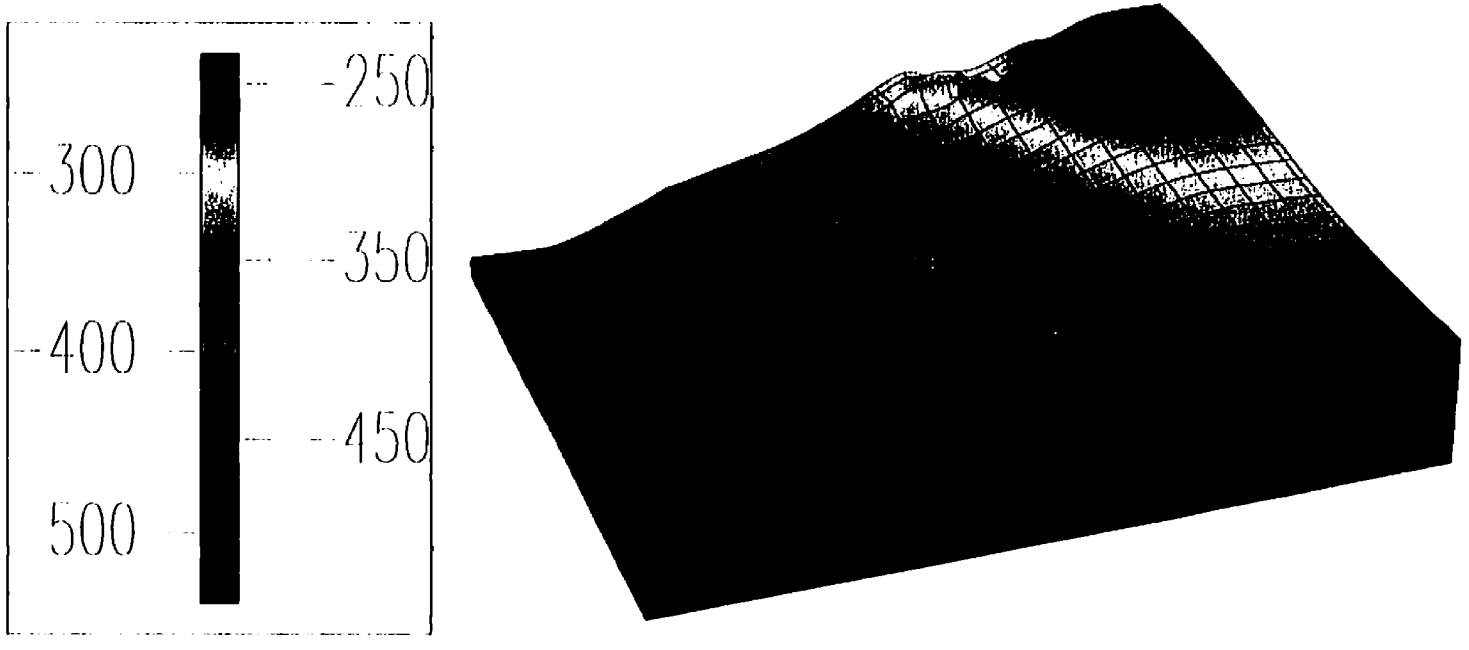


Figure 2.8. Stettler Formation block diagram.

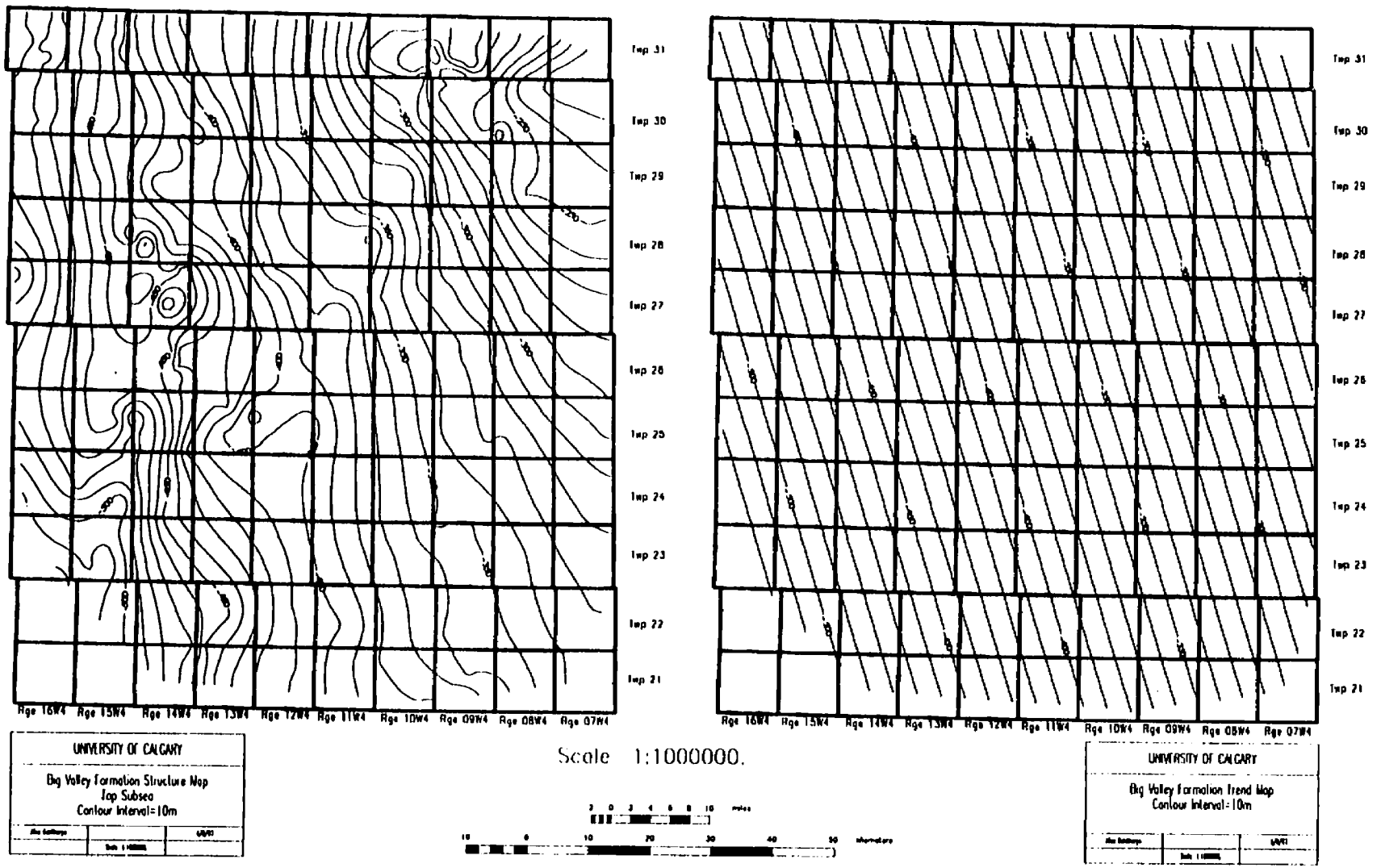


Figure 2.9 (a) and (b). Structure and trend maps on the upper surface of the Big Valley Formation.

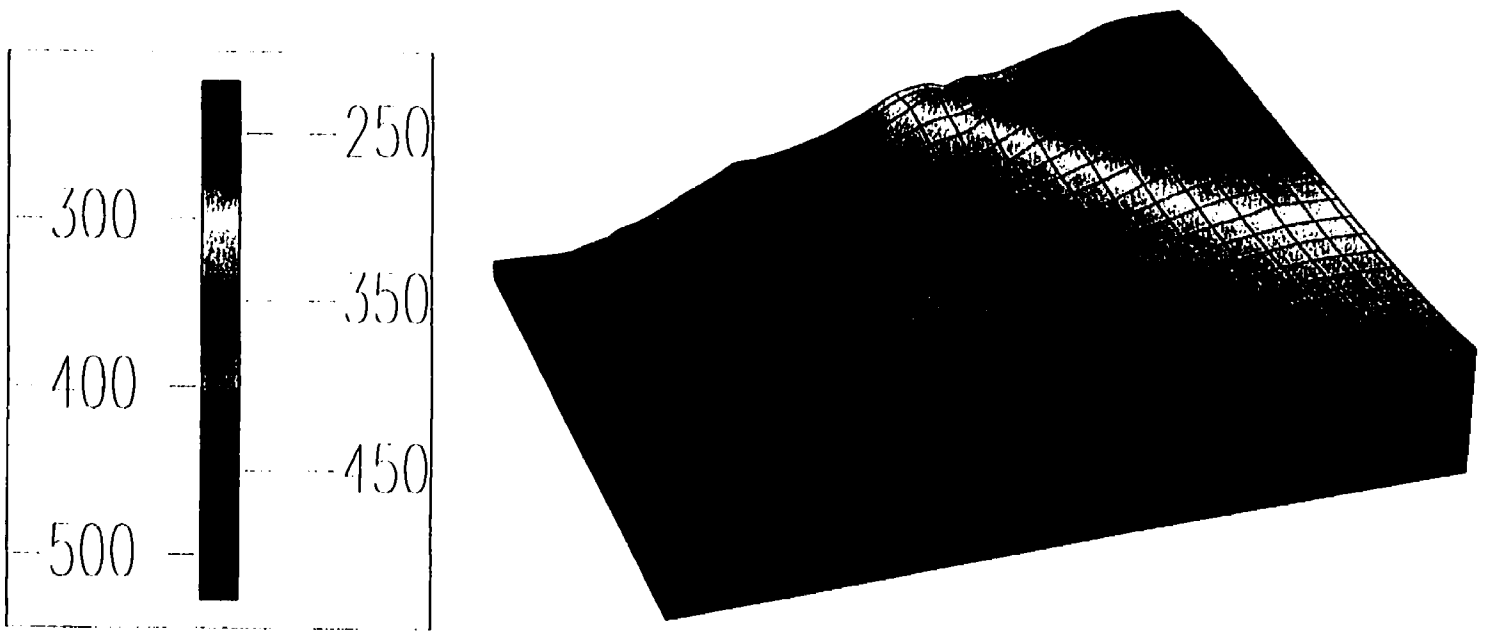


Figure 2.10. Big Valley Formation block diagram.

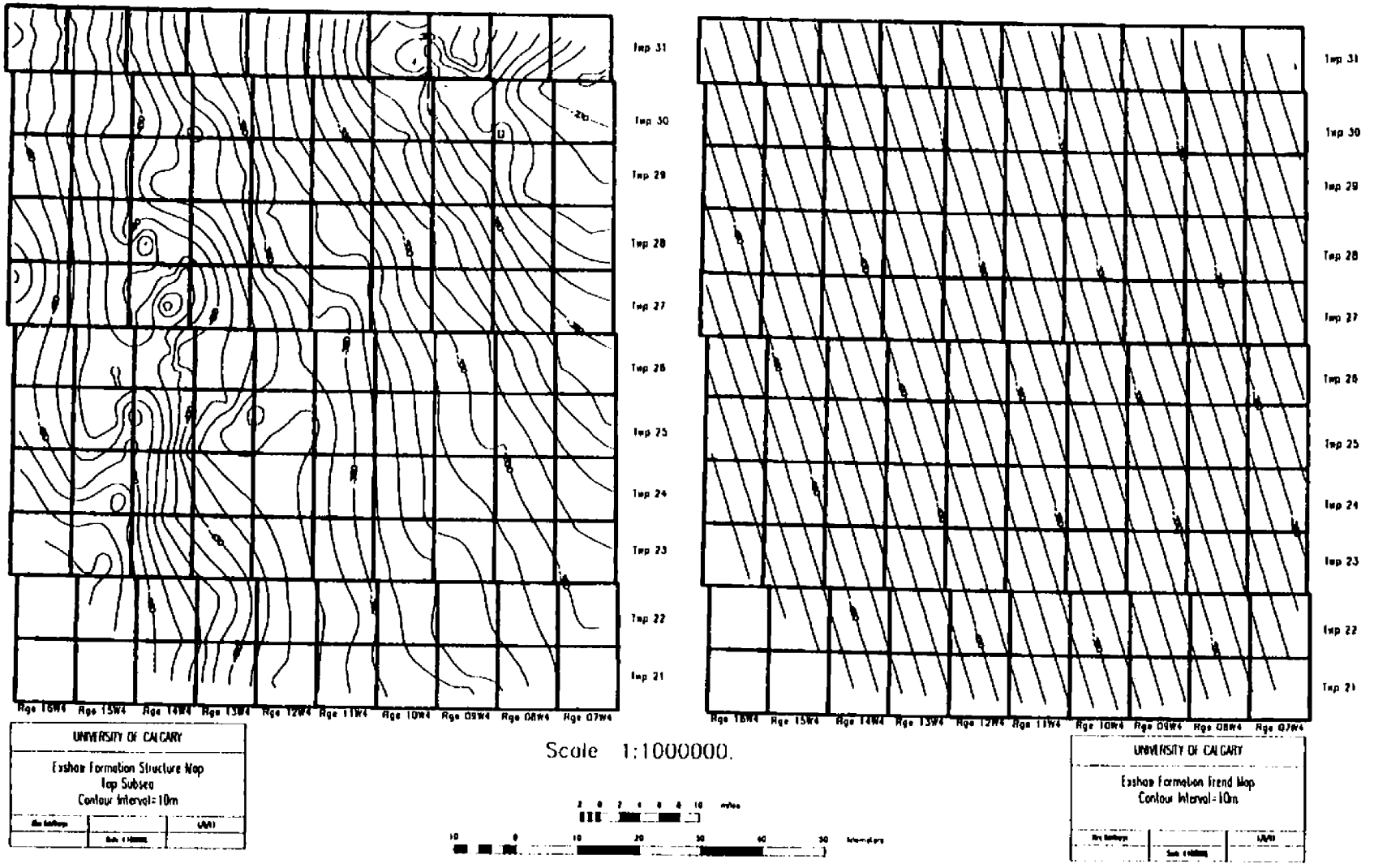


Figure 2.11 (a) and (b). Structure and trend maps on the upper surface of the Exshaw Formation.

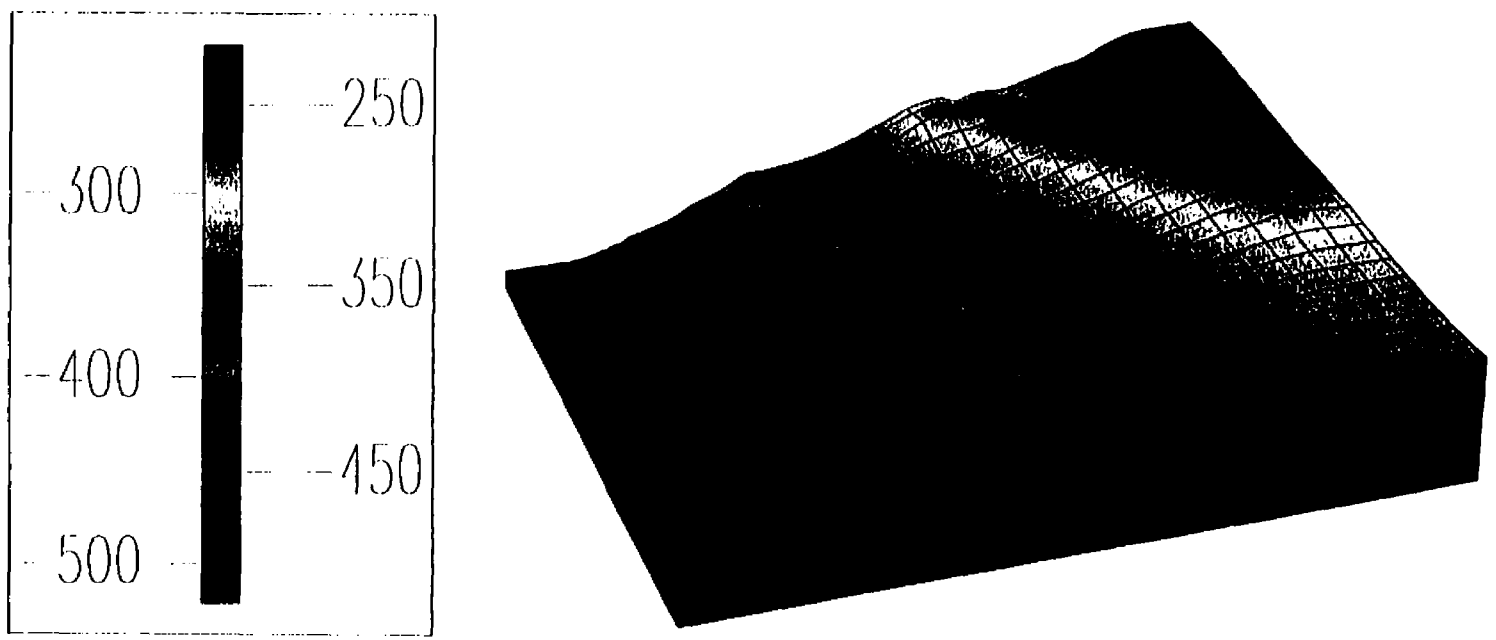


Figure 2.12. Exshaw Formation block diagram.

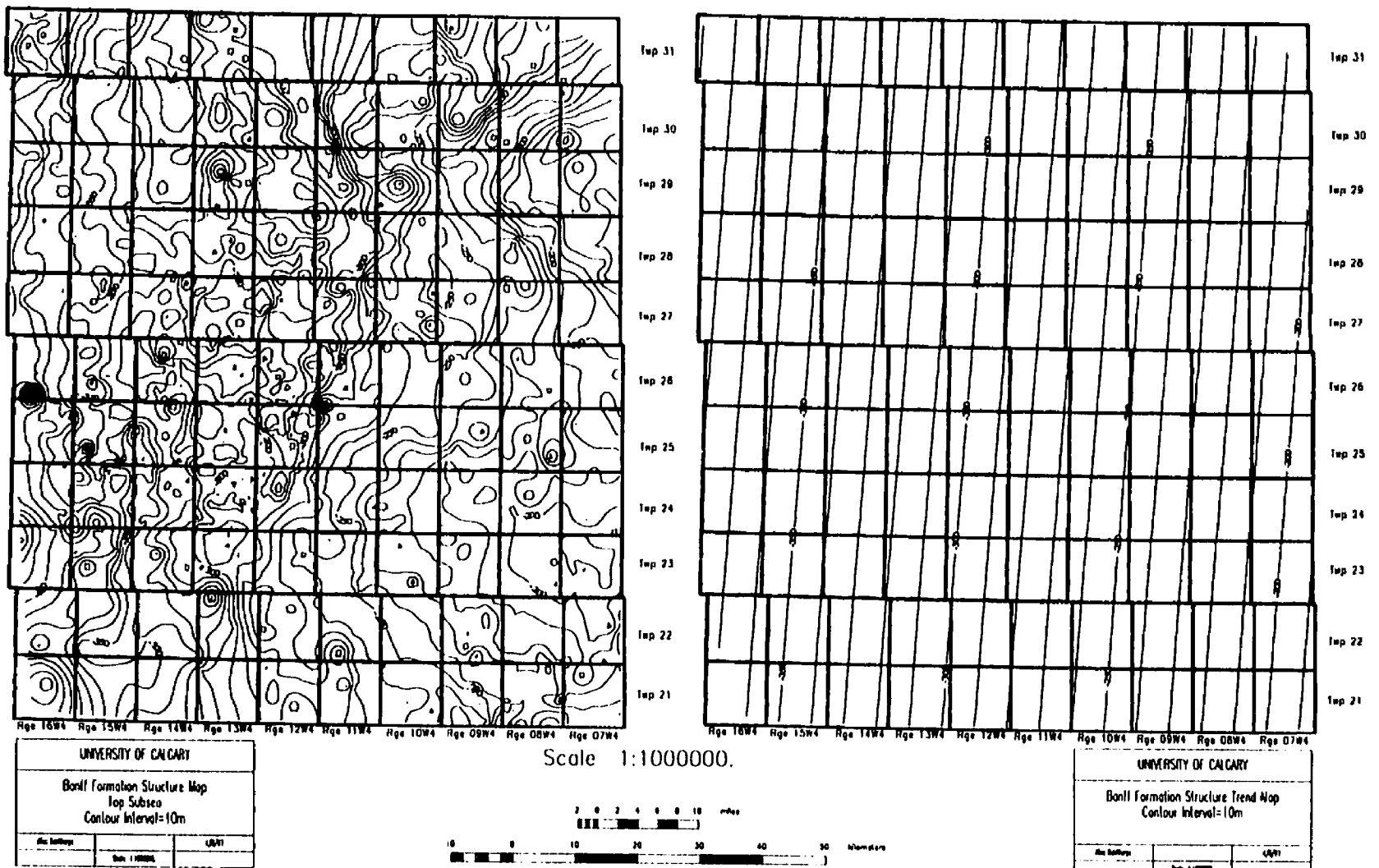


Figure 2.13 (a) and (b). Structure and trend maps on the upper surface of the Banff Formation.

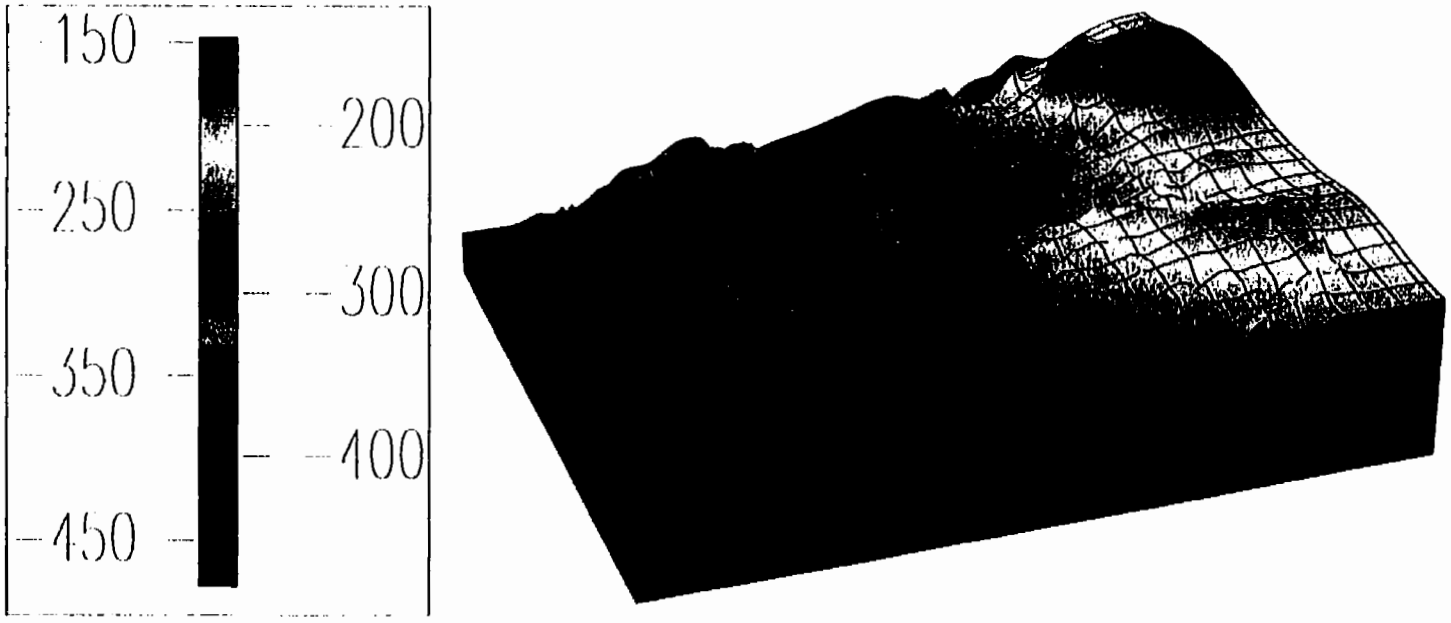


Figure 2.14. Banff Formation block diagram.

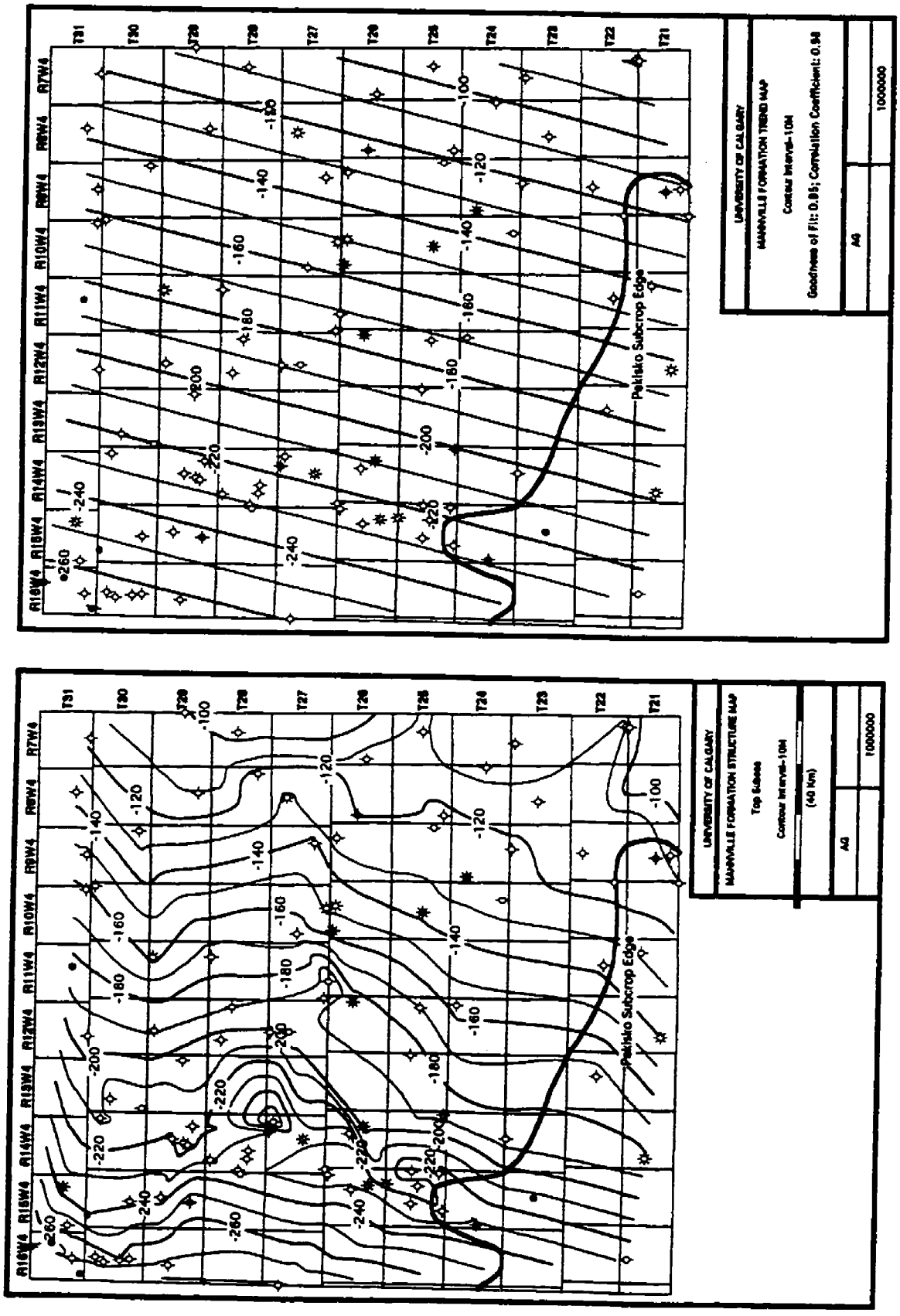


Figure 2.15 (a) and (b). Structure and trend maps on the upper surface of the Mannville Formation.

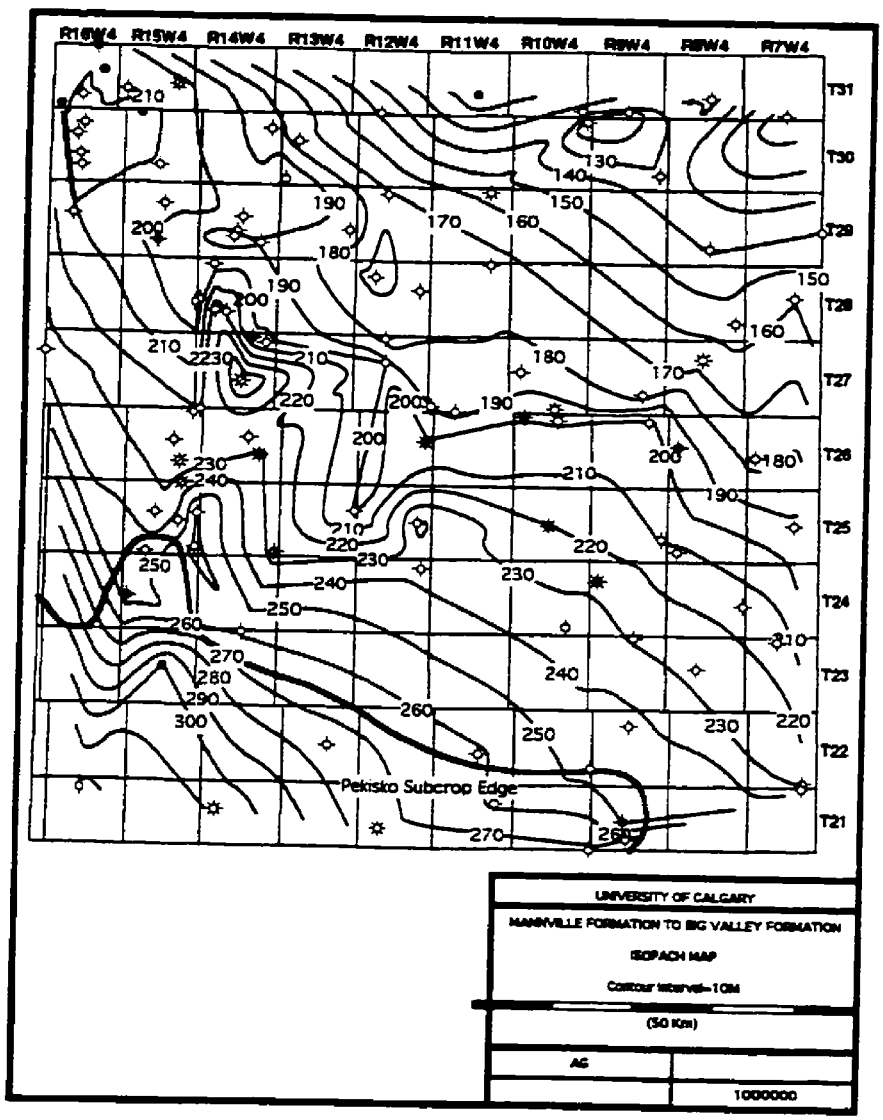


Figure 2.16. The isopach map of the Mannville to Big Valley Formations interval consists of approximately evenly-spaced, southwest-dipping sediments.

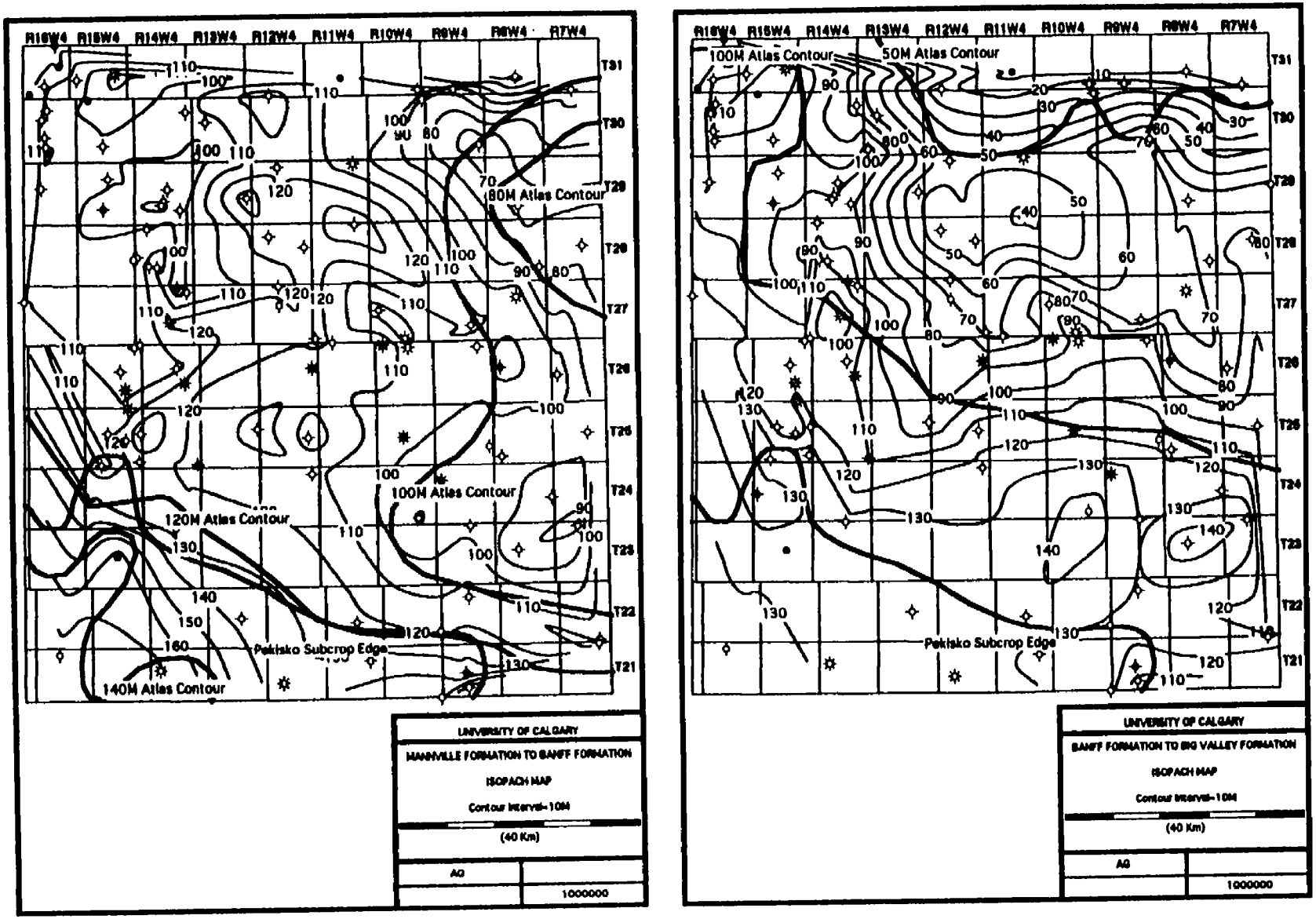


Figure 2.17 (a) and (b). Isopach maps of the Cretaceous (a) and Mississippian (b) strata in the Greater Cessford Area.

(Sedimentology) and 4 (Carbonate-Siliciclastic Mixtures and a Ramp Model for the Banff Formation).

2.2.5 Mapping of Banff Formation Units

Subsurface correlation in the Greater Cessford Area suggests that the Banff Formation can be divided into at least six regressive, shallowing- and coarsening-upward units. These units will be referred to as Units 1 through 6 where Unit 1 is the lowermost unit. Units 1-3 will be informally designated "lower" Banff Formation and Units 4-6 "upper" Banff Formation.

105 wells were selected for detailed analysis based on log quality and geographical distribution over the study area. Recently drilled wells were favoured because caliper and lithology (neutron, density, PEF) logs are generally run on these wells. Six unit boundaries were selected using the criteria discussed above and the percentage of shale/silt was calculated using a 50% gamma ray cutoff. This data is presented in Appendix B.

A series of cross-sections in several different orientations were constructed to cover the Greater Cessford Area. Two of these are presented in Figures 2.5 and 2.6 using a stratigraphic and structural datum for each. In addition, four log cross-sections were constructed, two in each of the strike (northwest-southeast) and dip (southwest-northeast) directions (Figures 2.18-2.22).

Isopach maps of the lowermost and uppermost three units respectively were generated in order to assess the depositional geometry of Units 1, 2, and 3 in combination and Units 4, 5, and 6 in combination, respectively (Figures 2.23). In addition, an isopach map of each of the 6 units illustrates the depositional geometry of each unit (Figures 2.24a-2.29a). Shale percentage maps contoured at 10-20% intervals highlight high shale/silt input areas separated by predominantly carbonate areas (Figures 2.24b-2.29b).

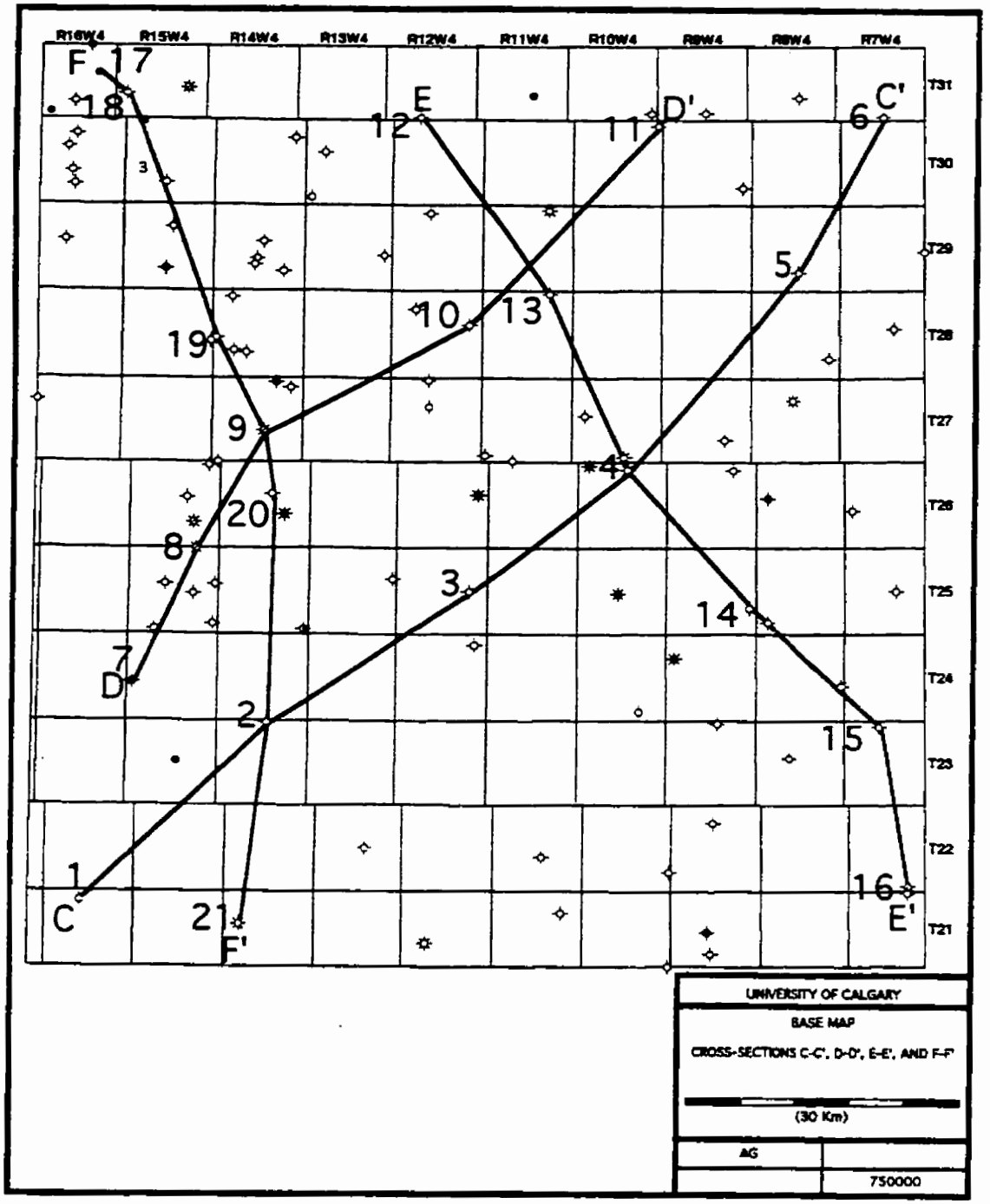


Figure 2.18. Base map illustrates locations of cross-sections C-C', D-D', E-E', and F-F' (Figures 2.19-2.22). Numbers correspond to numbered wells on the four cross-sections. Cross-sections C-C' and D-D' are dip parallel in contrast to cross-sections E-E' and F-F' which are parallel to strike.

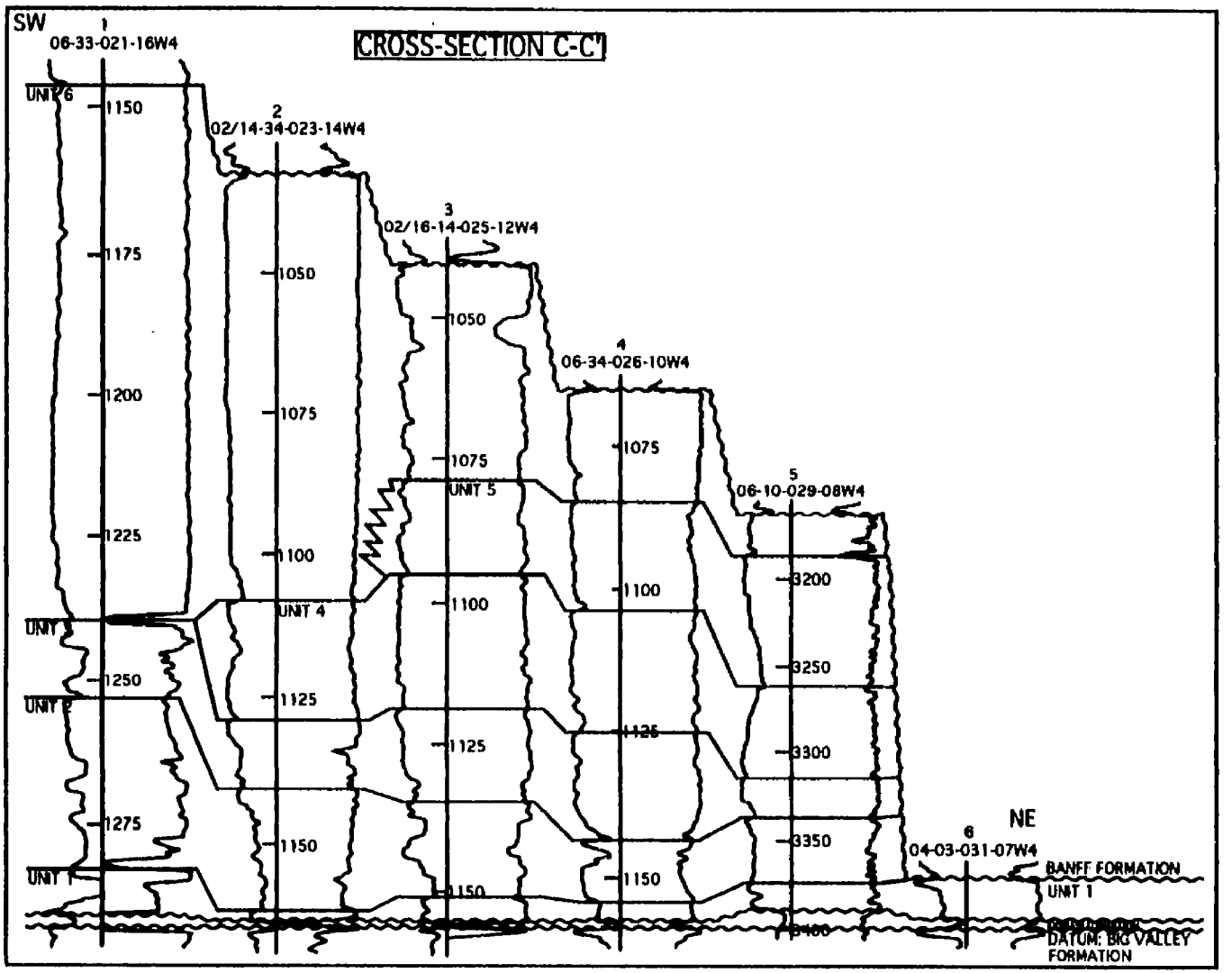


Figure 2.19. Stratigraphic cross-section datumed on the Big Valley Formation. Well logs are Gamma-ray/Density. The six units of the Banff Formation are indicated. See base map (Figure 2.18) for cross-section location.

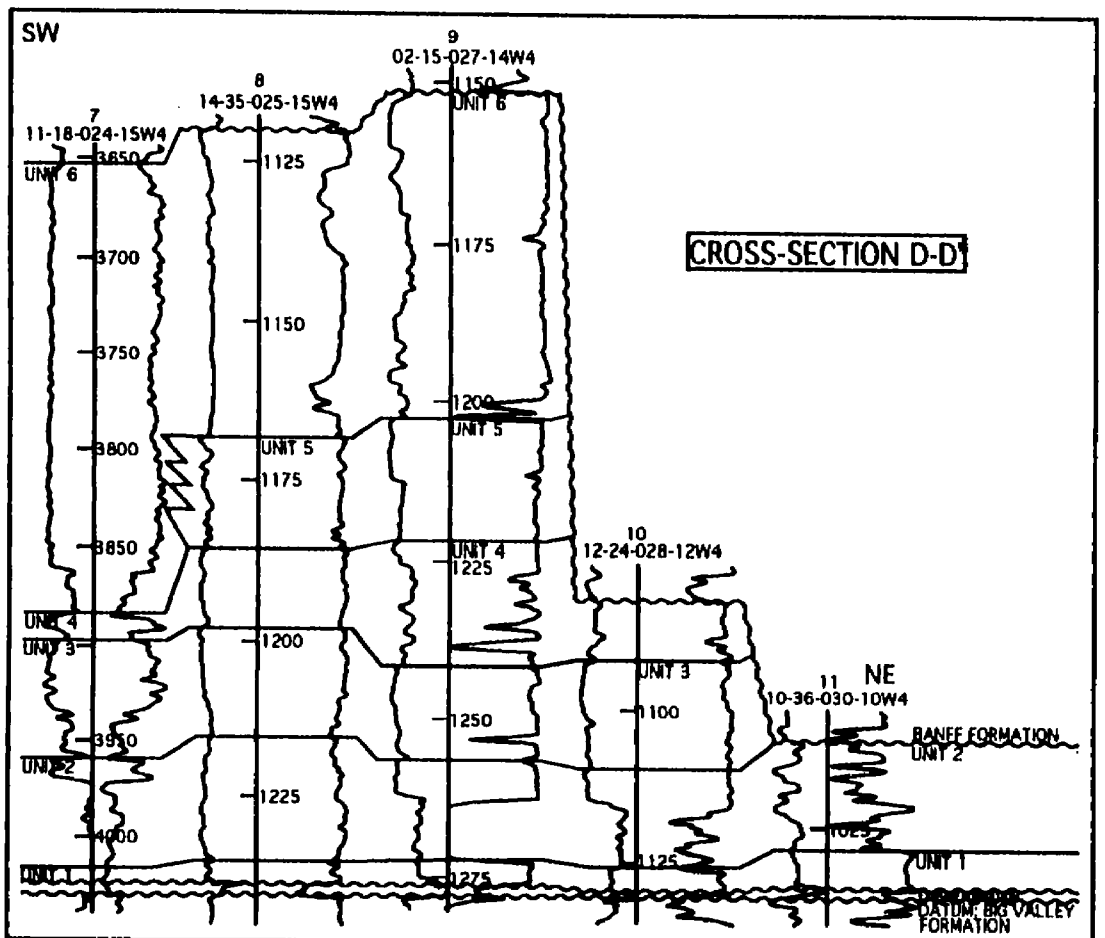


Figure 2.20. Stratigraphic cross-section datumed on the Big Valley Formation. Well logs are Gamma-ray/Density and Gamma-ray/Sonic. The six units of the Banff Formation are indicated. See base map (Figure 2.18) for cross-section location.

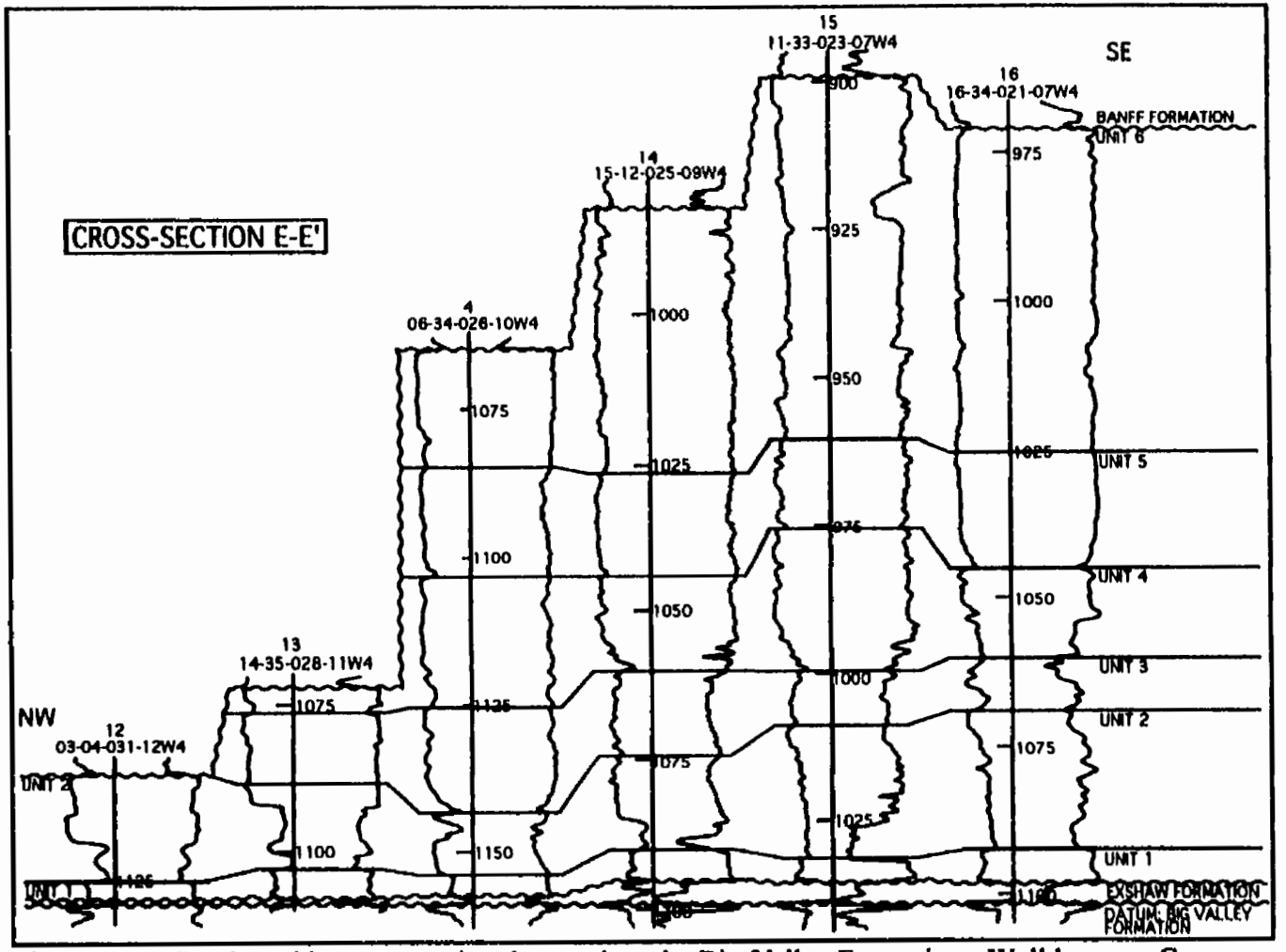


Figure 2.21. Stratigraphic cross-section datumed on the Big Valley Formation. Well logs are Gamma-ray/Density. The six units of the Banff Formation are indicated. See base map (Figure 2.18) for cross-section location.

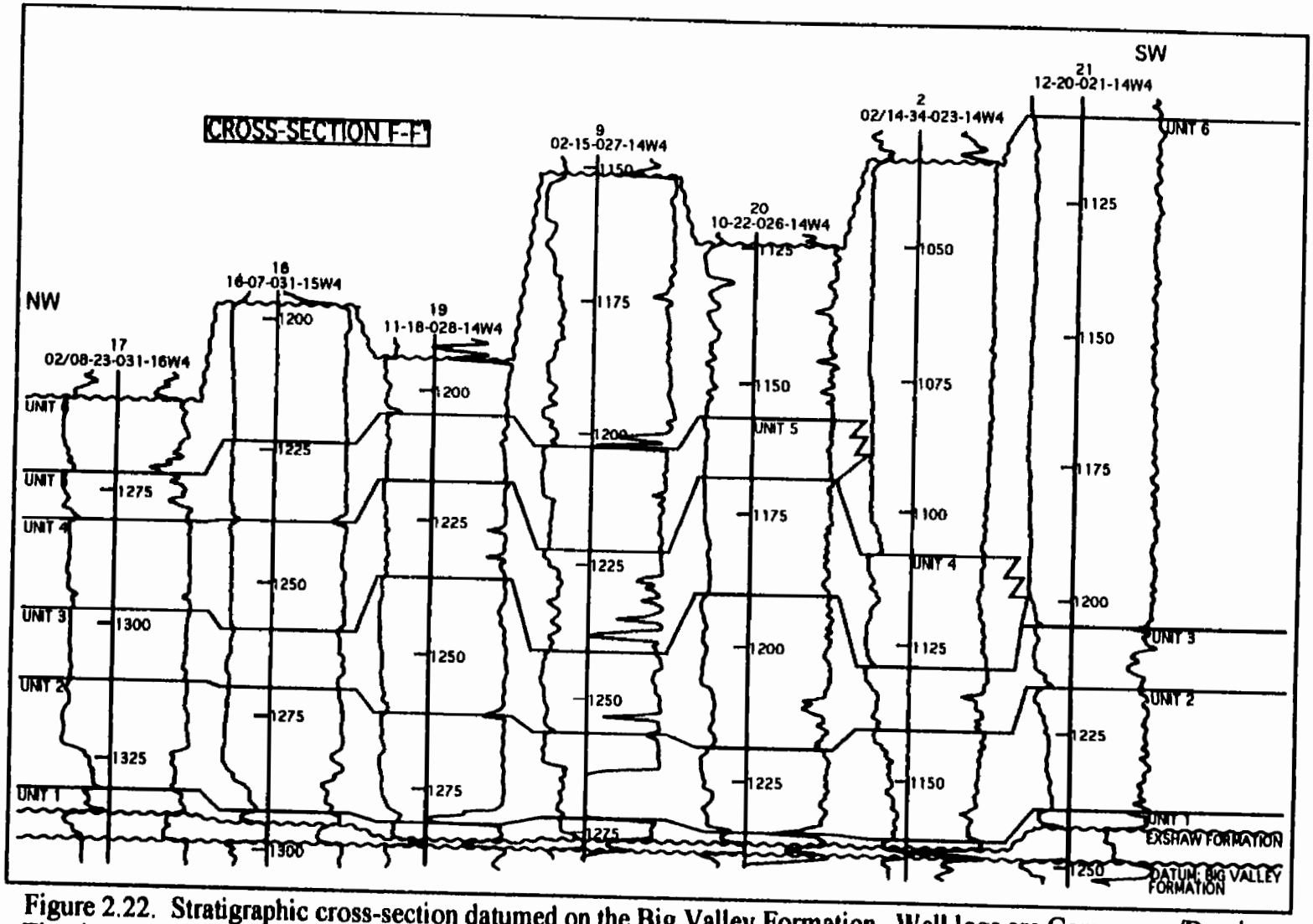
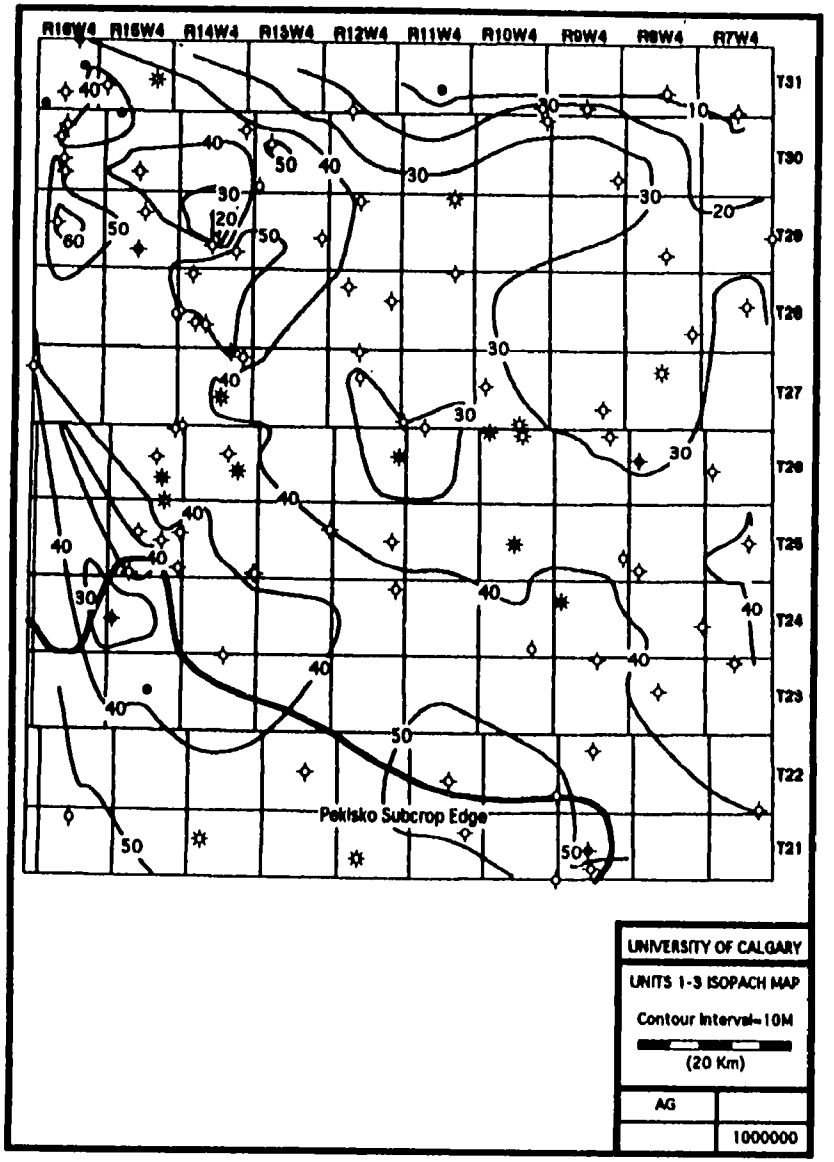


Figure 2.22. Stratigraphic cross-section datumed on the Big Valley Formation. Well logs are Gamma-ray/Density. The six units of the Banff Formation are indicated. See base map (Figure 2.18) for cross-section location.



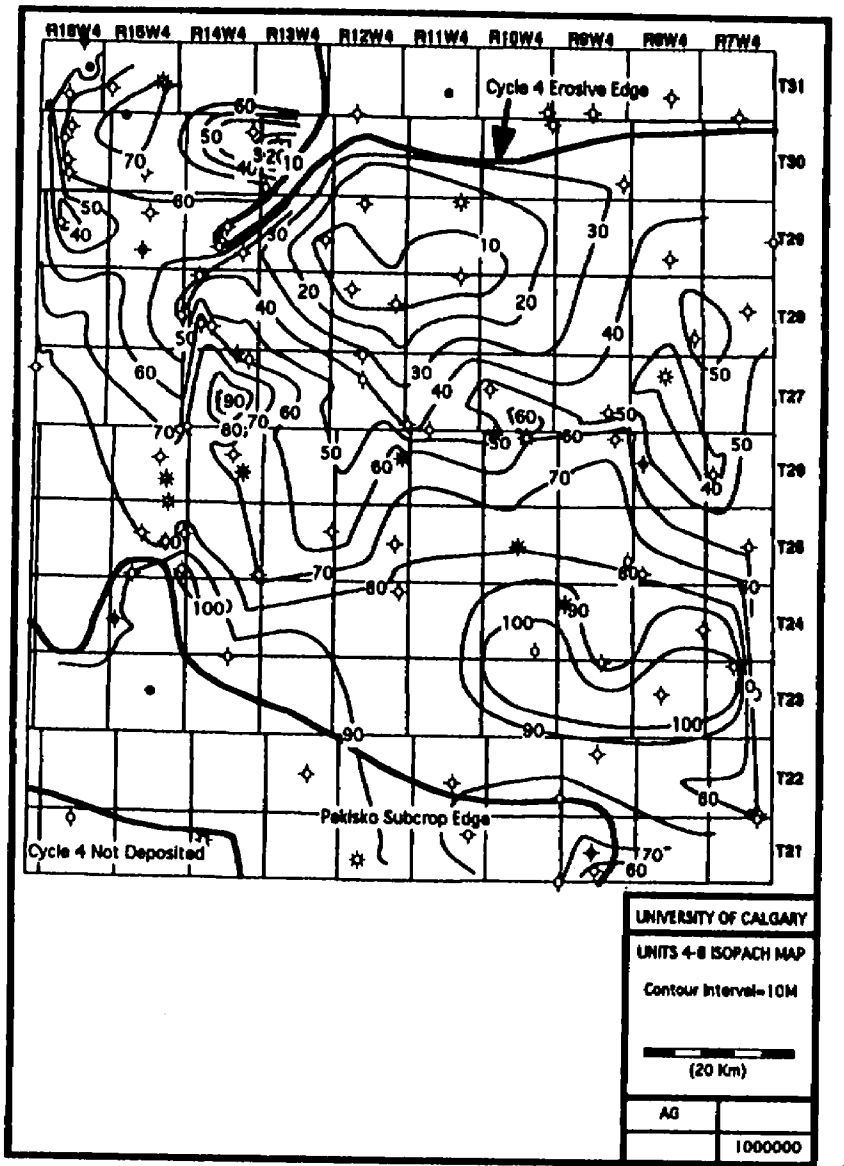


Figure 2.23 (a) and (b). Isopach maps of the upper and lower Banff Formation.

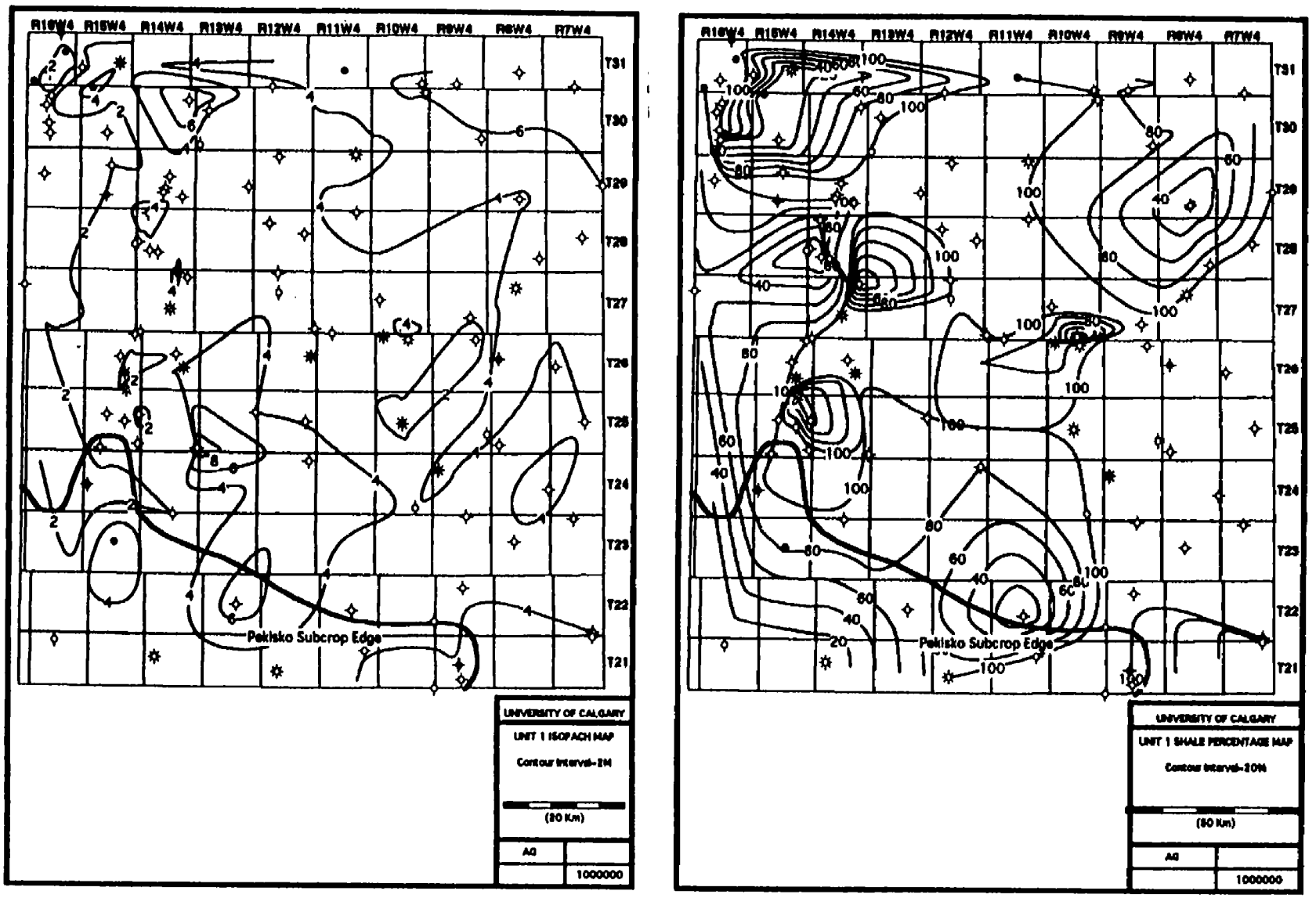
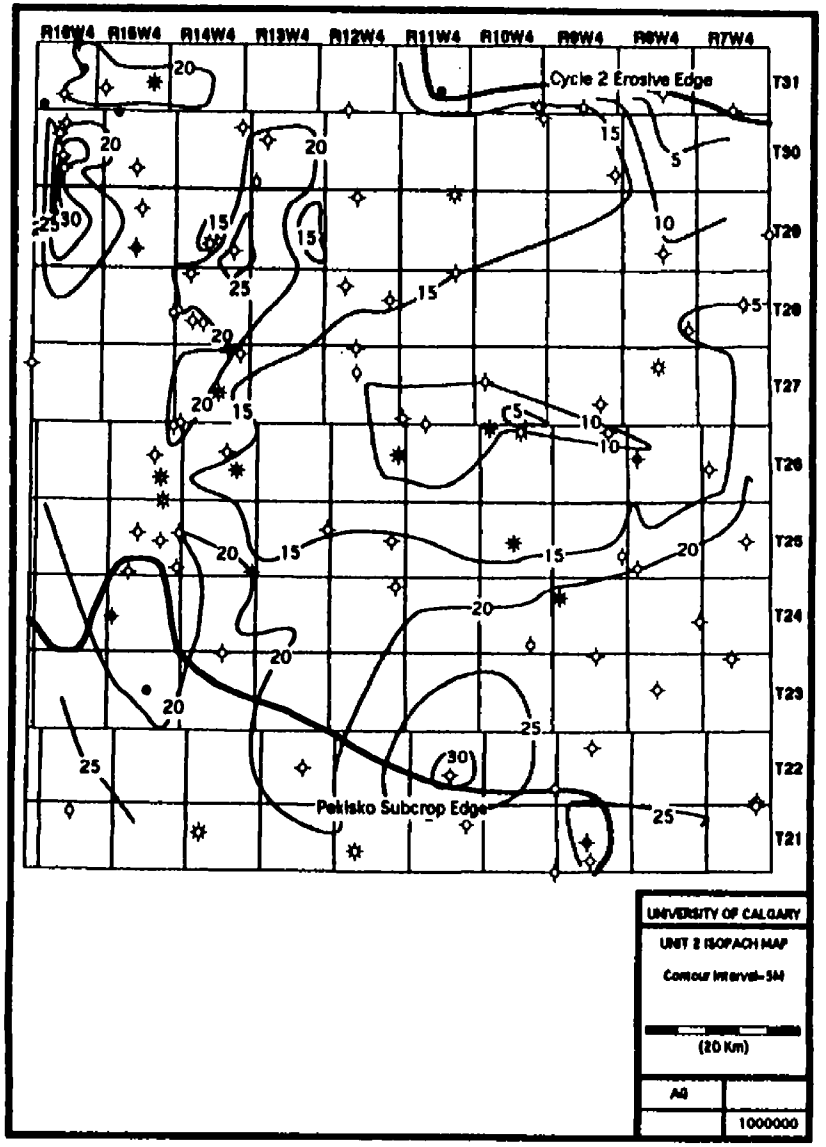


Figure 2.24 (a) and (b). Unit 1 isopach and shale percentage maps.



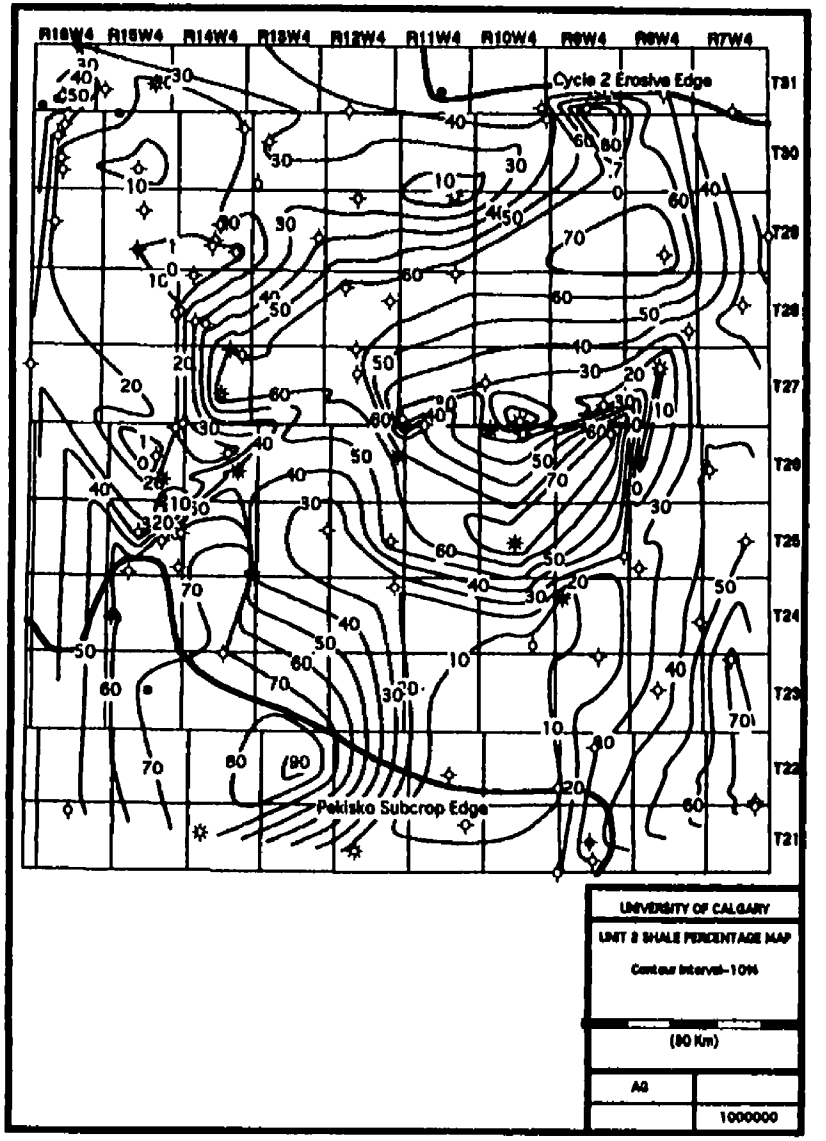
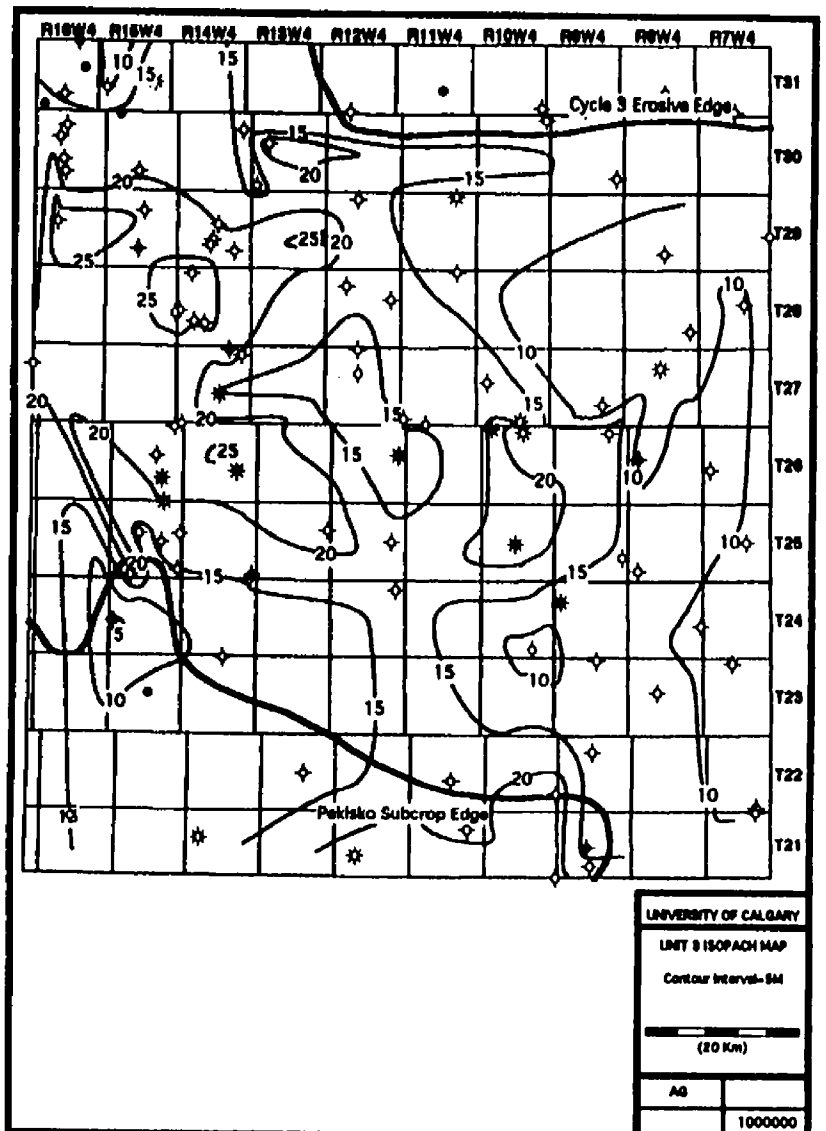


Figure 2.25 (a) and (b). Unit 2 isopach and shale percentage maps.



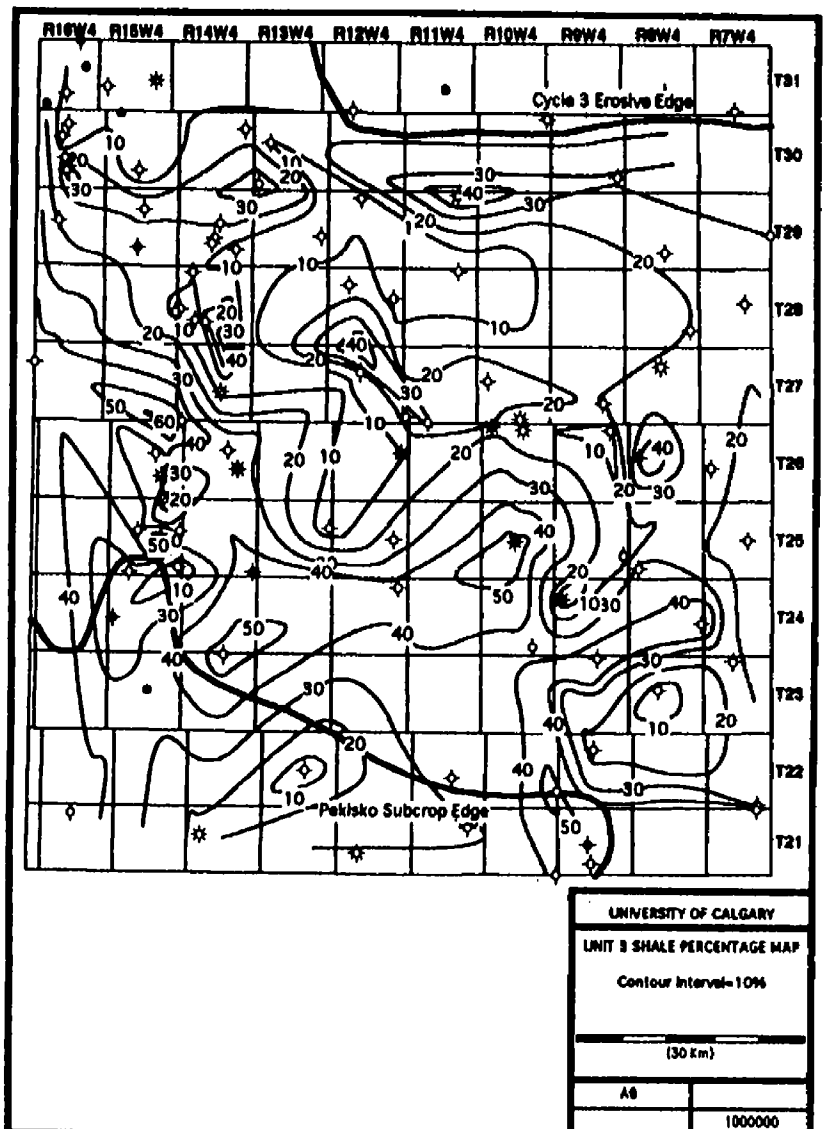
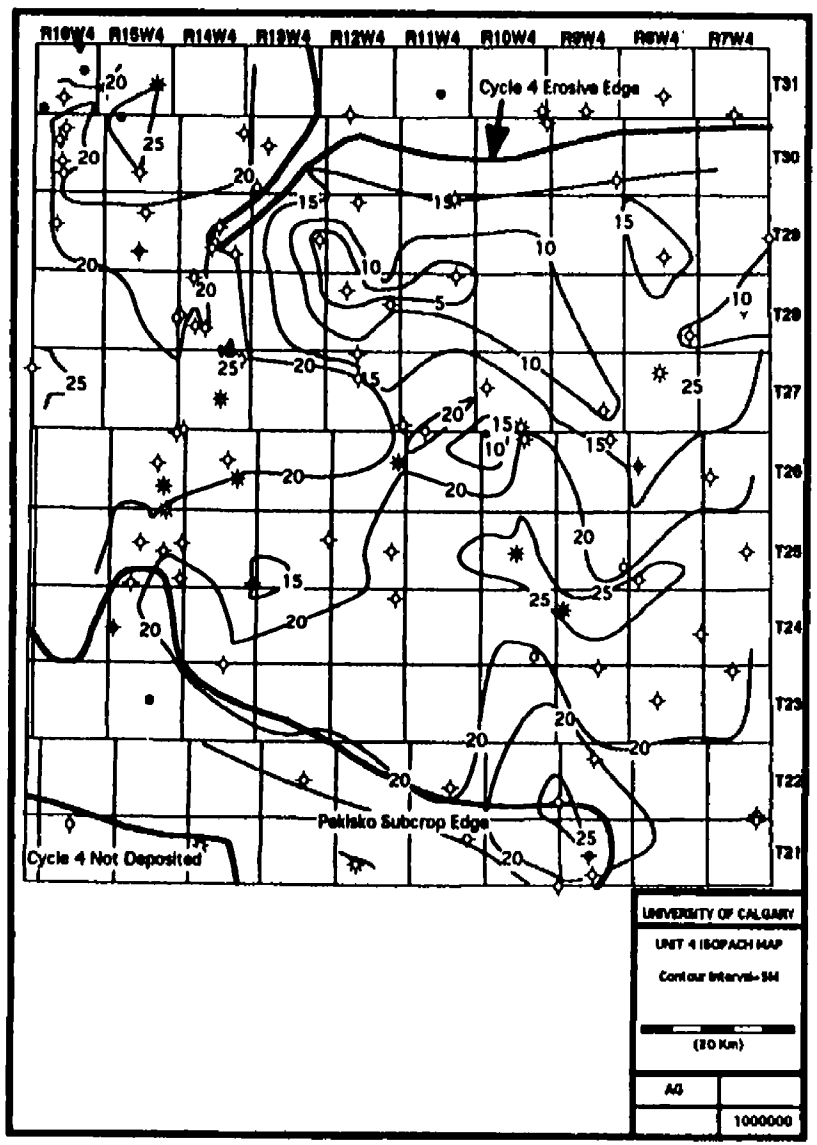


Figure 2.26 (a) and (b). Unit 3 isopach and shale percentage maps.



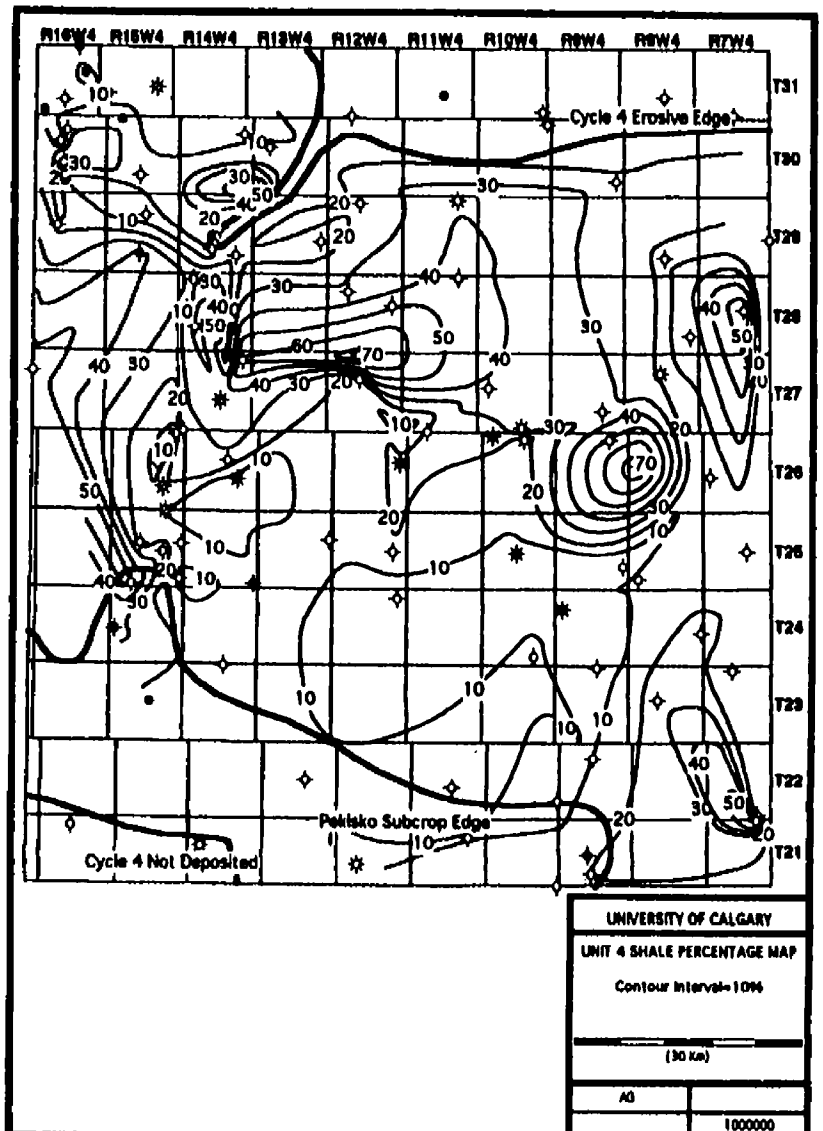
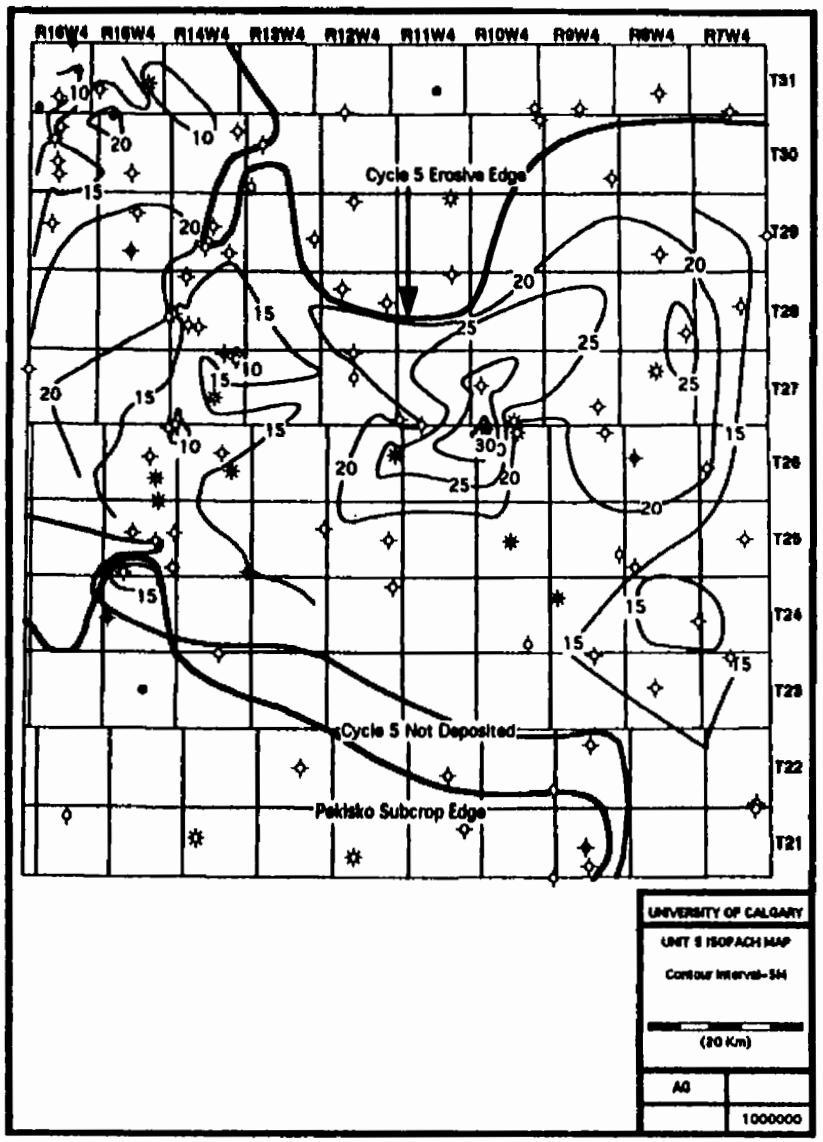


Figure 2.27 (a) and (b). Unit 4 isopach and shale percentage maps.



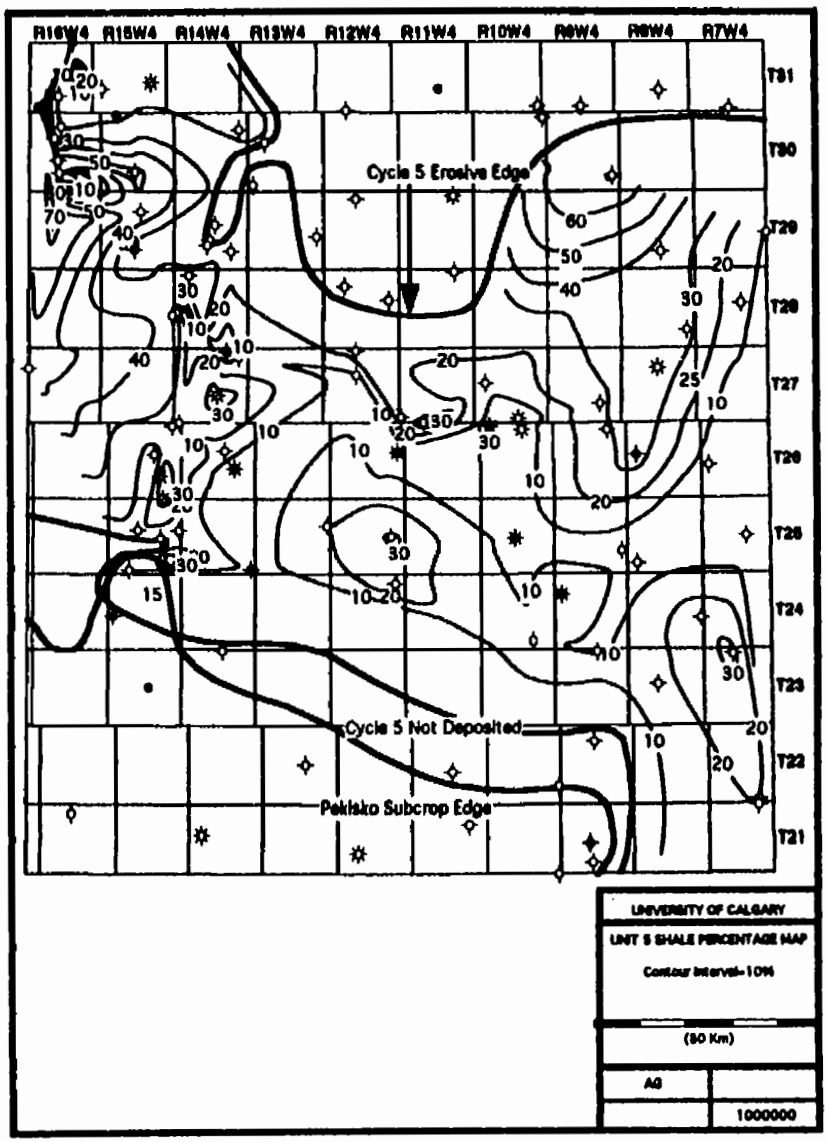
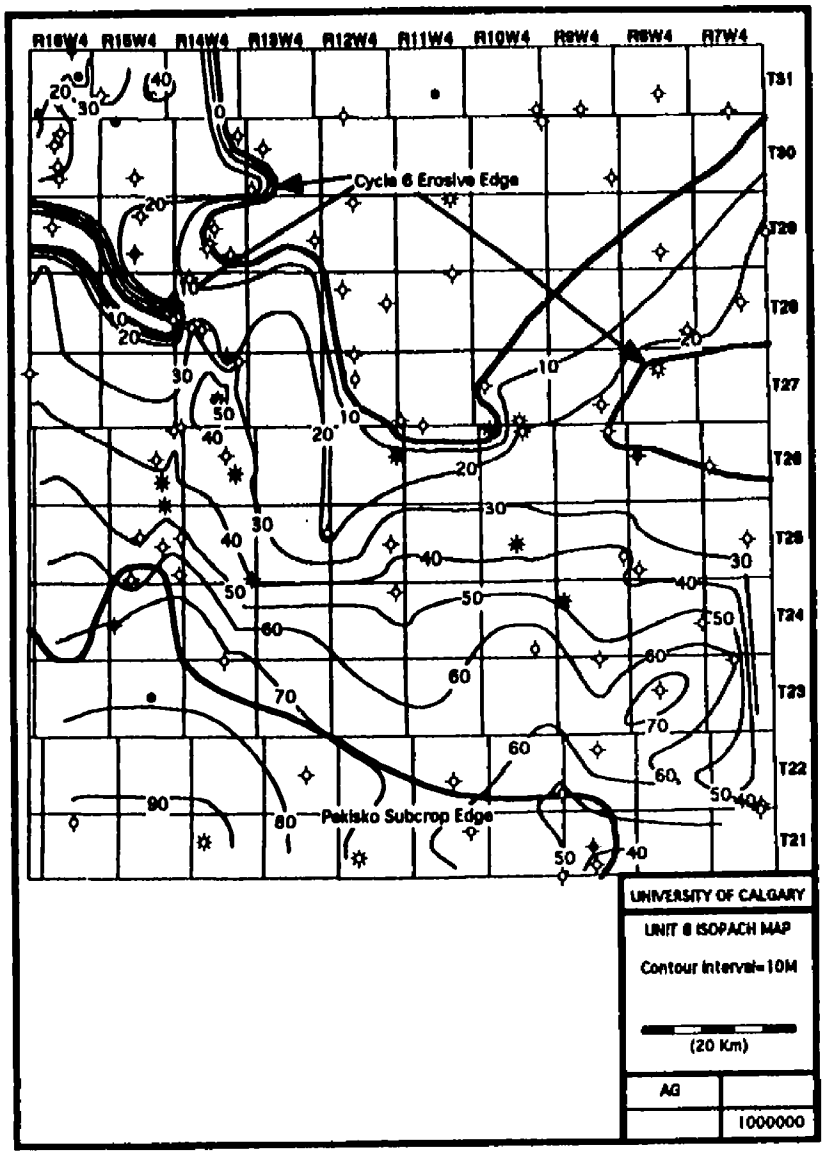


Figure 2.28 (a) and (b). Unit 5 isopach and shale percentage maps.



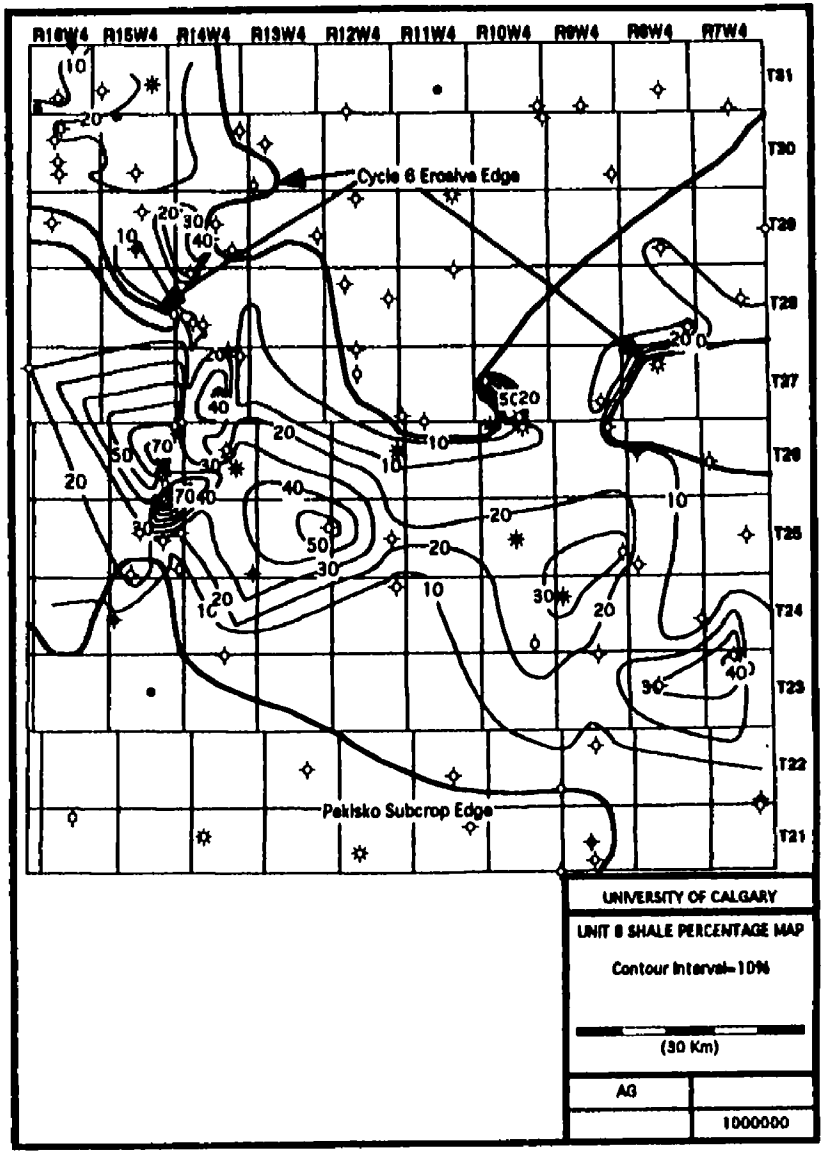


Figure 2.29 (a) and (b). Unit 6 isopach and shale percentage maps.

Gamma ray, neutron and density porosity logs were digitized for 10 representative wells. Neutron versus density porosity and neutron minus density porosity versus gamma ray were cross-plotted for each of the six units (Figures 2.30-2.35). The gamma ray values are plotted in API units (standard units as devised by the American Petroleum Institute) and the porosity logs are plotted on a limestone scale in porosity units. Each point was plotted from log sampling at a half metre increment and identified as one of the six units based on correlation work between logs and limited cores.

Cross-plotting is an established method for facilitating the understanding of sedimentologic relationships in sequences (Watney 1979; Asquith 1982). The cross-plots constructed for the present study illustrate changing lithologies and log signatures across the study area within each unit. They allow direct comparison of vertical and lateral changes in log properties between the six component units of the Banff Formation. Differences in log response exist due to variations in the abundance of clay, carbonate, quartz silt, and organic fractions.

2.3 DISCUSSION OF FORMATION SCALE MAPPING

The structure maps of the upper surface of the Stettler, Big Valley and Exshaw Formations consist of regularly spaced contours with little local variation (Figures 2.7, 2.9, 2.11). The exception to this is the low in Townships 27 and 28, Ranges 13 and 14W4 which is interpreted herein to be due to salt dissolution in the underlying Devonian sediments. Salt dissolution is discussed in greater detail in Chapter 4 (Carbonate-Siliciclastic Mixtures and a Ramp Model for the Banff Formation). Two northeast plunging noses in the structure contours on the west side of the map area (approximate extents Townships 24-28, Ranges 11-12W4 and Townships 22-27, Ranges 13-15W4) may be due to faulting. In contrast to the underlying stratigraphy, the irregular and pitted upper unconformity surface of the Banff Formation is revealed on

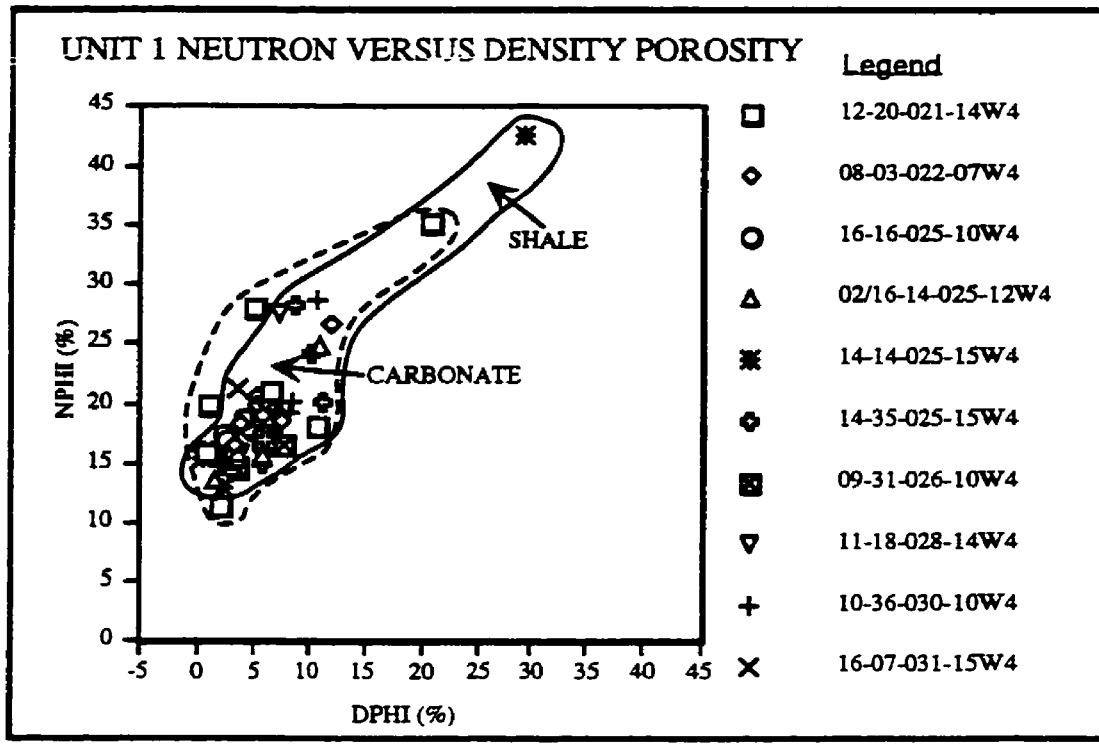


Figure 2.30 (a)

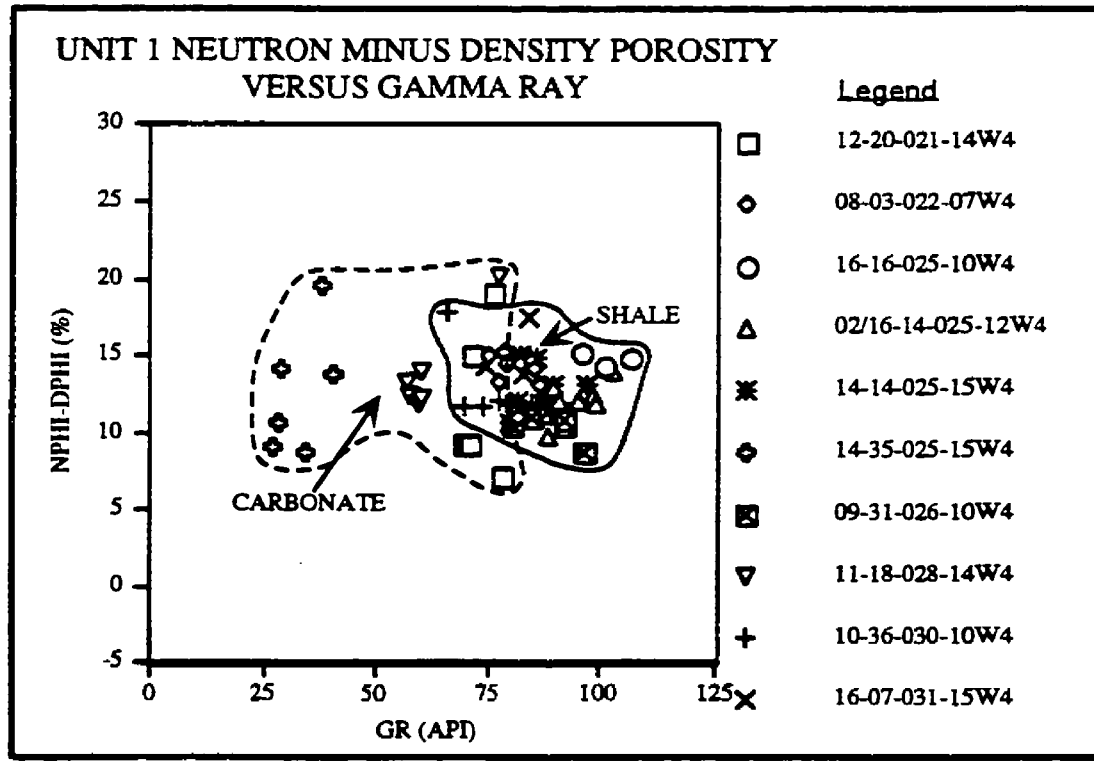


Figure 2.30 (b). Carbonate and shale lithologic domains are illustrated for Unit 1. The bottom cross-plot is more useful for differentiating between the two constituent lithologies.

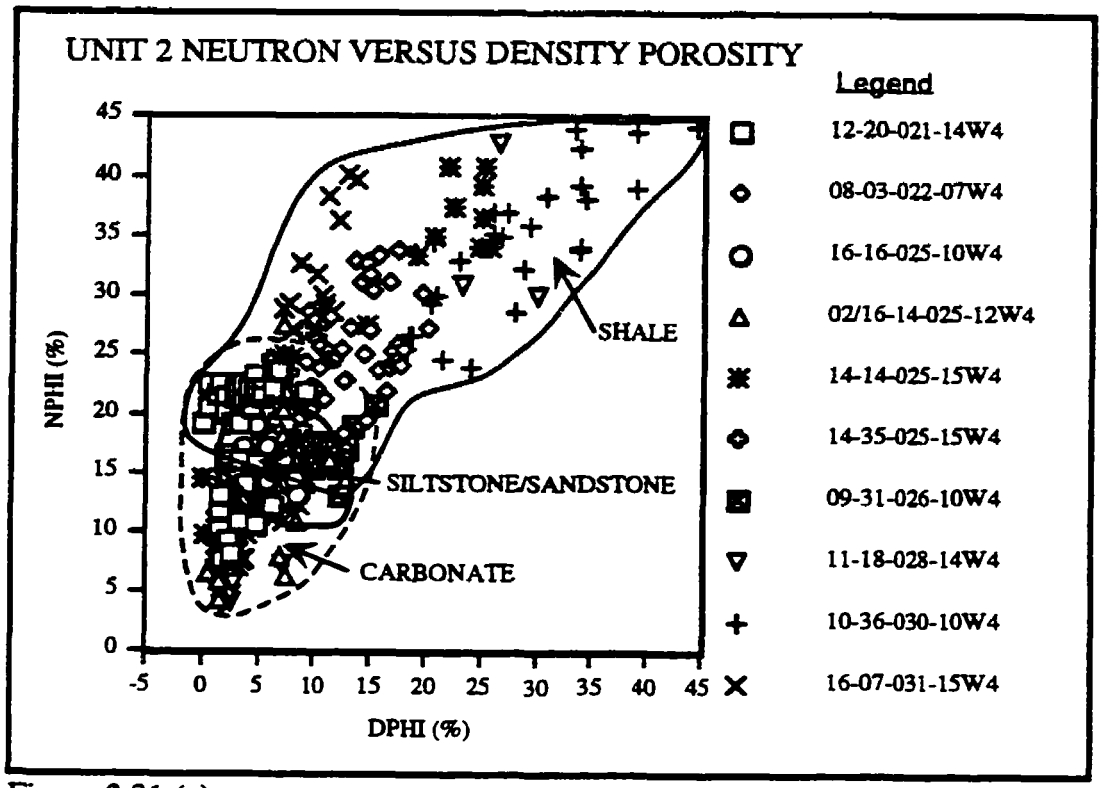


Figure 2.31 (a)

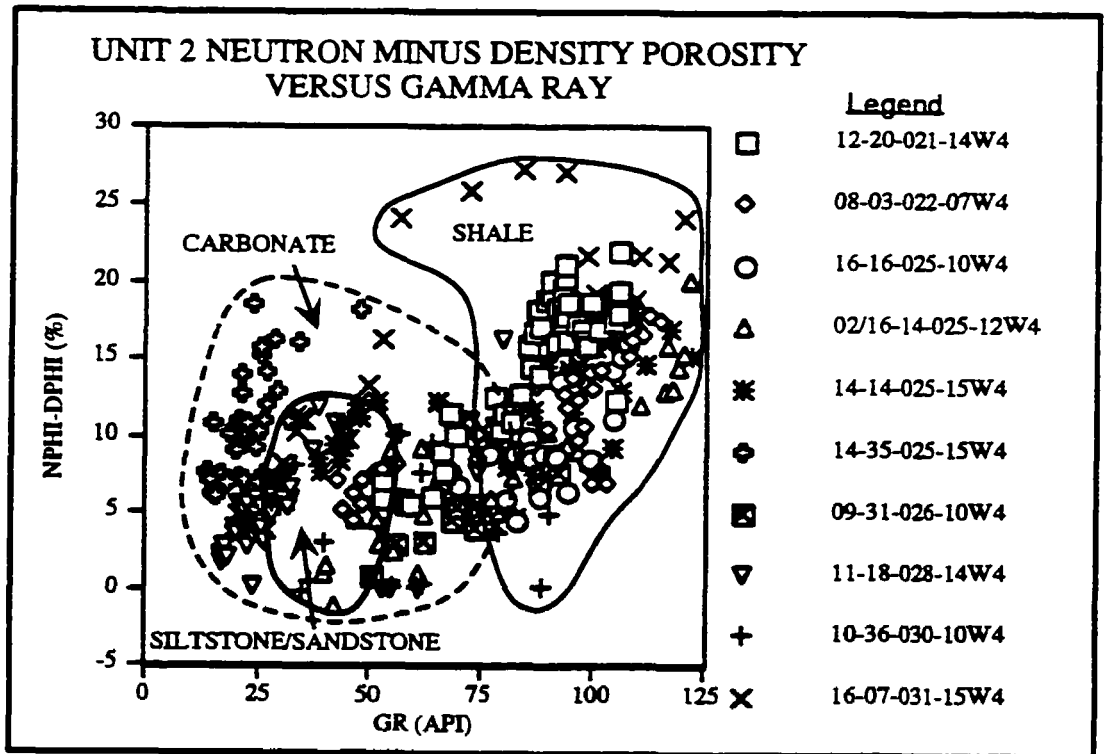


Figure 2.31 (b). Three lithologic domains can be identified in Unit 2. Shale and carbonate are easily differentiated from each other. In contrast, the siltstone/ sandstone domain is enclosed within the carbonate field on both cross-plots.

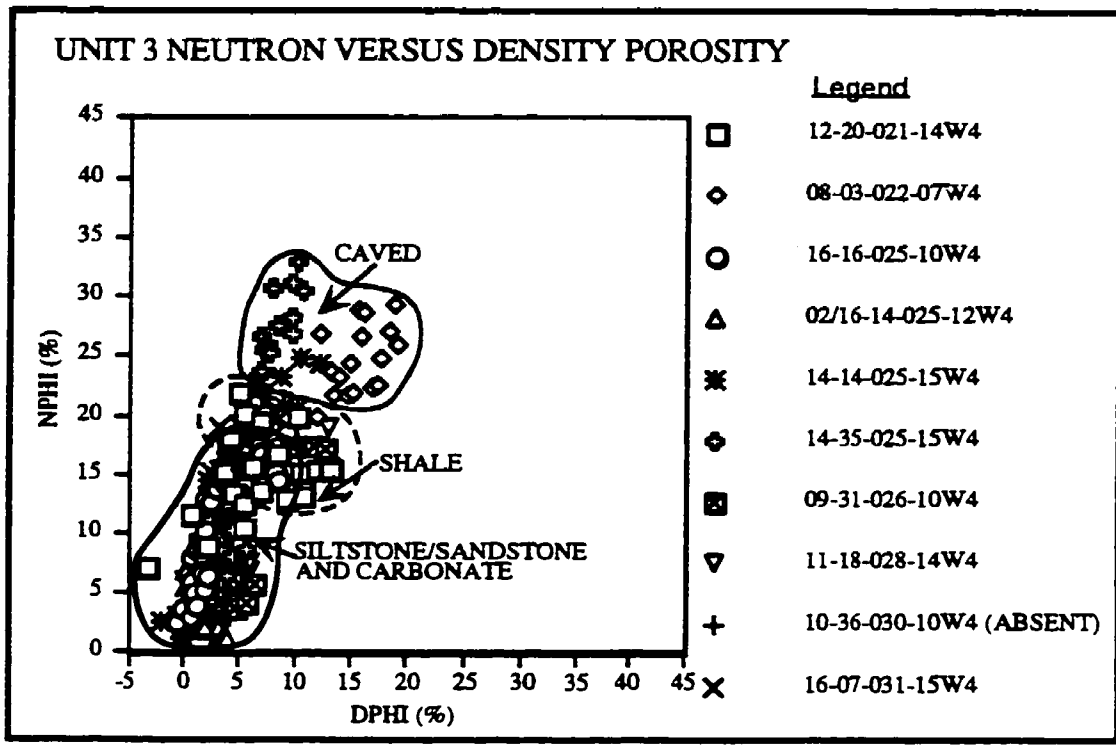


Figure 2.32 (a)

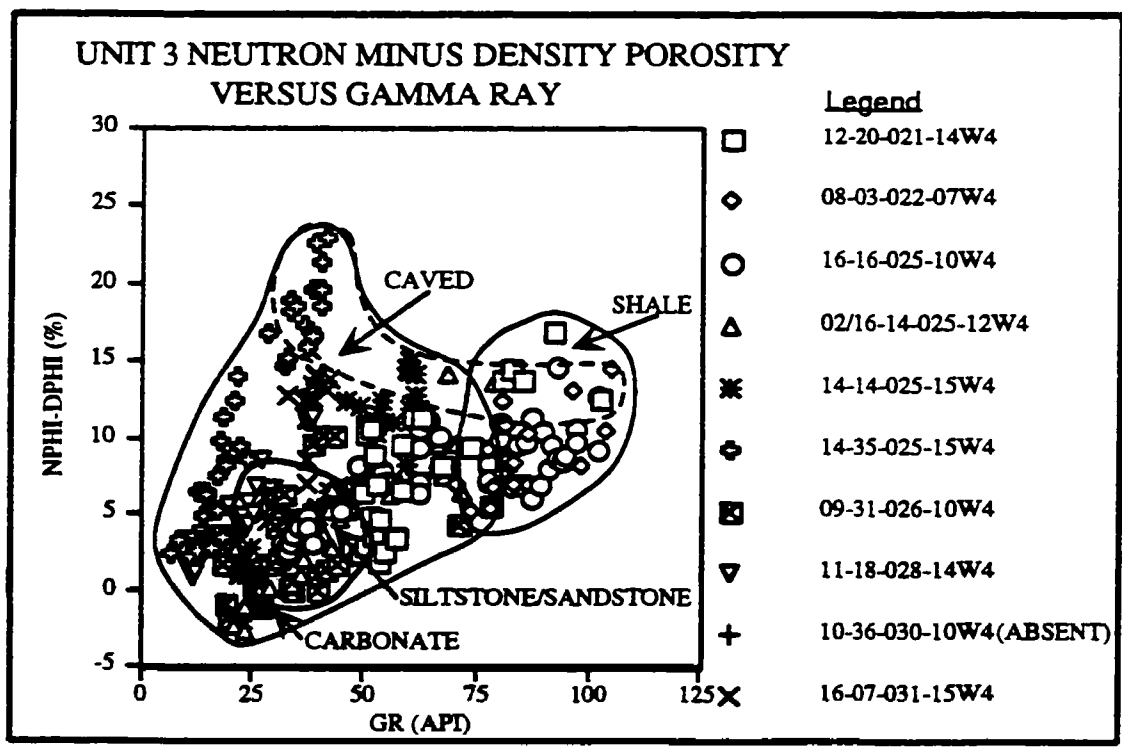


Figure 2.32 (b). The three component lithologies of Unit 3 are identified on the tw cross-plots. The anomalously high neutron and density porosity values are due to caving in the borehole.

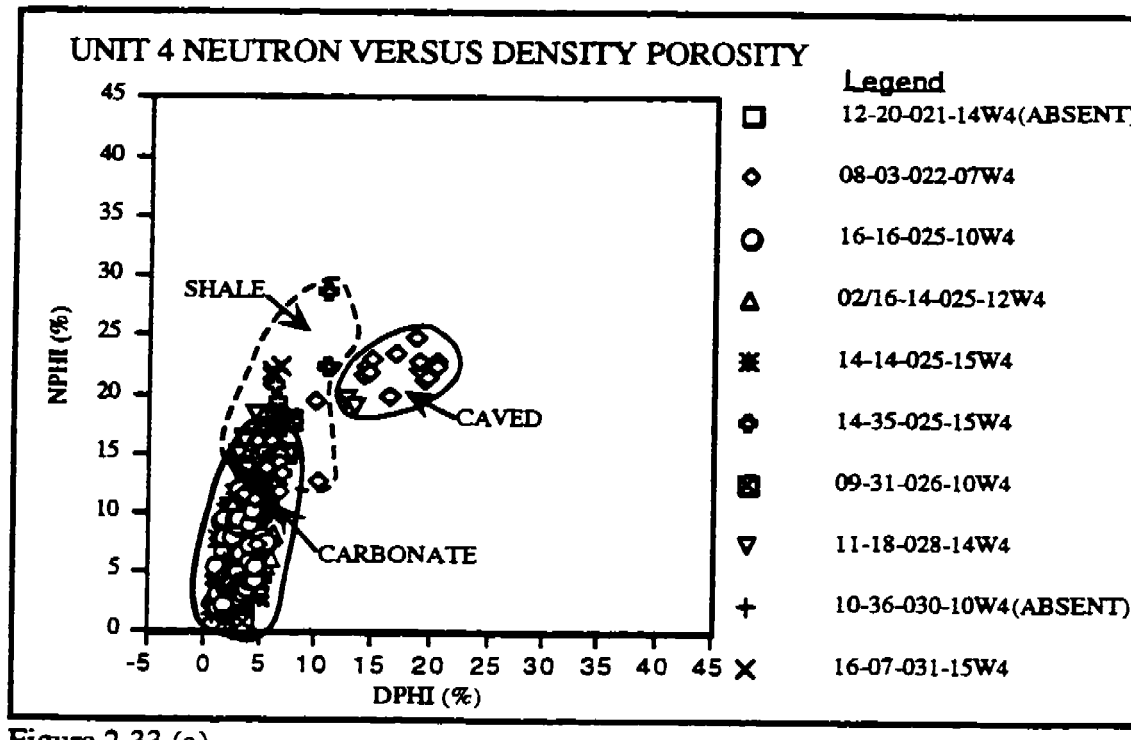


Figure 2.33 (a)

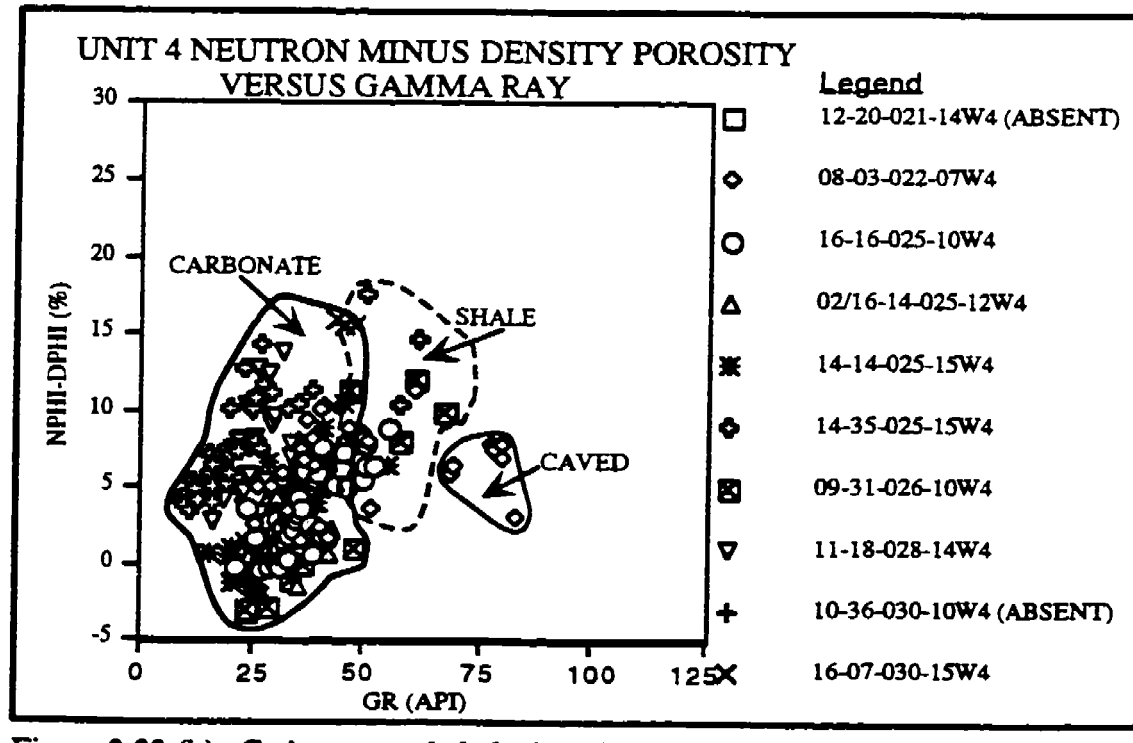


Figure 2.33 (b). Carbonate and shale domains are identified in Unit 4.

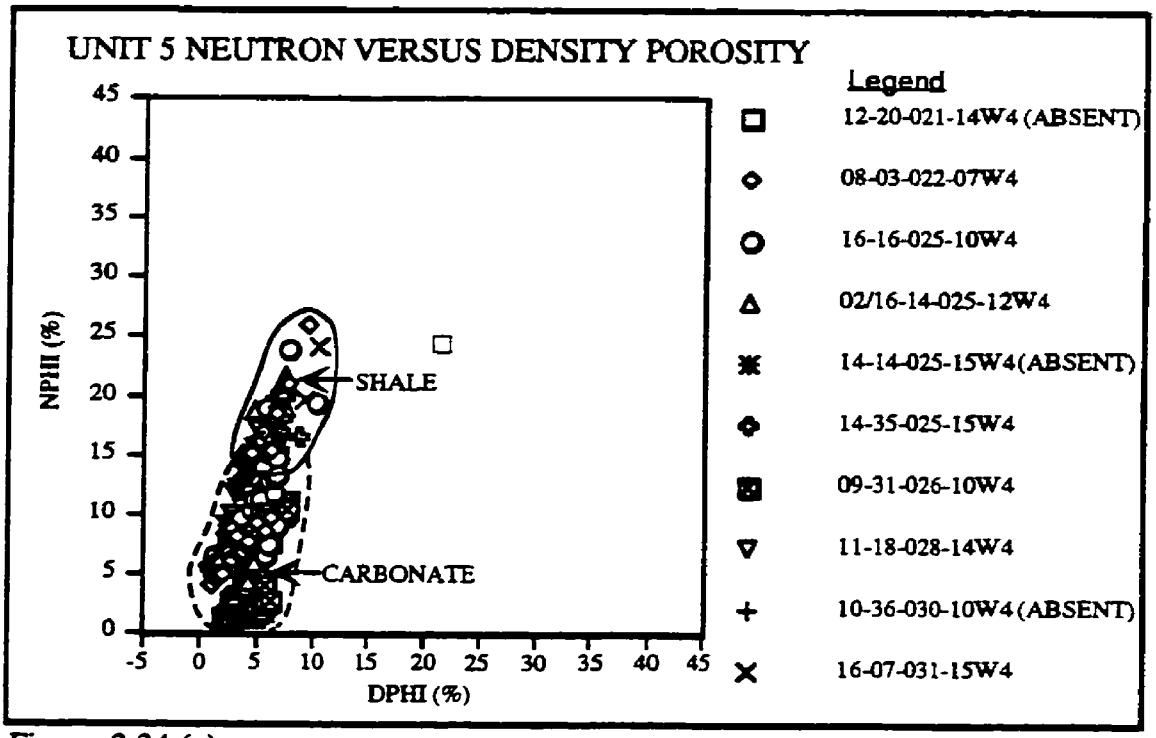


Figure 2.34 (a)

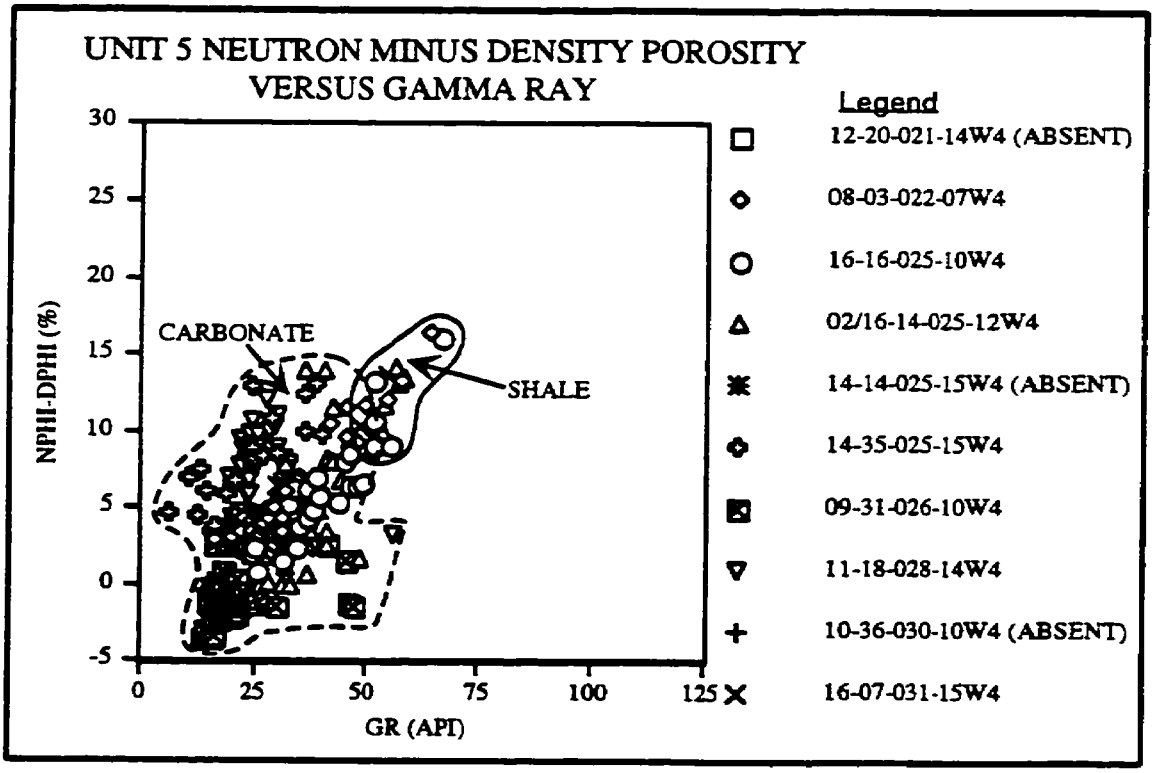


Figure 2.34 (b). Shale and carbonate deomains in Unit 5 are identified on the cross-plots. Log values are tightly constrained in contrast to the other five units of the Banf Formation.

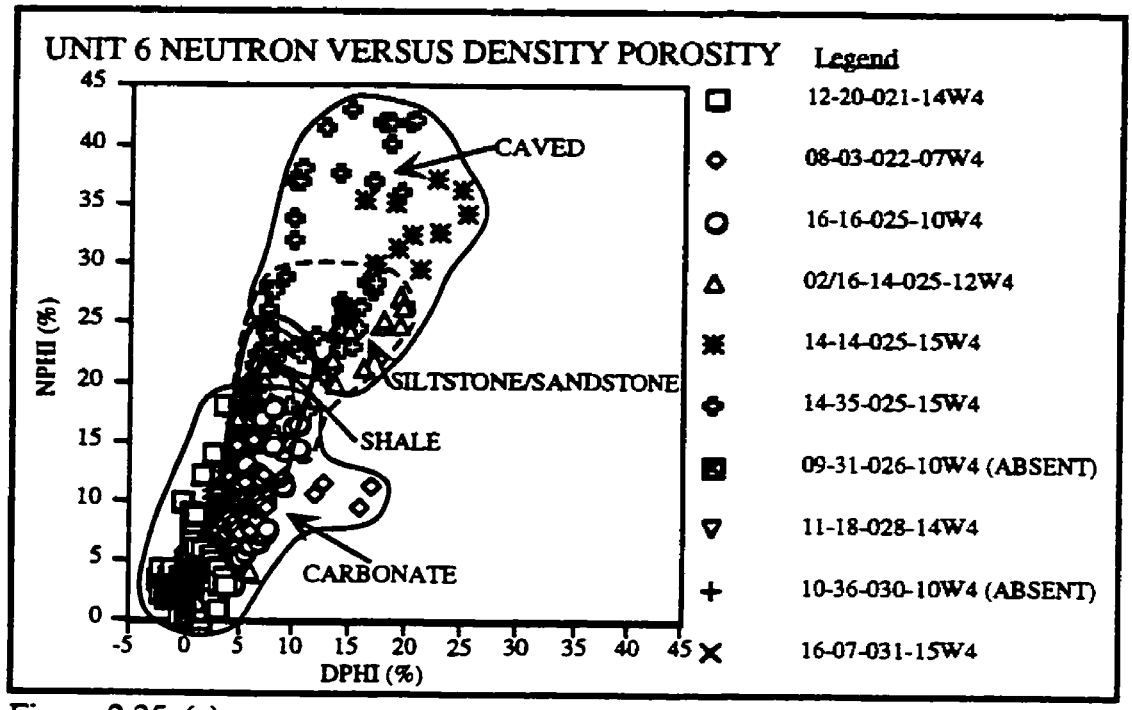


Figure 2.35 (a)

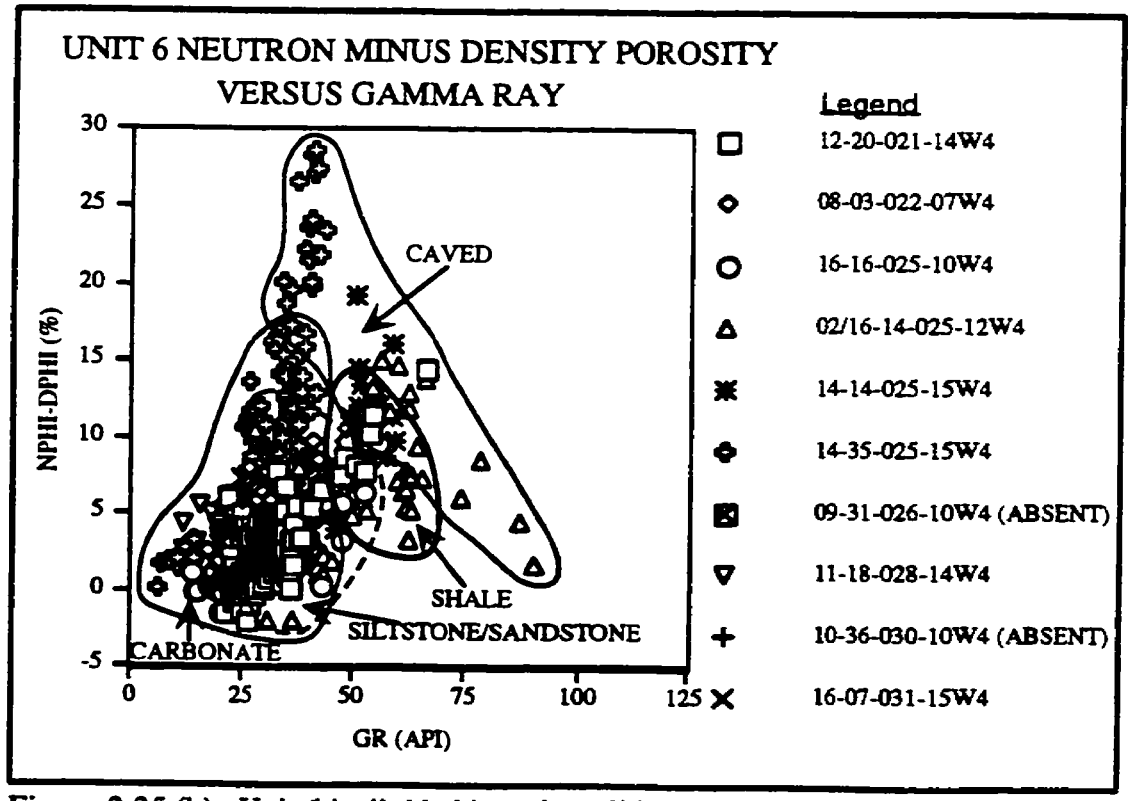


Figure 2.35 (b). Unit 6 is divided into three lithologic domains. Commonly fair to poor borehole conditions account for the caved domain.

the structure map by unevenly spaced contours and multiple, localized highs and lows (Figure 2.13).

The structure map on top of the Mannville Group consists of evenly spaced contours indicating a gently northwesterly dipping surface (Figure 2.15). The anomalous low in Townships 27 and 28 is still visible, but the structural noses are no longer present. This suggests that the low in the Banff Formation in Townships 27 and 28 which is interpreted to reflect pre-Mississippian topography on the underlying Wabamun Formation was substantial enough to persist through to Mannville Group deposition. The structural features appear to be confined to the Devonian and Mississippian sediments alone.

First order trend maps are planar surfaces of the actual map which remove local variations in the structure and allow examination of the regional structural trend. Trend maps on the upper surface of the Stettler, Big Valley, Exshaw, Banff and Mannville Formations illustrate a change from a northwest-southeast trend in the Devonian Stettler Formation to a dominantly north-south trend in the Banff Formation to a northeast-southwest trend in the Cretaceous Mannville Formation (Figures 2.7. 2.9, 2.11, 2.13, 2.15). This represents a 90° rotation in regional dip between the Devonian and Cretaceous periods.

A gently southwest to westerly dipping surface is illustrated by the block diagrams for the Stettler, Big Valley and Exshaw Formations (Figures 2.8, 2.10, 2.12). The two structural noses as well as the depression in Townships 27 and 28 are visible. The structure on these surfaces is somewhat distorted by a vertical exaggeration of a factor of 100. The Exshaw Formation block diagram (Figure 2.12) illustrates the paleotopography onto which the lower Banff Formation was deposited. In contrast to the three underlying formations, the block diagram of the Banff Formation (Figure 2.14) shows a westerly dipping surface with multiple localized highs and lows.

Approximately evenly spaced isopach contours increase in magnitude to the southwest on the Mannville Formation to Big Valley Formation isopach map (Figure 2.16). This map is broken down into component Mannville Formation to Banff Formation and Banff Formation to Big Valley Formation isopach maps (Figures 2.17). The Mannville Formation isopach map shows little change in thickness in the central part of the study area, to highly variable thicknesses in the northeast and southwest corners of the study area (Figure 2.17). In contrast, the thickness of the Banff Formation gradually increases to the southwest, while the gradient decreases (Figure 2.17). Several thicks are present in the southwest quadrant. The bold contours on both maps are taken from the Atlas of the Western Canada Sedimentary Basin (Richards et al. 1994) and generally match the isopach contours in the present study.

2.4 UNIT DESCRIPTIONS AND GEOMETRY

2.4.1 Introduction

Identification and correlation of unit boundaries in Units 1, 2, 3, and 6 was done with greater confidence than in Units 4 and 5. Units 1, 2, 3, and 6 are separated from under- and overlying units by shale or shaly carbonate marker beds which are easily identified by a peak in the gamma ray and porosity logs as discussed above. In contrast, a ragged or serrated log signature with no distinct log peaks in Units 4 and 5 makes recognition of unit boundaries more difficult.

Figure 2.23 is a pair of isopach maps of the lower and upper three units respectively. The upper three units are much thicker and represent a greater proportion of the Banff Formation than the lower three units. Overall, Units 1-3 combined increase in thickness from only a few metres in the northeast quadrant to 50 or 60 metres on the west and south sides of the Greater Cessford Area. Units 4-6 combined range in thickness from zero metres in the northeast quadrant of the study area where they have largely been removed by erosion to in excess of 100 metres in the southwest. The

distribution of sediments in both the lower and upper Banff Formation is somewhat irregular and is not in concentric bands as will be demonstrated in more detail on a unit-by-unit basis below.

2.4.2 Unit 1

Three log profiles are observed in Unit 1. These are: (1) high radiation blocky (Figure 2.19, well 4), (2) low radiation blocky (Figure 2.22, well 21), and (3) decreasing radiation upwards (Figure 2.19, well 6). Unit 1 is the only unit which is present over the entire study area. Boundary selection in Unit 1 is the simplest of the 6 Banff Formation units, as it is underlain by the highly radioactive shales of the Exshaw Formation and overlain by the basal shales of Unit 2. Hole conditions and log quality are typically very good.

On average, Unit 1 is the thinnest of the six units, ranging from 1-9 metres thick with a thickness of 4 metres being most common. It was deposited as a series of irregularly shaped sediment piles (Figure 2.24a). Unit 1 is generally thinnest along the western boundary of the Greater Cessford Area. One or several thick sediment pile(s) (6-8 metres) are located in the northeast, northwest, and southwest quadrants. Predominantly carbonate sediments in the southwest and northeast quadrants are separated by a northwest-southeast trending belt of shale (Figure 2.24b).

Unit 1 is commonly comprised entirely of shale (log profile 1) that is distributed in a northwest-southeast trending band through the centre of the study area. Less commonly, argillaceous carbonate alone (log profile 2) or overlying a shaly base (log profile 3) are located in the northeast and southwest quadrants as well as in isolated pods throughout the study area.

The neutron versus density porosity log cross-plot is not very useful for differentiating between the shale and carbonate lithologies of Unit 1 because the two fields are overlapping (Figure 2.30a). In contrast, the two lithologies are more clearly separated on the neutron minus density porosity versus gamma ray log cross-plot

because although the range in neutron minus density porosity values is almost identical, the shale lithology has consistently greater gamma radiation (Figure 2.30b).

2.4.3 Unit 2

Four log profiles are present within Unit 2: (1) upward decrease in gamma radiation (Figure 2.20, well 10), (2) several relatively thin cycles which decrease upward in radiation (Figure 2.19, well 3), (3) serrated (Figure 2.20, well 11), and (4) low radiation blocky (Figures 2.20, well 8). Unit 2 is present over the entire study area except where it has been eroded near the subcrop edge in the northeast (Figure 2.25).

The base of this unit is marked by shales which overlie Unit 1. The upper boundary is characterized by a slight increase in the gamma radiation with little accompanying movement in the porosity logs. Within Unit 2, there is increasing separation between the neutron and density porosity logs from the northeast to southwest quadrants of the study area. Hole conditions are highly variable with some caving in the lower, shalier parts of Unit 2.

Unit 2 varies in thickness from 4-32 metres (typically 15 metres). The isopach map shows overall thinning from the western and southern extents of the study area to the northeastern parts (Figures 2.25a). Sediment is distributed in piles of varying shape, size and thickness. Shale/silt percentage is highly variable but is generally between 30 and 50% (Figure 2.25b).

A shale-based, coarsening-upward cycle variably overlain by clean or argillaceous carbonates, or less commonly, by quartzose siltstones and sandstones is the most commonly occurring form of Unit 2 (log profile 1). This profile generally corresponds to the thickest pods on the isopach map and the highest percentages on the shale percent map (Figure 2.25b). It is present in the southern portion of the study area and in the northwest quadrant. More rarely, it is present in the central part of the Greater Cessford Area.

Two or three shale-based, coarsening-upward cycles overlain variably by argillaceous carbonates or quartzose siltstones and sandstones are concentrated in a central belt around Township 25, but are present throughout the study area (log profile 2). This profile corresponds to average thicknesses and slightly greater than average siliciclastic percentages on the pair of Unit 2 maps (Figure 2.25).

Metre-scale cycles consisting of shale and carbonate are the thinnest deposits of Unit 2 and are present in the northeast part of the study area. The proportion of shale is generally very high (log profile 3). Locally, on the west side of the study area, a massive carbonate is present (log profile 4).

Higher neutron and density porosities are associated with the shalier, more northern wells in the neutron versus density porosity log cross-plot (Figure 2.31a). The scatter of data on the neutron minus density versus gamma ray log cross-plot reflects the highly variable lithologies encountered in Unit 2 (Figure 2.31b). Three overlapping domains can be identified for the shale, carbonate and quartzose siltstone/sandstone lithologies.

2.4.4 Unit 3

Three log profiles are present in Unit 3: (1) low radiation blocky (Figure 2.22, well 19), (2) upward decrease in gamma radiation (Figure 2.20, well 7), and (3) serrated (Figure 2.21, well 14). Unit 3 is present throughout the study area except where it has been removed by erosion along the subcrop edge (Figure 2.26).

The lower boundary is marked by an increase in gamma radiation due to the presence of a 1-2 metre thick basal shale. Similarly, the upper boundary is marked by an increase in gamma radiation due to the overlying basal shale or shaly carbonates of Units 4 through 6. Hole conditions in Unit 3 are commonly poor with the lower, shalier half of the unit often badly caved.

The total thickness of Unit 3 ranges from 4 to 27 metres. No clear thickness patterns emerge from the isopach map (Figure 2.26a). Sediments are distributed in piles

of variable shape and areal extent. Thickness variations among closely spaced wells can be quite substantial. There is some suggestion of an inverse thickness relationship between Units 2 and 3 (Figures 2.5-2.6, 2.25a, 2.26a). Thicker sediment piles of Unit 3 commonly correspond to thinner areas on the isopach map of Unit 2 and vice-versa. Siliciclastic content is generally lower than in Units 1 and 2 and ranges from 10-30% (Figure 2.26b). A west-northwest south-southeast trending band runs through the centre of the Greater Cessford Area and consists of sediments with >30% clastic sediments. Sediments in the northeast, northwest and southwest quadrants contain <30% clastic sediments.

Massive carbonate (log profile 1) is present in the northwest and northeast quadrants of the study area. In contrast, a shale-based, coarsening-upward cycle overlain by carbonate (log profile 2) is present in the southwest and southeast. Less commonly, two shale-based cycles are present in the southwest quadrant. Metre-scale, coarsening-upward cycles of shale, siltstone, sandstone and carbonate (log profile 3) are restricted to the central portion of the Greater Cessford area.

Neutron and density log values are generally lower and more clustered than in the previous two units on the neutron versus density porosity log cross-plot (Figure 2.32a). The quartzose siltstone/sandstone and carbonate domains coincide on this plot and slightly overlap with the higher neutron and density porosity log values of the shale domain. Clean and argillaceous carbonates, quartzose siltstones and sandstones, and shale domains can be recognized on the neutron minus density porosity versus gamma ray log cross-plot (Figure 2.32b). The quartzose siltstone/sandstone field is completely enclosed by the carbonate domain. Some of the higher neutron minus density porosity differences are due to caving in the borehole.

2.4.5 Unit 4

Three log profiles are present within Unit 4: (1) low radiation blocky (Figure 2.22, well 18), (2) serrated (Figure 2.20, well 9), and (3) upward decrease in radiation

(Figure 2.21, well 16). A massive carbonate in Unit 6 directly overlies Unit 3 in the southwest corner of the study area where both Units 4 and 5 are not present or are confined within Unit 6 but cannot be differentiated (Figure 2.19). Erosion associated with the post-Mississippian unconformity has removed Unit 4 in the northeast corner of the study area (Figure 2.27). Hole conditions are typically good with some caving in the basal, shalier parts of the section.

The sediments of unit 4 are deposited in a series of piles ranging in thickness from 9-28 metres (Figure 2.27a). Overall, thickness increases from relatively thin piles of sediment in the northeast quadrant of the study area to thicker piles in the other three quadrants. Thicker sediment piles of Unit 4 commonly overlie the thinner sediment piles of Unit 3 (Figures 2.5-2.6, 2.26-2.27).

Shale/silt content is highly variable (5-70%) with extreme highs commonly located adjacent to lows (Figure 2.27b). Shale/silt content is highest (40-70%) in a series of pods located slightly north of the middle of the study area and decreases out to the map edges in all directions. Therefore, shale/silt content is low in the northeast, highest in the north-central portion of the study area, and declines again in the southwest quadrant.

A massive carbonate is present in the northwest, west-central and southeast quadrants of the study area (log profile 1). In contrast, a series of metre-scale, coarsening-upward cycles are present in the central part of the study area (log profile 2). This profile is characterized by a high proportion of clastic sediments (Figure 2.27b). More rarely, one or two shale-based, coarsening-upward cycles are present (log profile 3). One cycle is observed in the southeast, northwest and southwest quadrants while two cycles are observed in the southwest and east and west central parts of the study area.

It is difficult to separate the shale and carbonate domains on the neutron versus density porosity log cross-plot, although the shales generally have higher porosity

values (Figure 2.33a). In contrast, two slightly overlapping shale and carbonate domains can be distinguished on the neutron minus density porosity versus gamma ray log cross-plot (Figure 2.33b).

2.4.6 Unit 5

Two log profiles are present within Unit 5: (1) low radiation blocky (Figure 2.22, well 18) and (2) serrated (Figure 2.21, well 15). Unit 5 is the most areally restricted of the 6 units (Figure 2.28). A good marker can usually be identified at the top and bottom by a distinct shift to higher radiation in the gamma ray signature. Hole conditions are often very poor in this unit.

Unit 5 ranges from 6 to 33 metres thick. Isopach thicknesses are at a maximum in the centre of the study area and decrease out to the map edge and erosive edges (Figure 2.28a). Again, the sediments are deposited in a series of distinct piles and as with Units 3 and 4, thicker sediment packages commonly overlie thinner sediments of the underlying unit. Clastic sediment content is highly variable. 10-30% clastics is typical but several extreme values (up to 70%) are scattered throughout the study area (Figure 2.28b). A high clastic percentage, northwest-southeast trending band of pods is present through the central part of the study area. Several high values along the erosive edge are due to erosion of most of the upper carbonates, leaving behind the shalier base of Unit 5.

Massive carbonate is restricted to the northwest quadrant and west-central parts of the Greater Cessford Area (log profile 1). In contrast, a series of metre-scale, coarsening-upward cycles consisting of shale or argillaceous carbonates overlain by cleaner carbonates comprise Unit 5 in the central and southeastern parts of the study area (log profile 2). This profile corresponds to several high siliciclastic content pods in Figure 2.28b. Unit 5 was not deposited or cannot be differentiated from Unit 6 in the southwest quadrant of the study area and was removed by erosion in the northeast.

Unit 5 shows little scatter on the neutron versus density porosity log cross-plot and resembles that of Unit 4. Very little spread in density values occurring with wide ranging neutron porosities are observed (Figure 2.32a). The wells in the central portion of the study area tend to have higher gamma ray and neutron minus density porosity values reflecting a more argillaceous carbonate lithology (Figure 2.32b). In contrast, Unit 5 consists of massive carbonate in the more northern wells which plot in the southwest quadrant of the second cross-plot (lower gamma ray and neutron-minus-density porosity difference values).

2.4.7 Unit 6

Two log profiles are present within Unit 6: (1) low radiation blocky (Figure 2.22, well 21), and (2) serrated (Figure 2.21, well 15). Unit 6 has been removed by erosion near the Banff Formation subcrop erosional edge (Figure 2.29). It directly underlies the post-Mississippian unconformity surface in most of the study area, and the Pekisko Formation in the southwest quadrant. Unit 6 variably overlies Units 3, 4 and 5.

The identification of the lower boundary of Unit 6 is relatively easy where it overlies Unit 3 or 4. It can be difficult to distinguish from Unit 5 in successions with a serrated log signature that has no distinctive breaks. The upper boundary of Unit 6 is the top of the Banff Formation (see above). Good hole conditions are encountered in the massive carbonates with increasingly worse hole conditions in the more argillaceous intervals.

The thickness of Unit 6 ranges from 3 to 93 metres with a full section thickness (i.e. below the subcrop edge) of approximately 40 to 93 metres (Figure 2.29a). In contrast to Units 1-5 which were deposited in sedimentary piles, the sediments of Unit 6 were deposited in approximately parallel, evenly-spaced sediment belts. Unit 6 is thinnest along the northeastern erosional boundary and thickens to the southwest (Figure 2.5, 2.29a). Clastic sediment content is highest (up to 70%) in a west-northwest

to east-southeast band running through the centre of the map area and declines to the northeast and southwest (10-20%) (Figure 2.29b).

Massive carbonate is present in the northwest, southwest and southeast quadrants of the study area (log profile 1). Metre-scale, coarsening-upward cycles of shale, carbonate, and quartzose siltstone/sandstone comprise Unit 6 in the central portion of the study area and correspond to a west-northwest to east-southeast trending band on Figure 2.29b.

The high values associated with the wells in Township 25 on the neutron versus density porosity log cross-plot are due to caving in the borehole (Figure 2.35a). The neutron versus density porosity log cross-plot is not very useful for distinguishing between the lithologies of Unit 6. In contrast, three overlapping fields can be identified on the neutron minus density porosity versus gamma ray log cross-plot (Figure 2.35b). The quartzose siltstones and sandstones have more restricted gamma radiation values than the carbonates in Unit 6 and thus are wholly contained within the carbonate field. In contrast, shales can be identified by generally higher gamma radiation than under and overlying sediments and 5-15% neutron minus density porosity difference.

2.5 SUMMARY

To date, previous workers have focused on thick, sedimentary ramp successions that are correlated using widely-spaced outcrop or subsurface data. Gently dipping clinoforms which prograde towards the basin result from this scale of correlation and imply that unit sedimentation is of relatively uniform thickness and lithology over crude geographic areas.

A summary chart compiles thickness, shale percentage, log profile, and hole condition information for the six units of the Banff Formation (Table 2.1). Three log profiles are observed for Unit 1 in the Greater Cessford Area. A high radiation, blocky log profile is indicative of a shale lithology which is distributed in a northwest-southeast

SUMMARY CHART OF UNIT CHARACTERISTICS

UNIT	THICKNESS (M)	CLASTIC (%)	LOG PROFILES	HOLE CONDITIONS
1	1-9	0-100	A, B, C	GOOD
2	4-32	0-94	B, C, D, E	GOOD
3	4-27	4-61	B, C, E	POOR
4	9-28	0-62	B, C, E	GOOD
5	6-33	0-74	B, E	POOR
6	3-93	0-85	B,E	FAIR

Log Profile Legend:
A=high radiation blocky
B=low radiation blocky
C=decreasing radiation upwards
D=several thin cycles with decreasing radiation upwards
E=serrated

Table 2.1. Summary chart of unit thickness, clastic content, log profiles and hole conditions.

trending band through the centre of the Greater Cessford Area. Argillaceous carbonate alone (low radiation blocky signature) or overlying a shaly base (decrease in radiation upward) are located in the northeast and southwest quadrants, as well as in isolated wells throughout the central part of the study area.

In contrast, Unit 2 is comprised of four different log profiles. A single shale-based, coarsening-upward cycle overlain by carbonate or quartzose siltstone/sandstone in the northwest and southwest gradually changes to two shale-based cycles overlain variably by carbonate or quartzose siltstone/sandstone in the middle of the study area to a series of metre-scale, shale and carbonate cycles in the northeast quadrant. A massive carbonate is locally deposited on the western side of the study area. The quantity of siliciclastic material is relatively high (30-50%) over the Greater Cessford Area.

Units 3 and 4 consist of one or two shale-based, coarsening-upward cycles overlain by carbonate in the south which grade laterally into a series of metre-scale, shale, carbonate and quartzose siltstone/sandstone cycles which in turn grade into massive carbonates in the north. The highest proportion of siliciclastics is in a west-northwest to east-southeast trending band running through the central part of the study area.

The uppermost two units consist variably of massive carbonates or a series of metre-scale, coarsening-upward cycles of shale, carbonate and quartzose siltstone/sandstone. The massive carbonates were deposited in the southwest and northeast and laterally grade into metre-scale cycles deposited in the central portion of the Greater Cessford Area. As with Units 3 and 4, Units 5 and 6 are comprised of a greater proportion of clastic sediment in a west-northwest to east-southeast trending sediment belt.

Sedimentation in the Banff Formation in the Greater Cessford Area deviates from existing ramp models in the literature in two critical ways. Firstly, the sigmoidal bed surfaces observed on a regional scale cannot be established by correlation between

relatively close-spaced wells in the Greater Cessford Area. Instead of sedimentary packages of uniform thickness, cross-sections and isopach maps generated from geophysical well log data illustrate that in the Banff Formation, with the exception of Unit 6, differential sedimentation of some kind has resulted in piles of sediment with highly variable shape, size, thickness and areal extent. No clear thickness patterns are observed in Units 1 and 2. In contrast, Units 3-5 appear to commonly fill in low areas on the underlying surface with thicker sediment deposits. Unit 6 sedimentation is distinctly different from the five underlying units. It is deposited as a series of broad, roughly shore-parallel, evenly-spaced sediment belts. Possible mechanisms for the sediment piling documented in Units 1-5 and the implications for Banff Formation ramp geometry will be discussed in Chapter 4 (Carbonate-Siliciclastic Mixtures and a Ramp Model for the Banff Formation).

Secondly, the Banff Formation does not consist of a uniform lithology over the study area. Unit 2 consists of carbonate and quartzose siltstones and sandstones isolated in shale. In contrast, Units 3-6 contain a medial clastics belt that separates two carbonate belts.

CHAPTER 3: SEDIMENTOLOGY

3.1 INTRODUCTION

As discussed in the previous chapter, the Banff Formation can be divided into at least 6 shoaling-upward, carbonate-siliciclastic units in the subsurface. The lithofacies discussed below have been elucidated from core work combined with thin section and scanning electron microscopy, as well as X-ray diffraction (Appendix G) and gamma ray, PEF, neutron and density log response. Log response is particularly important for the lower five units which are rarely cored (Appendix H). In contrast, Unit 6 is well represented by core and it is on this unit that the most sedimentological study was conducted.

Six lithofacies have been identified in the Banff Formation in the Greater Cessford Area. These are: (1) shale, (2) bioturbated mudstone, (3) dolomitic/calcareous quartzose siltstone/sandstone, (4) pelleted mudstone to packstone, (5) crinoidal bioclastic wackestone to packstone, and (6) crinoidal bioclastic grainstone. Any alteration and weathering of the uppermost few metres of the Banff Formation sediments is due to processes related to the post-Mississippian unconformity and are not synsedimentary features associated with Banff Formation deposition. Residual sediments and diagenetic processes associated with the post-Mississippian unconformity will be discussed in some detail in Chapter 5 (Diagenesis).

The lithofacies of the Banff Formation can be interpreted in terms of three carbonate ramp depositional environments. Burchette and Wright (1992) divided carbonate ramps into inner-, mid- and outer-ramp environments (Figure 3.1). The inner ramp environment is the zone of ramp deposition between upper shoreface and fair-weather wave base where the sea floor experiences almost constant wave agitation. The mid-ramp environment is characterized by deposition between fair-weather wave base and storm wave base in which bottom sediments are frequently reworked by storm

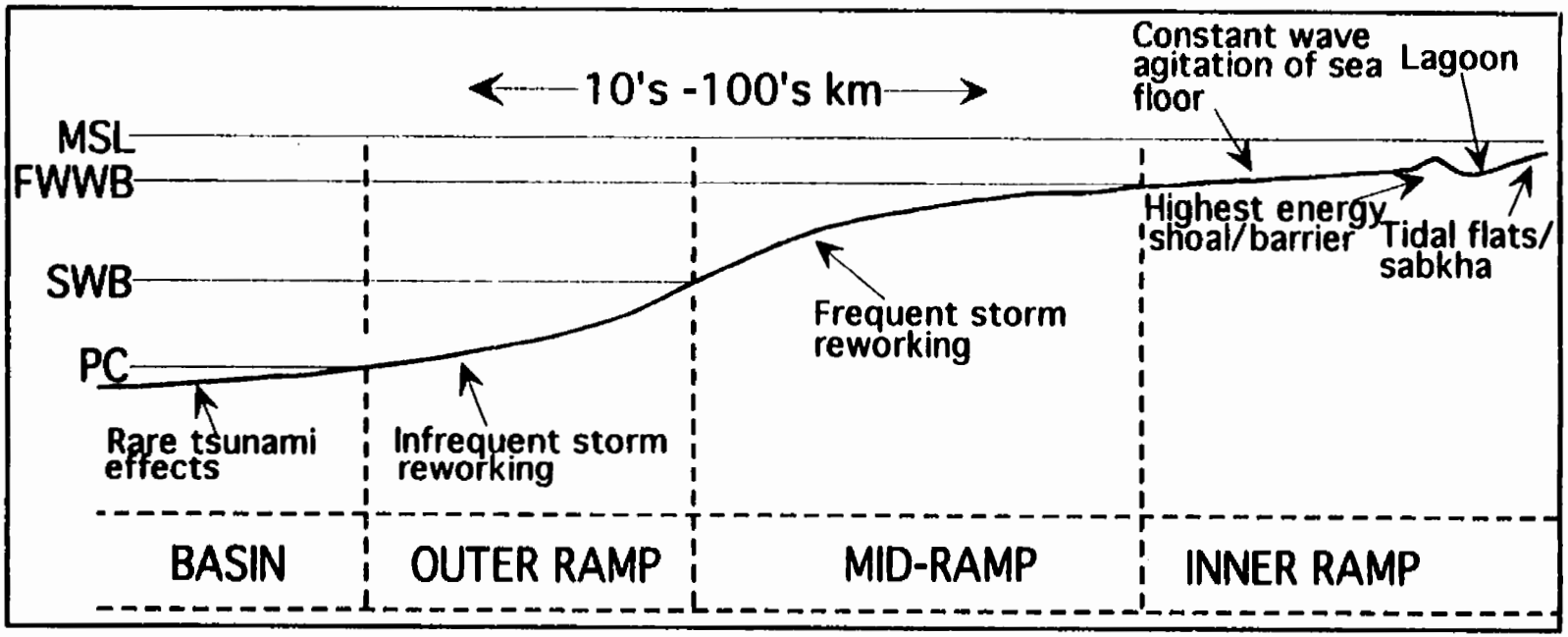


Figure 3.1. The main environmental subdivisions of a "homoclinal" carbonate ramp. MSL=mean sea level; FWWB=fair-weather wave base; SWB=storm wave base; PC=pycnocline (not always identifiable in the rock record). Water depths corresponding to these boundaries are variable (after Burchette and Wright 1992).

waves. Deposition below normal storm wave base is characterized by mudstone deposition and rare storm beds and is termed the outer ramp.

Wilson (1975) defined a set of nine standard facies belts for the subenvironments of an idealized carbonate platform and slope. Each facies belt is characterized by a limited suite of microfacies which reflect changes in water depth, water movement, oxygenation, and light penetration. Wilson (1975) demonstrated that 24 microfacies could be used to describe virtually all carbonate rocks in the ancient record. In addition to placing each lithofacies of the Banff Formation into an inner-, mid- or outer-ramp environment, each lithofacies will also be placed into one or more of Wilson's facies belts.

3.2 LITHOFACIES

3.2.1 Shale

3.2.1.1 Description

Black and green shale, millimetre- to decimetre-scale, individual lamina to lamina sets to beds are variably silty and insignificantly to moderately bioturbated (Plate 1a, b). Macrofossils are rare but comminuted echinoderm and brachiopod fragments are locally present.

The gamma ray log characteristically records >75 API for shales throughout the Banff Formation. Porosity values from nuclear logs are correspondingly high, with neutron and density porosity logs typically reading >15 and >5 limestone porosity units respectively.

3.2.1.2 Thickness and Distribution

Shales are present throughout the Greater Cessford Area and are associated and interbedded with all five of the other Banff Formation component lithofacies on various scales. In Units 1, 2, 3, 4, 5, and 6, the shales range from 0-8 metres, 1-15 metres, 1-8 metres, 1-4 metres, 1-3 metres, and 0-6 metres thick respectively.

PLATE 1-SHALE AND BIOTURBATED SILTY MUDSTONE LITHOFACIES

A) SHALE. Green shale is interbedded with white crinoidal bioclastic grainstone as millimetre- to centimetre-wide lamina and lamina sets. Pinpoint vugular pores are present in the grainstone beds. This is the upper part of a metre-scale, coarsening-upward cycle that consists of shale overlain by crinoidal bioclastic grainstone. (1301.50-1301.72 metres, 16-31-031-16W4, Unit 3).

B) SHALE. Black shale with scattered skeletal fragments is very thinly bedded with white crinoidal bioclastic grainstone. This is part of a metre-scale, coarsening-upward cycle that consists of crinoidal bioclastic wackestone, packstone and grainstone lithologies. (1389.88-1390.02 metres, 14-32-029-16W4, Unit 6).

C) BIOTURBATED SILTY MUDSTONE. A sharp, irregular surface separates light brown and dark gray bioturbated, silty mudstones. Subhorizontal, continuous and discontinuous, black shale laminae are present in the lower mudstone. Rare skeletal fragments (dominantly crinoids) are scattered in both mudstones. The bioturbated silty mudstones are part of a coarsening-upward cycle and are overlain by the crinoidal bioclastic grainstone lithofacies. (1125.33-1125.53 metres, 14-35-025-15W4, Unit 6).

D) BIOTURBATED SILTY MUDSTONE. A light brown, bioturbated silty mudstone with subvertical, millimetre-wide fractures bleeding oil comprises the base of a metre-scale, coarsening-upward cycle. (1045.85-1046.01 metres, 02/16-14-025-12W4, Unit 6).

Note: Coin is 21 millimetres in diameter.

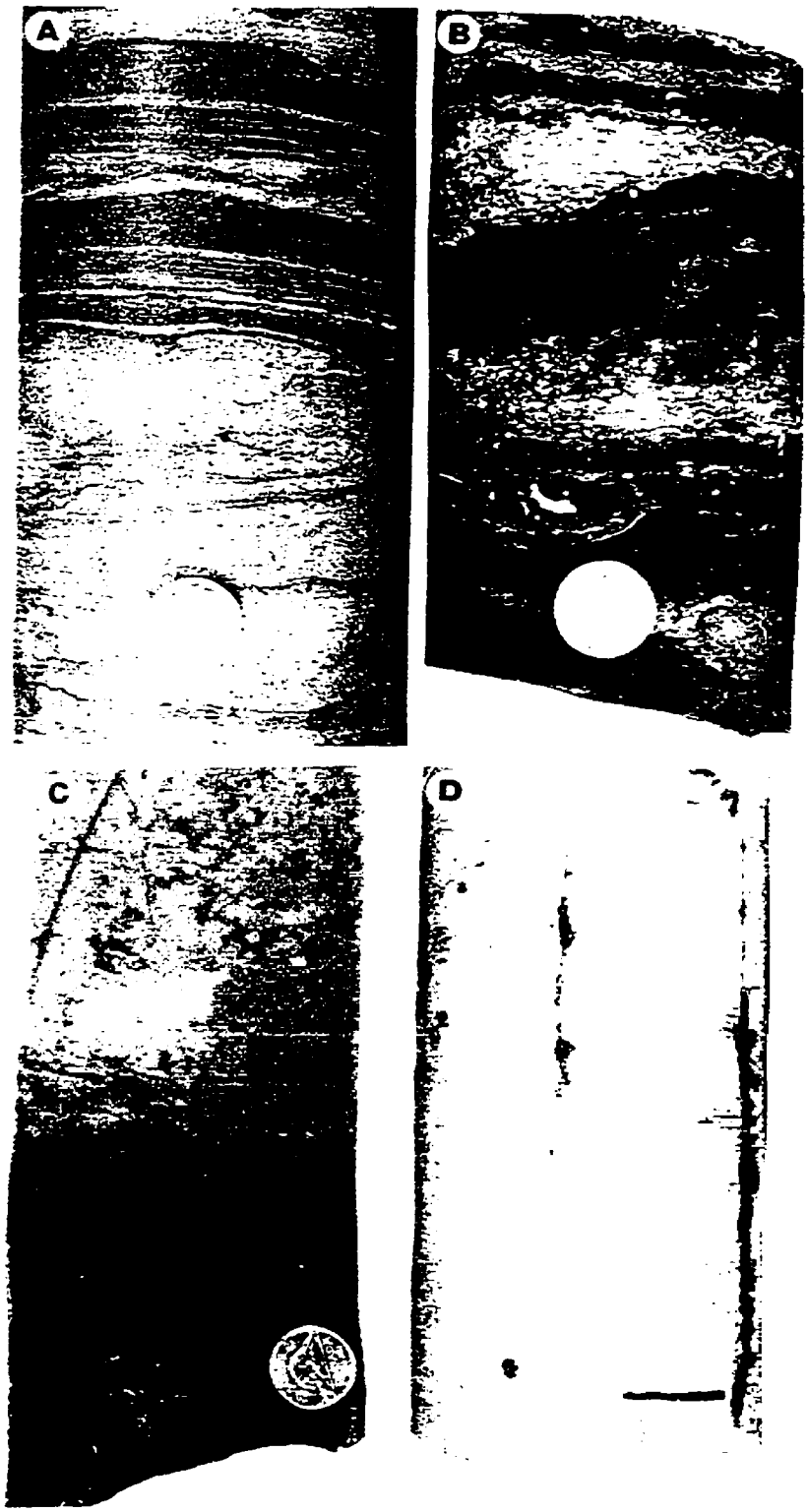


PLATE 1

Shale is preserved alone or as the base of a coarsening-upward succession capped by the bioturbated mudstone lithofacies in Unit 1. In Unit 2, shale is preserved in three types of successions: (1) a thick succession underlying the dolomitic/calcareous quartzose siltstone/sandstone or crinoidal, bioclastic wackestone to packstone lithofacies, (2) a moderately thick succession which forms the base of two coarsening-upward cycles that are variably overlain by the dolomitic/calcareous quartzose siltstone/ sandstone or crinoidal bioclastic wackestone to packstone lithofacies, and (3) thin shale lamina sets to beds interbedded on a millimetre- to metre-scale with the crinoidal bioclastic wackestone to packstone lithofacies.

Similarly, shale is preserved as the base of one or several metre-scale, coarsening-upward cycle(s) in Units 3-6. The shale lithofacies is variably overlain by any of the other lithofacies of the Banff Formation described below. The shaly base of a sedimentary succession is typically thinner in Units 3-6 than in Unit 2.

3.2.1.3 Depositional Environment

Quiet water suspension deposition of the shale lithofacies is suggested by the very fine-grained nature of the sediments and the general lack of whole macrofossils. Metre- to decimetre-thick shale successions in the Banff Formation are interpreted to have been deposited in quiet, deeper water areas in an open marine setting on the mid-ramp. Rare skeletal debris may have been transported in suspension by storm events. Dark coloured shales are typical of Wilson's second standard facies belt which consists of carbonates and shales deposited on the open shelf.

Alternatively, centimetre- to metre-thick shale beds at the base of metre-scale cycles or interbedded with the crinoidal bioclastic wackestone to packstone lithofacies are interpreted to represent deposition in a semi-restricted, shallow, protected marine environment on the inner ramp. The slightly siltier shales interbedded with the pelleted mudstones to packstones lithofacies represent periods of time when currents carried siliciclastic sediment into shallow lagoons.

It is very difficult to distinguish between the shales deposited on the mid-ramp from those deposited on the inner ramp strictly from sedimentological characteristics. The deeper water shales tend to be darker coloured than those deposited in a more restricted environment. The depositional environment of a particular shale can be deduced by examining its position in the sedimentary succession and by studying the under and overlying lithofacies.

3.2.2 Bioturbated Mudstone

3.2.2.1 Subfacies Bioturbated Mudstone

3.2.2.1.1 Description

The first subfacies of the bioturbated mudstone lithofacies consists of green-gray, bioturbated, dolomitic mudstone with scattered whole crinoidal stems and broken crinoidal and other skeletal fragments. Unbroken skeletal pieces are more common than comminuted fragments. Subhorizontal, millimetre-scale, black shale laths and disseminated pyrite specks are common. The bioturbated mudstone lithofacies commonly has a mottled appearance due to churning of sediment by organisms. No lithologic contacts with under and overlying beds are penetrated by core.

The bioturbated mudstone lithofacies is identified on logs by its blocky gamma ray log appearance and records approximately 55-70 API (30-95 API range). PEF log values are typically between 3.5 and 4 and the neutron and density porosity logs are commonly separated indicating a dolomitic lithology (Figure 3.2 h).

3.2.2.1.2 Thickness and Distribution

The bioturbated mudstone lithofacies entirely comprises or overlies a shaly base in Unit 1. It is thickest (up to 6 metres) in the southwest and northeast quadrants of the study area (Figure 2.24a). Towards the Banff Formation subcrop edge in the northeast, the bioturbated mudstone is the only lithofacies present as illustrated by the core from well 16-04-031-11W4 (Figure 3.2 h; Appendix D).

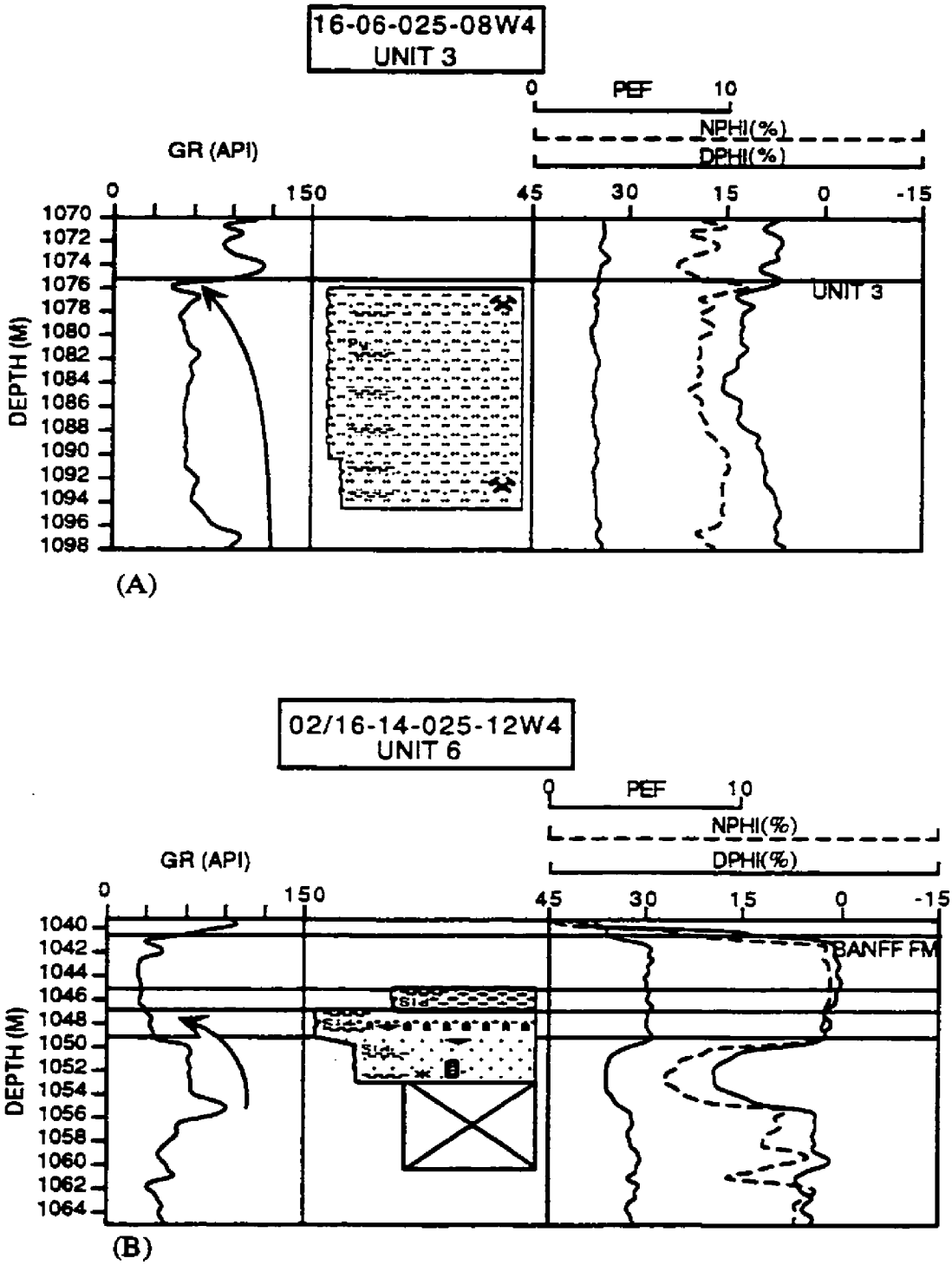
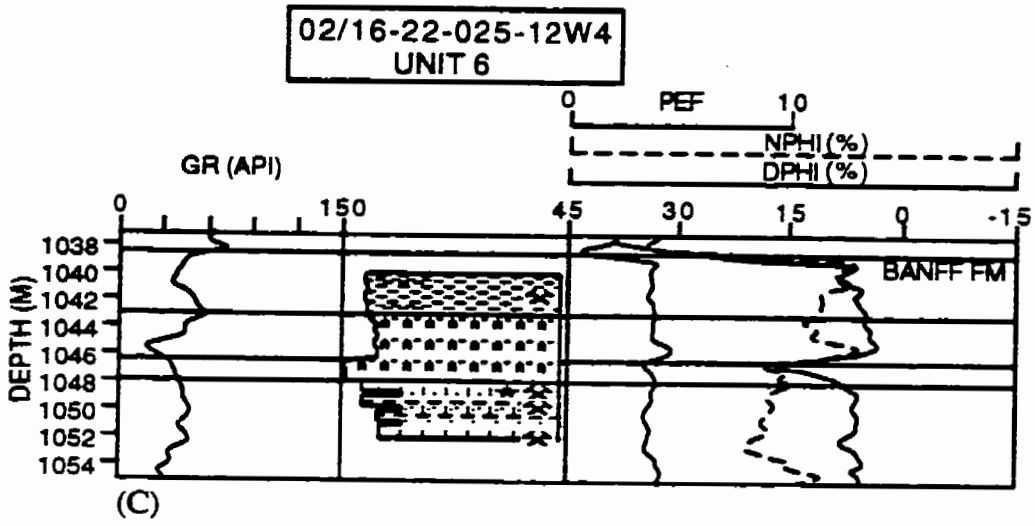
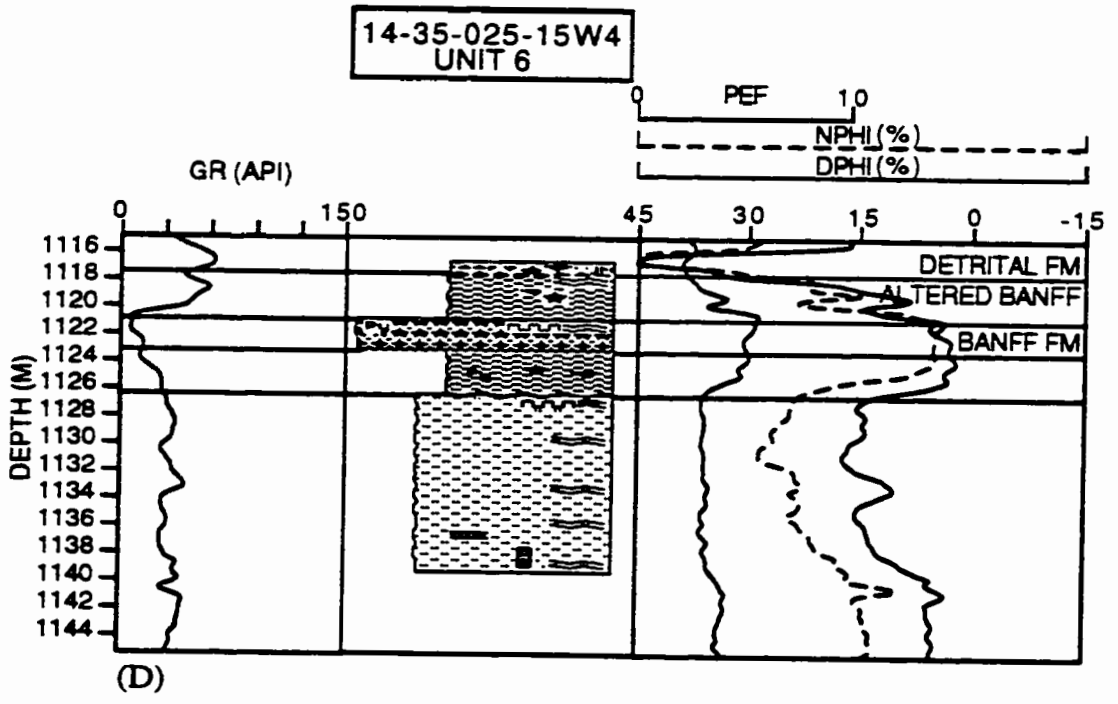


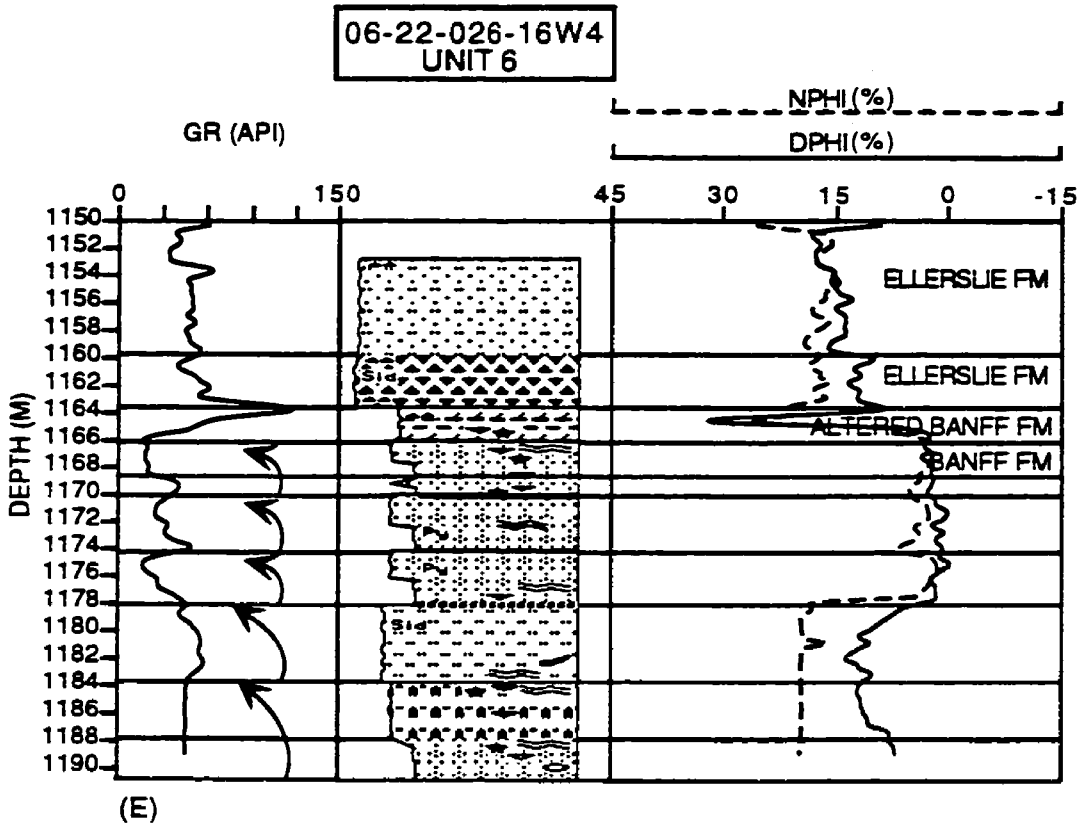
Figure 3.2. Core description and log response of Ellerslie, Detrital and Banff Formation lithofacies from selected wells. Please see Appendix D for the legend and detailed core descriptions.


02/16-22-025-12W4
UNIT 6
PEF
0
10
NPHI (%)
DPHI (%)
GR (API)
0
150
45
30
15
0
-15
DEPTH (M)
1038
1040
1042
1044
1046
1048
1050
1052
1054
BANFF FM

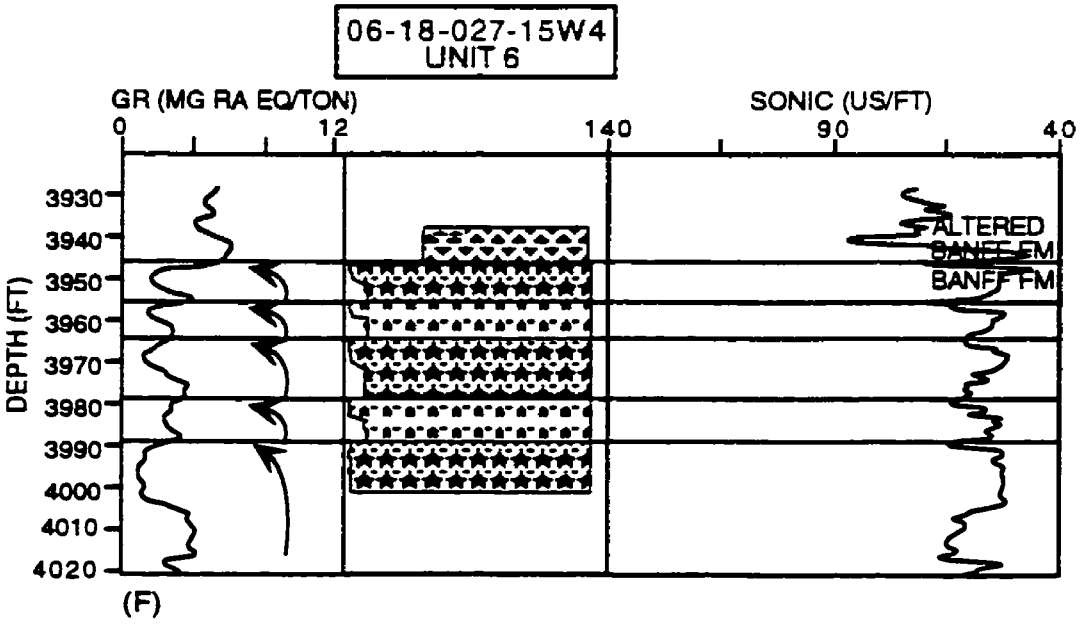
(C)


14-35-025-15W4
UNIT 6
PEF
0
10
NPHI (%)
DPHI (%)
GR (API)
0
150
45
30
15
0
-15
DEPTH (M)
1116
1118
1120
1122
1124
1126
1128
1130
1132
1134
1136
1138
1140
1142
1144
DETRITAL FM
ALTERED BANFF
BANFF FM

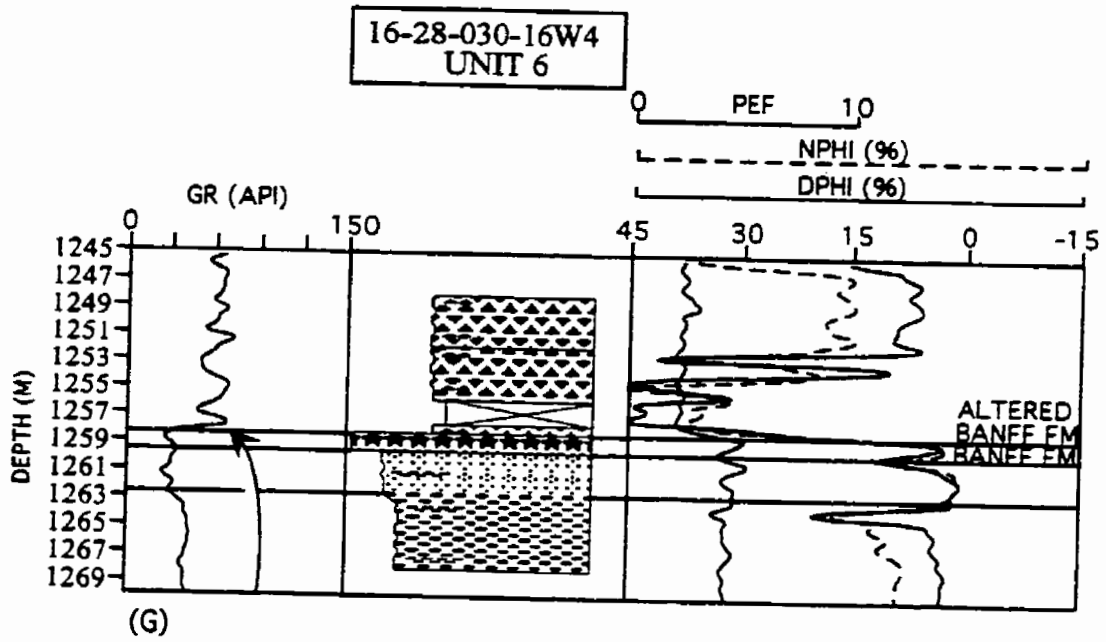
(D)

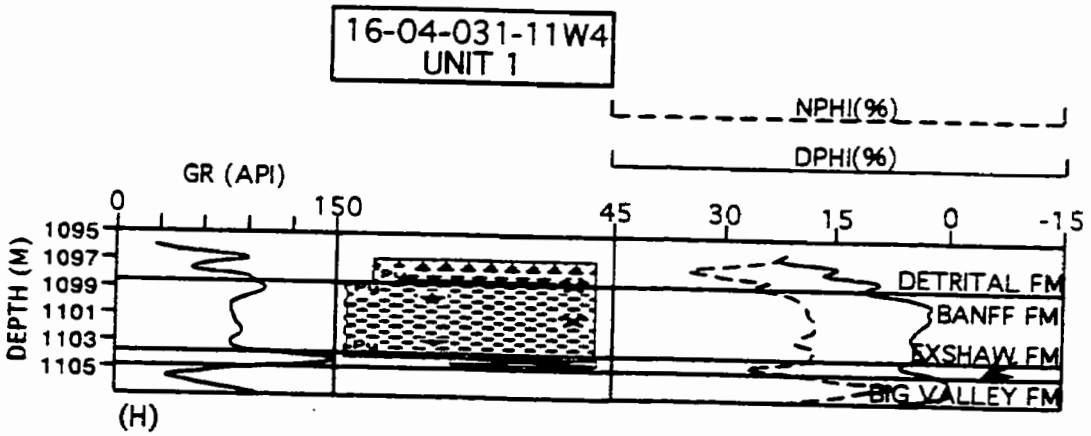

06-22-026-16W4
UNIT 6
GR (API)
NPHI (%)
DPHI (%)
0
150
45
30
15
0
-15
DEPTH (M)
1150
1152
1154
1156
1158
1160
1162
1164
1166
1168
1170
1172
1174
1176
1178
1180
1182
1184
1186
1188
1190
ELLERSLIE FM
ELLERSLIE FM
ALTERED BANFF FM
BANFF FM
Sltst
Sltst

(E)


06-18-027-15W4
UNIT 6
GR (MG RA EQ/TON)
SONIC (US/FT)
0
12
140
90
40
DEPTH (FT)
3930
3940
3950
3960
3970
3980
3990
4000
4010
4020
ALTERED
BANFF FM
BANFF FM

(F)


16-28-030-16W4
UNIT 6
PEF
0
10
NPHI (%)
DPHI (%)
GR (API)
0
150
45
30
15
0
-15
DEPTH (M)
1245
1247
1249
1251
1253
1255
1257
1259
1261
1263
1265
1267
1269
ALTERED BANFF FM
BANFF FM
(G)


16-04-031-11W4
UNIT 1
NPHI(%)
DPHI(%)
GR (API)
0
150
45
30
15
0
-15
DEPTH (M)
1095
1097
1099
1101
1103
1105
DETRITAL FM
BANFF FM
EXSHAW FM
BIG VALLEY FM
(H)

Units 2-4 are commonly comprised entirely of the bioturbated mudstone lithofacies in the southwest quadrant of the Greater Cessford Area. Alternatively, the bioturbated mudstone lithofacies is overlain by the crinoidal bioclastic wackestone to packstone lithofacies. Although no cores penetrate the bioturbated mudstone lithofacies in Units 5 and 6, log signatures suggest that it is present in the southwest quadrant of the study area.

3.2.2.1.3 Depositional Environment

In the mid-ramp environment, the sea floor is affected by storm waves but not by fair-weather waves. As a result, sediment deposition is dominated by suspension fall-out and reflects varying degrees of storm influence (Burchette and Wright 1992). The dominance of lime mud, sparse fauna, and commonly unbroken crinoids suggest that the bioturbated mudstone lithofacies was deposited in moderately deep, normal salinity water on the mid-ramp below fair-weather wave base. The bioturbated mudstone lithofacies is extensively bioturbated which is a characteristic of mid-ramp deposits (Burchette and Wright 1992).

Black shale laths commonly encountered in this lithofacies may be the result of storm-generated currents transporting shale laths from a semiconsolidated mud deposit. An extensively bioturbated, massive to faintly laminated mudstone consisting of lime mud, silt-sized peloids and scattered skeletal material was interpreted as a mid-ramp deposit by Chen and Webster (1994) in the Lodgepole Formation.

The bioturbated mudstone lithofacies is similar to sediments deposited in the third standard facies belt of Wilson (1975). In this facies belt, fine detritus is transported off of the inner ramp and deposited out of suspension on the mid-ramp.

3.2.2.2 Subfacies Bioturbated Silty Mudstone

3.2.2.2.1 Description

The second bioturbated mudstone subfacies consists of gray-brown, bioturbated, silty mudstone with scattered whole to highly comminuted skeletal fragments

(dominantly crinoids) (Plate 1c, d). Subhorizontal, millimetre-scale, continuous and discontinuous, black to green shale lamina and lamina sets are commonly present. Locally, a sharp irregular surface separates mottled, lighter and darker coloured mudstones (Plate 1c). Bioturbation of this subfacies is indicated by the swirling of different coloured muddy sediments (Plate 1c, upper mudstone bed). Skeletal fragments are typically 1% of the bulk rock composition, but up to 15-20% in several centimetre-thick intervals. Disseminated specks of pyrite are scattered throughout this subfacies. Calcite commonly infills fossil molds, cavities and subvertical fractures. The basal contact is either bioturbated or undulatory in the cores examined (Plate 2a).

The bioturbated silty mudstone lithofacies consists of subangular to subrounded quartz grains in micrite (Plate 3a). This lithofacies is moderately to intensively bioturbated as indicated by the irregular distribution of mud in thin section.

Under the scanning electron microscope, the bioturbated, silty mudstone subfacies consists of subangular quartz grains and subhedral calcite grains. This subfacies has no visible porosity and illite is scattered along some grain surfaces (Plate 4a, b).

The bioturbated silty mudstone lithofacies generally has PEF values between 4 and 5 and a gamma radiation reading of 30-45 API. Neutron and density logs typically record <10 limestone porosity units (Figure 3.2b, c, d, g). In contrast to the first bioturbated mudstone subfacies, the bioturbated, silty mudstone is usually not dolomitized. This is observed in core and verified by the geophysical log suite.

3.2.2.2.2 Thickness and Distribution

The bioturbated, silty mudstone lithofacies is present in Units 2 through 6 and is generally 0-8 metres thick. More commonly, the bioturbated silty mudstone subfacies is present in a series of metre-scale, coarsening-upward cycles which grade from the shale lithofacies to mudstone to the crinoidal and/or pelleted bioclastic wackestone to

PLATE 2-LITHOLOGIC CONTACTS

A) An undulatory contact is present between dolomitic quartzose siltstone and overlying, bioturbated, silty mudstone at 1126.25 metres. Millimetre-scale, subhorizontal, continuous and discontinuous, black shale laminae are present in the siltstone. Skeletal fragments are dominated by crinoid ossicles and are scattered through both lithofacies. Note the concentration of skeletal fragments along the upper surface of the contact. The dolomitic quartzose siltstone and bioturbated silty mudstone lithofacies are part of a metre-scale, coarsening-upward cycle in Unit 6 which is capped by the crinoidal bioclastic grainstone lithofacies. (1126.12-1126.35 metres, 14-35-025-15W4, Unit 6).

B) A gradational contact is present between massive, calcareous quartzose siltstone and overlying medium gray, crinoidal bioclastic packstone. These two lithofacies are part of a metre-scale, coarsening-upward cycle in Unit 6 that is capped by the crinoidal, bioclastic packstone pictured here. The calcareous quartzose siltstone is bleeding oil. (1048.70-1048.82 metres, 02/16-14-025-12W4, Unit 6).

C) A bioturbated contact between the dolomitic quartzose siltstone and the overlying crinoidal bioclastic wackestone is present. A brachiopod lag and pyrite mineralization are preserved along the top of the contact. The dolomitic quartzose siltstone is part of a series of metre-scale, coarsening-upward cycles in Unit 6. It is overlain by four crinoidal bioclastic wackestone-packstone-grainstone lithofacies cycles, a portion of which is illustrated in photograph D. (1180.09 metres, 06-22-026-16W4, Unit 6).

D) A sharp contact separates two crinoidal bioclastic wackestone-packstone-grainstone, metre-scale, coarsening-upward cycles in Unit 6. The contact is located in the middle of the photograph. The top of the basal cycle is marked by crinoidal bioclastic grainstone overlain by wackestone at the base of the overlying cycle. The oxidation and reduction of iron imparted the red and green colours to these sediments and is associated with weathering related to the post-Mississippian unconformity. (1171.12-1171.32 metres, 06-22-026-16W4, Unit 6).

E) A bioturbated contact separates a medium gray, crinoidal bioclastic wackestones with subhorizontal, millimetre-wide, shale laminae from light brown, bioturbated, silty mudstones. (1042.90-1043.07 metres, 02/16-22-025-12W4, Unit 6).

Note: Coin is 21millimetres in diameter.

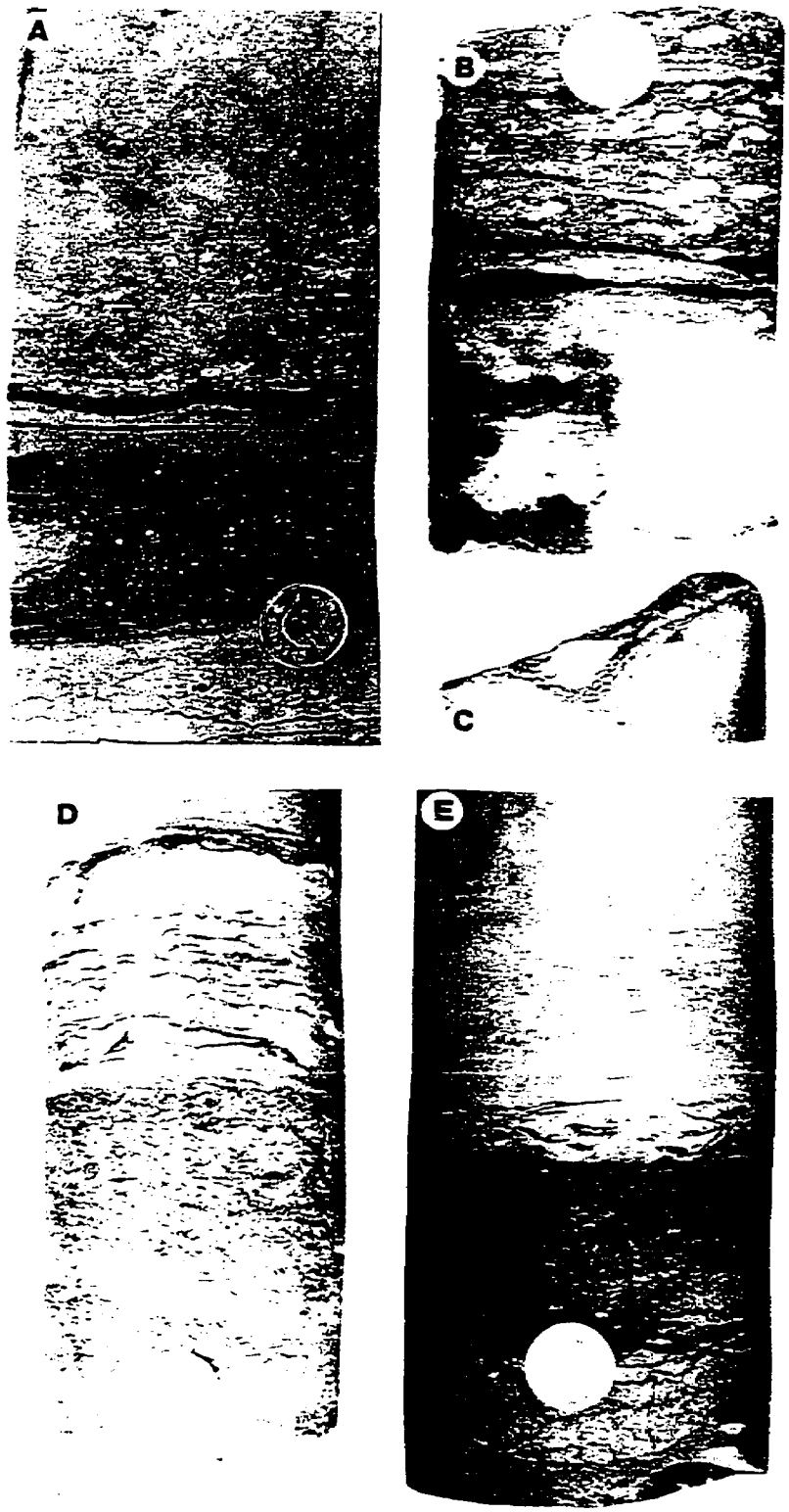


PLATE 2

PLATE 3-BIOTURBATED SILTY MUDSTONE, PELLETED MUDSTONE TO PACKSTONE AND CRINOIDAL BIOCLASTIC WACKESTONE TO PACKSTONE LITHOFACIES

A) BIOTURBATED SILTY MUDSTONE. The bioturbated, silty mudstone lithofacies consists of subangular quartz grains in micrite. (1099.75 metres, 16-04-031-11W4, Unit 1, plane-polarized light).

B) PELLETED WACKESTONE TO PACKSTONE. One generation of poorly developed, finely crystalline, equant calcite cement has crystallized in this photomicrograph of the pelleted, crinoidal, bioclastic wackestone to packstone lithofacies. Pellets are approximately 25% of the total framework components. (987.00 metres, 14-34-023-09W4, Unit 6, plane-polarized light).

C and D) CRINOIDAL BIOCLASTIC WACKESTONE TO PACKSTONE. Both photomicrographs are from the same highly bioturbated sample which shows the transition from crinoidal bioclastic wackestone (photomicrograph C) to packstone (photomicrograph D). Two calcite cement generations are present in the packstone. The first generation consists of pyramidal, isopachous fringe cement which has crystallized in the sheltered skeletal pores along the underside of platy skeletal fragments. The second generation cement is restricted to intergranular spaces and leached out portions of skeletal fragments and consists of equant, coarsely crystalline cement. Photomicrograph D is dominated by bryozoan fragments and pellets. (1126.00 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

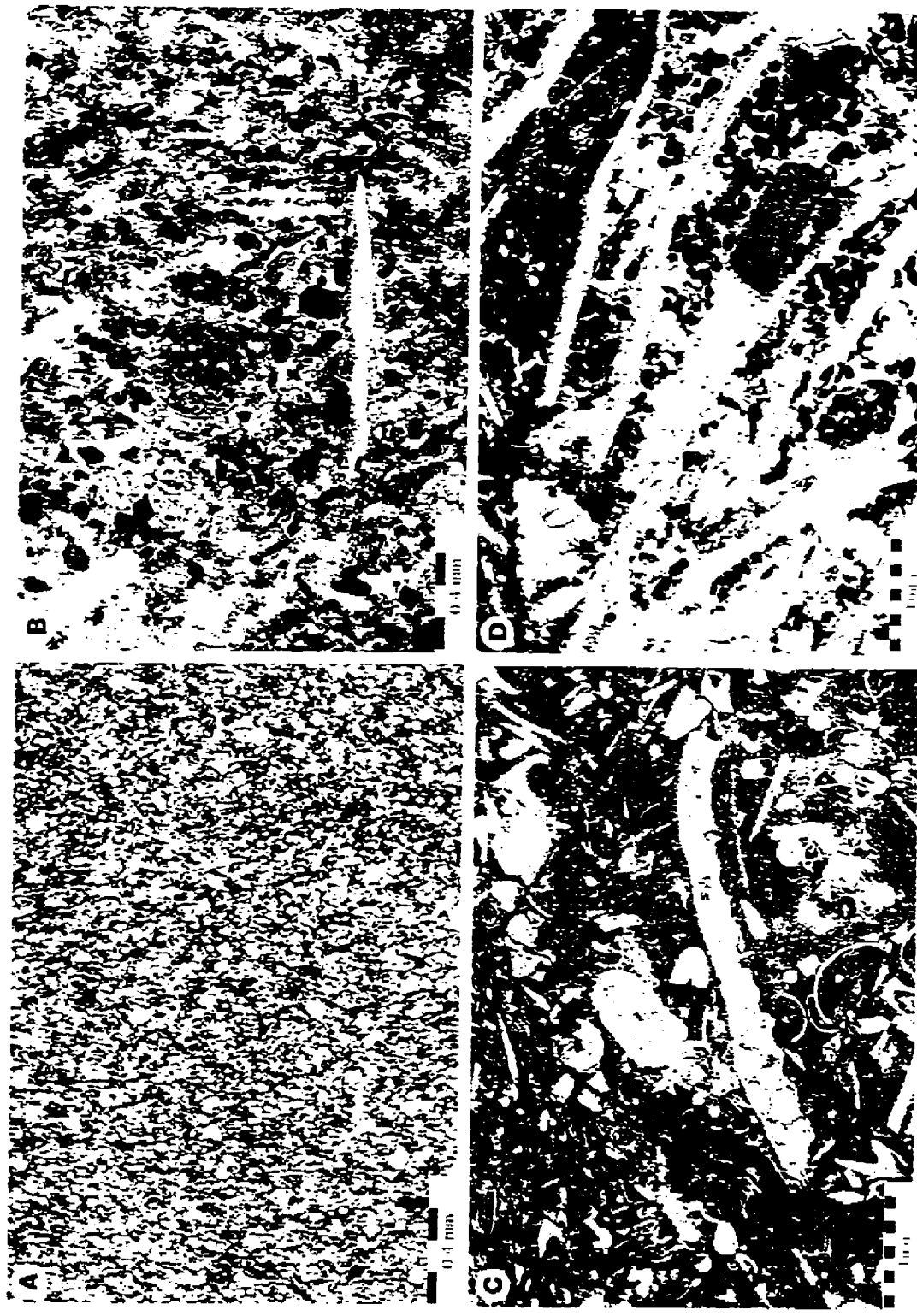


PLATE 3

PLATE 4-BIOTURBATED SILTY MUDSTONE AND DOLOMITIC QUARTZOSE SILTSTONE LITHOFACIES

A and B) BIOTURBATED SILTY MUDSTONE. Low porosity bioturbated silty mudstone consists of subangular quartz grains and subhedral calcite grains. (1045.20 metres, 02/16-14-025-12W4, Unit 6).

C and D) DOLOMITIC QUARTZOSE SILTSTONE. The dolomitic quartzose siltstone lithofacies consists of subangular quartz grains, subhedral calcite grains and euhedral dolomite rhombs. Dolomite crystals have serrated and frayed crystal edges and euhedral dolomite rhombs line pore throats in photomicrograph D. Some illite clay is scattered along grain surfaces. (1049.52 metres, 02/16-14-025-12W4, Unit 6).

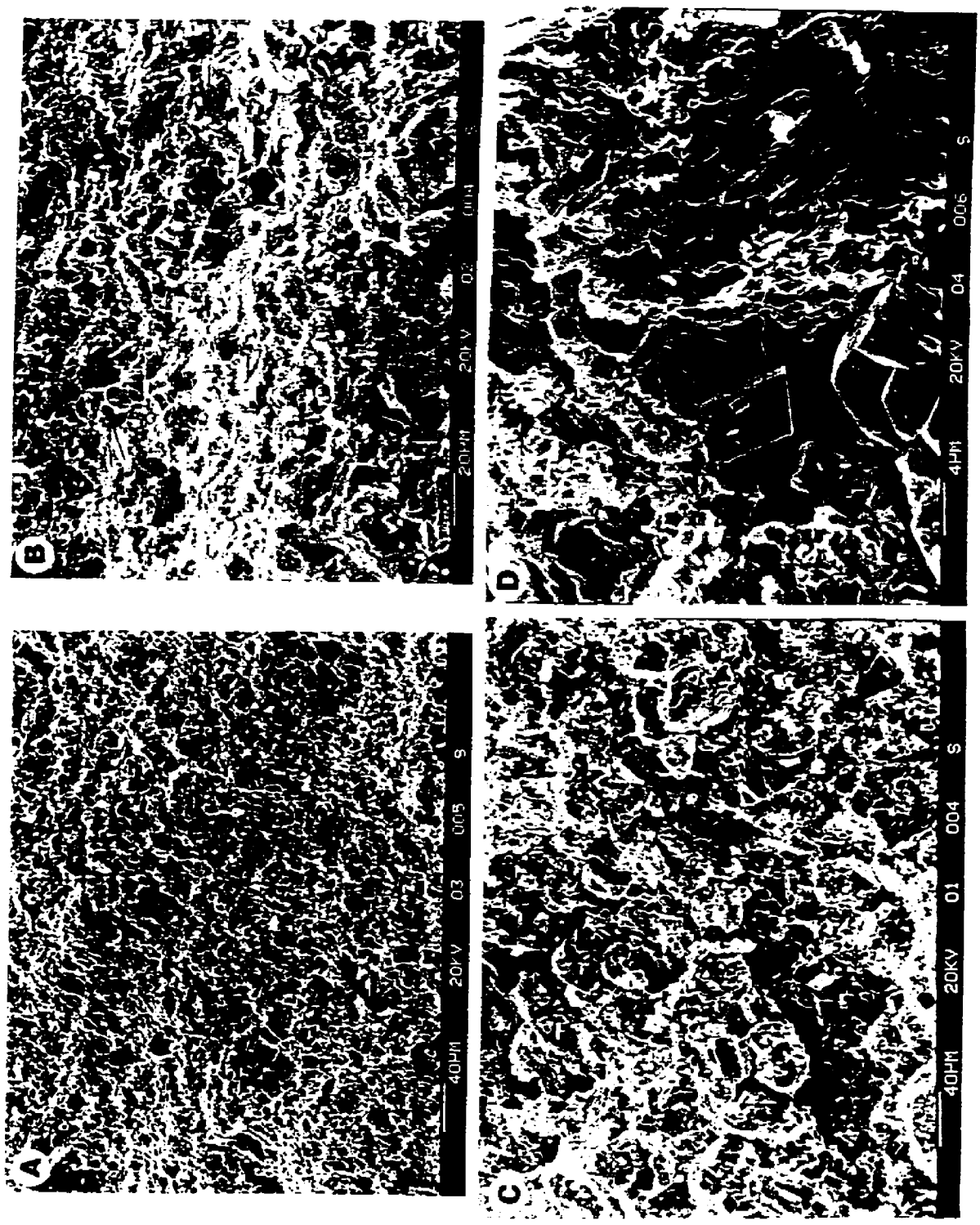

A
40µM 20KV 03 005 S
B
20µM 20 KV 02
C
40µM 20KV 01 004 S
D
4µM 20KV 04 006 S

PLATE 4

packstone or dolomitic/calcareous quartzose siltstone to sandstone lithofacies in Units 2-6.

3.2.2.2.3 Depositional Environment

The bioturbated, silty mudstone subfacies is interpreted as open marine sediments deposited on the inner ramp above fair-weather wave base. Normal marine salinity and moderate water circulation are indicated by the fossil content and intensive bioturbation activity. Possible depositional environments include open lagoons and bays that were protected by a hydraulic barrier.

The sharp, irregular surface separating two different coloured mudstones (Plate 1c) is interpreted as a hardground. Fine-grained siliciclastic material is postulated to have been periodically introduced to the lagoon system by eolian processes. This lithofacies was likely deposited in Wilson's (1975) seventh standard facies belt on the open platform which consists of extensively bioturbated mudstones and wackestones.

3.2.3 Dolomitic/Calcareous Quartzose Siltstone/Sandstone

3.2.3.1 Description

A light gray-brown, massive, moderate to well sorted, coarsening-upward, quartzose siltstone to sandstone is the third lithofacies of the Banff Formation (Plate 5a). This lithofacies consists of very fine-grained quartz within a variably dolomitized carbonate mudstone matrix. Millimetre-scale, subhorizontal, continuous and discontinuous, black and green shale laminae vary from 0 to 20% of the total bulk rock composition and are commonly partially stylolitized.

Physical structures have been largely disrupted or destroyed by intensive bioturbation but some poorly preserved flaser bedding is present (Plate 5b). Generally, the base of this lithofacies is more intensively bioturbated and has a greater abundance of mud laminae than the upper part. Rare scattered skeletal fragments, disseminated pyrite specks, euhedral pyrite crystals, and calcite-filled cavities are locally present. Trace fossils identified include *Teichichnus* and *Asterosoma* .

PLATE 5-DOLOMITIC QUARTZOSE SILTSTONE AND CRINOIDAL BIOCLASTIC WACKESTONE TO PACKSTONE LITHOFACIES

A) DOLOMITIC QUARTZOSE SILTSTONE. A light gray-brown, bioturbated, dolomitic quartzose siltstone with bioturbated, millimetre-scale, subhorizontal, continuous and discontinuous, black shale laminae is the top of a decimetre-scale, coarsening-upward cycle. (1133.39-1133.51 metres, 14-35-025-15W4, Unit 6).

B) DOLOMITIC QUARTZOSE SILTSTONE. A light brown dolomitic quartzose siltstone with poorly preserved flaser bedding is the top a metre-scale coarsening-upward cycle that is underlain by crinoidal bioclastic wackestones and packstones. (1181.94-1182.04 metres, 06-22-026-16W4, Unit 6).

C) CRINOIDAL BIOCLASTIC WACKESTONE. A crinoidal bioclastic wackestone contains a well preserved gastropod shell. The red to maroon sediment colouration is due to the oxidation of iron associated with weathering along the post-Mississippian unconformity. This lithofacies is part of a metre-scale, coarsening-upward cycle in a stacked series of these cycles. (1172.43-1172.60 metres, 06-22-026-16W4, Unit 6).

D) CRINOIDAL BIOCLASTIC PACKSTONE. The basal contact of this brown crinoidal bioclastic packstone is characterized by soft-sediment deformation. This is the upper portion of a metre-scale, coarsening-upward cycle. (1177.25-1177.34 metres, 06-22-026-16W4, Unit 6).

Note: Coin is 21 millimetres in diameter.

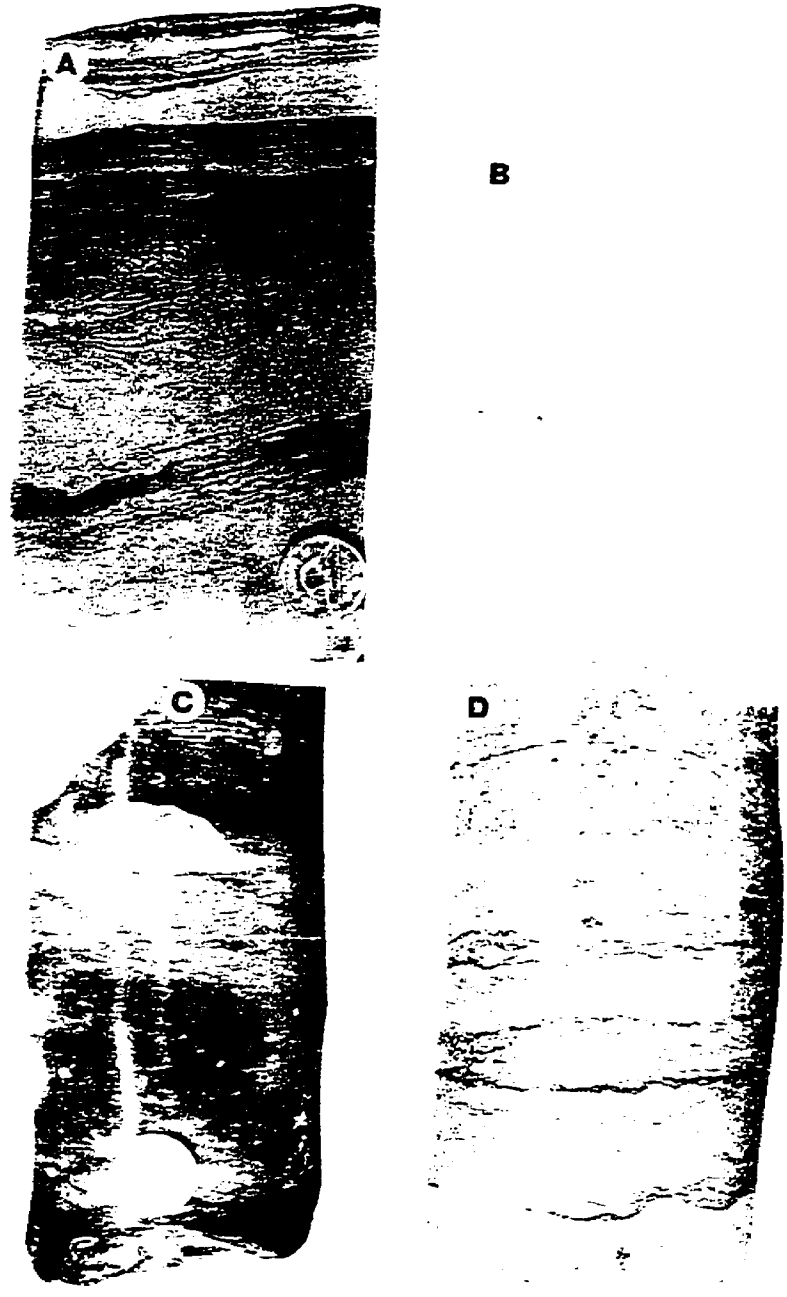


PLATE 5

The upper and lower contacts of the dolomitic/calcareous quartzose siltstone to sandstone lithofacies are highly variable in style and are only observed in cores from Unit 6. Upper lithologic contacts are variably sharp, gradational or bioturbated (Plate 2a, b, c). Lower lithologic contacts are commonly sharp or, more rarely, are gradational. A concentration of shelly material is observed along the upper contact in Plate 2a.

The dolomitic/quartzose siltstone to sandstone lithofacies consists of subangular quartz grains (typically 35-65% bulk rock composition) with variable quantities of euhedral dolomite rhombs (typically 0-45%) and subhedral calcite crystals (typically 10-30%) (Plate 6a-d). Dolomite rhombs have inclusion-rich centres which contrast with the clean crystal exteriors.

Total, inhomogeneously distributed interparticle porosity ranges from 0-25%, with a typical range of 5-10%. Micrite crystals can be seen in the pore space at high magnification. Locally, rare ferroan calcite and witherite grains, oversized pores and bitumen filled fractures are present. Quartz grains range in size from 10-90 micrometres, but are typically 25 micrometres long. Dolomite and calcite rhombs are slightly larger, ranging in size from 15-70 micrometres but are generally 35 micrometres long.

The dolomitic/calcareous quartzose siltstone/sandstone lithofacies is comprised of subangular quartz grains, euhedral dolomite rhombs and subhedral calcite grains (Plate 4c, d). Serrated crystal edges are observed on dolomite grains using the scanning electron microscope and dolomite rhombs line pore throats.

The siltstone lithofacies is marked on log profiles by relatively high porosity values (0-20% in Units 2 and 3; 6-30% in Unit 6) compared to adjacent relatively low porosity bioturbated mudstone and crinoidal bioclastic wackestone to packstone lithofacies. PEF log values are intermediate (3-3.5) between sandstone (2) and limestone (5) lithologies. The gamma ray log records approximately 30-45 API with rare occurrences up to 90 API (Figure 3.2a, b, d, e).

PLATE 6-DOLOMITIC QUARTZOSE SILTSTONE LITHOFACIES

A) DOLOMITIC QUARTZOSE SILTSTONE. The dolomitic quartzose siltstone lithofacies consists of subangular quartz grains, euhedral dolomite rhombs with high relief, and subhedral to euhedral calcite crystals. Subhorizontal dissolution seams are present. Total porosity of this sample is approximately 10%. (1091.95 metres, 16-06-025-08W4, Unit 3, plane-polarized light).

B) DOLOMITIC QUARTZOSE SILTSTONE. Subangular quartz grains, subhedral to euhedral dolomite rhombs, and anhedral calcite crystals comprise the dolomitic quartzose siltstone in this photomicrograph. Irregularly distributed porosity is estimated to be 8-10%. (1077.10 metres, 16-06-025-08W4, Unit 3, plane-polarized light).

C) DOLOMITIC QUARTZOSE SILTSTONE. Euhedral dolomite rhombs, subhedral calcite grains and subangular quartz grains comprise this rock. Euhedral, high relief dolomite rhombs have inclusion-rich centres and clean crystal exteriors. Total porosity is approximately 10-15%. (1128.00 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

D) DOLOMITIC QUARTZOSE SILTSTONE. This photomicrograph of a dolomitic quartzose siltstone consists of subangular quartz grains and euhedral dolomite rhombs. Irregularly distributed total porosity is approximately 20%. (1328.00 metres, 16-35-026-18W4, Unit 6, plane-polarized light).

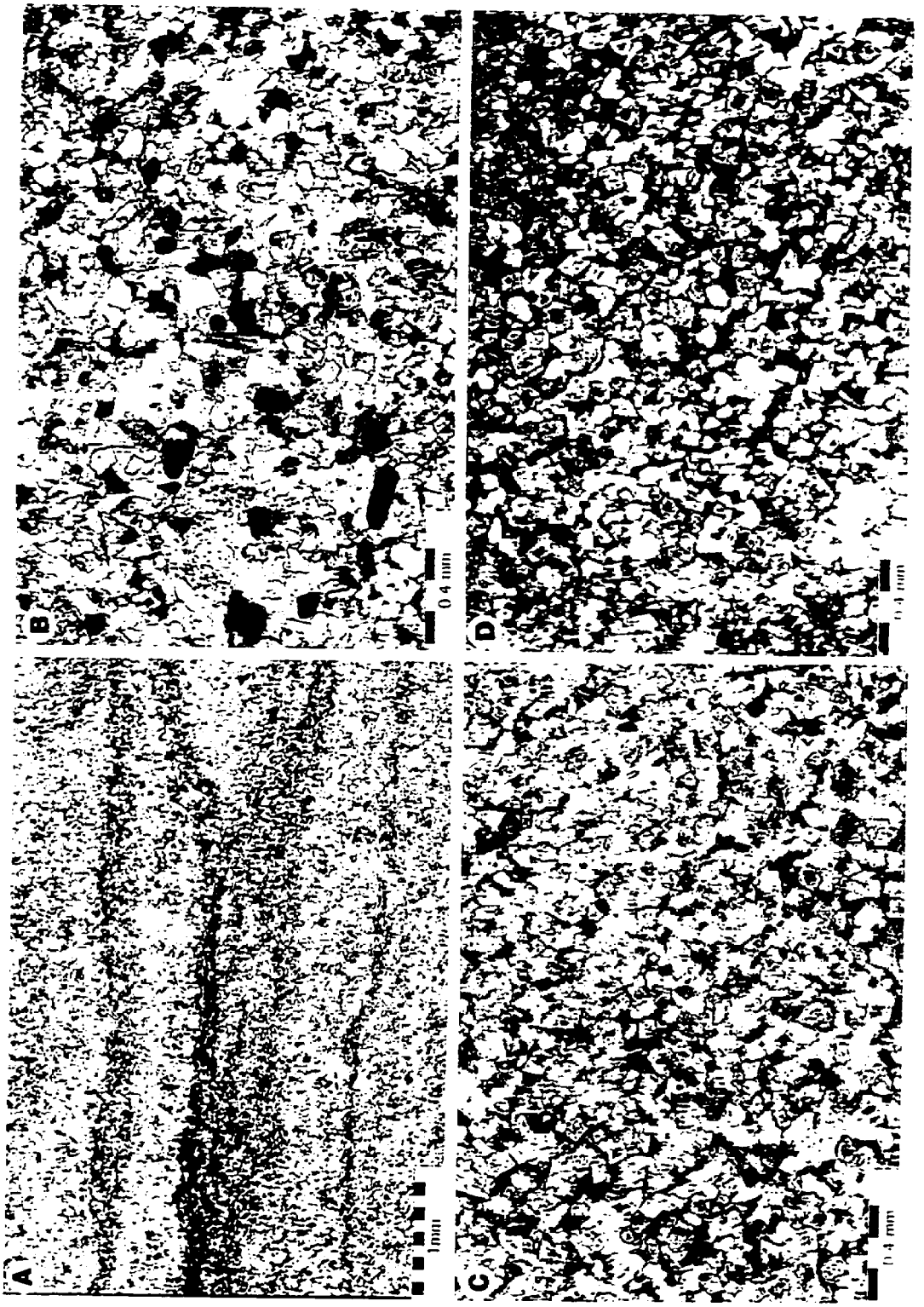


PLATE 6

3.2.3.2 Thickness and Distribution

The dolomitic/calcareous quartzose siltstone to sandstone lithofacies occurs in Units 2, 3, and 6. It is commonly a fine-grained sandstone in Units 2 and 3 where it is preserved as a part of shale-based, coarsening-upward cycles. One to three of these cycles are commonly present. Thickness varies from 0-6 metres in Unit 2 and 0-8 metres in Unit 3. Identification of this lithofacies in Unit 2 is entirely log based in the southwest quadrant of the study area.

Within Unit 6, a dolomitic/calcareous quartzose siltstone succession 2-15 metres thick is distributed in a west-northwest to east-southeast trending band through the centre of the Greater Cessford Area (Figure 3.3). This dolomitic quartzose siltstone is known informally as the "Banff sandstone". Two dip-parallel cross-sections illustrate that the siltstone is not always present in closely-spaced wells (Figure 3.4-3.5). It is commonly underlain by the crinoidal bioclastic wackestone to packstone lithofacies, and overlain by the bioturbated mudstone or crinoidal bioclastic wackestone to packstone lithofacies depending on location. The crinoidal bioclastic grainstone lithofacies caps the coarsening-upward cycle, or more rarely, directly overlies the siltstone lithofacies.

3.2.3.3 Depositional Environment

The significance of the dolomitic/calcareous quartzose siltstone to sandstone lithofacies lies in its occurrence as a siliciclastic unit deposited within a carbonate-dominated succession. The nature and extent of mixing of carbonate and siliciclastic sediments in the geologic record is still largely undetermined and will be discussed in greater detail in Chapter 4 (Carbonate-Siliciclastic Mixtures and a Ramp Model for the Banff Formation).

Poorly preserved flaser bedding in the dolomitic/calcareous quartzose siltstone to sandstone lithofacies suggests that the siltstone was reworked by shallow marine processes. The intensity of bioturbation indicates that invertebrate life was abundant and sedimentation rates were relatively low. *Teichichnus* and *Asterosoma* are traces

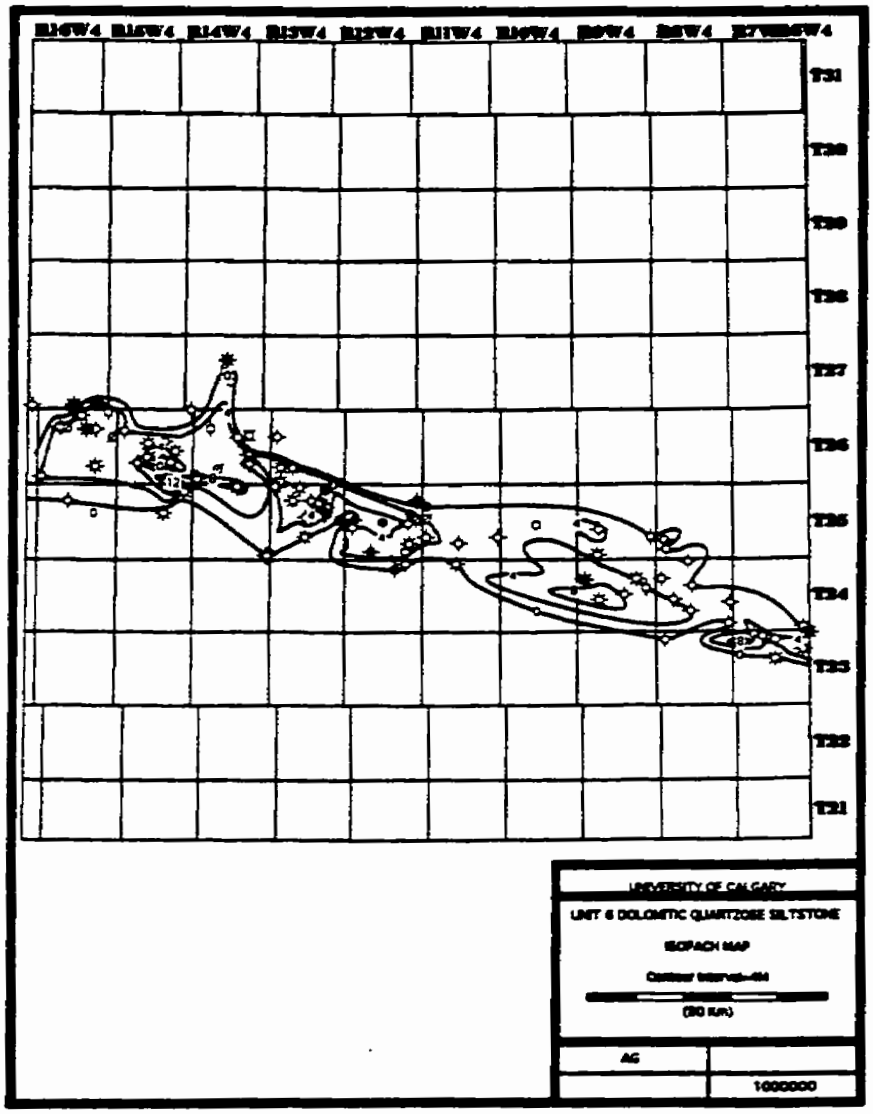


Figure 3.3. A west-northwest to east-southeast trending band of quartzose siltstone in Unit 6 is 2-15 metres thick in the Greater Cessford Area.

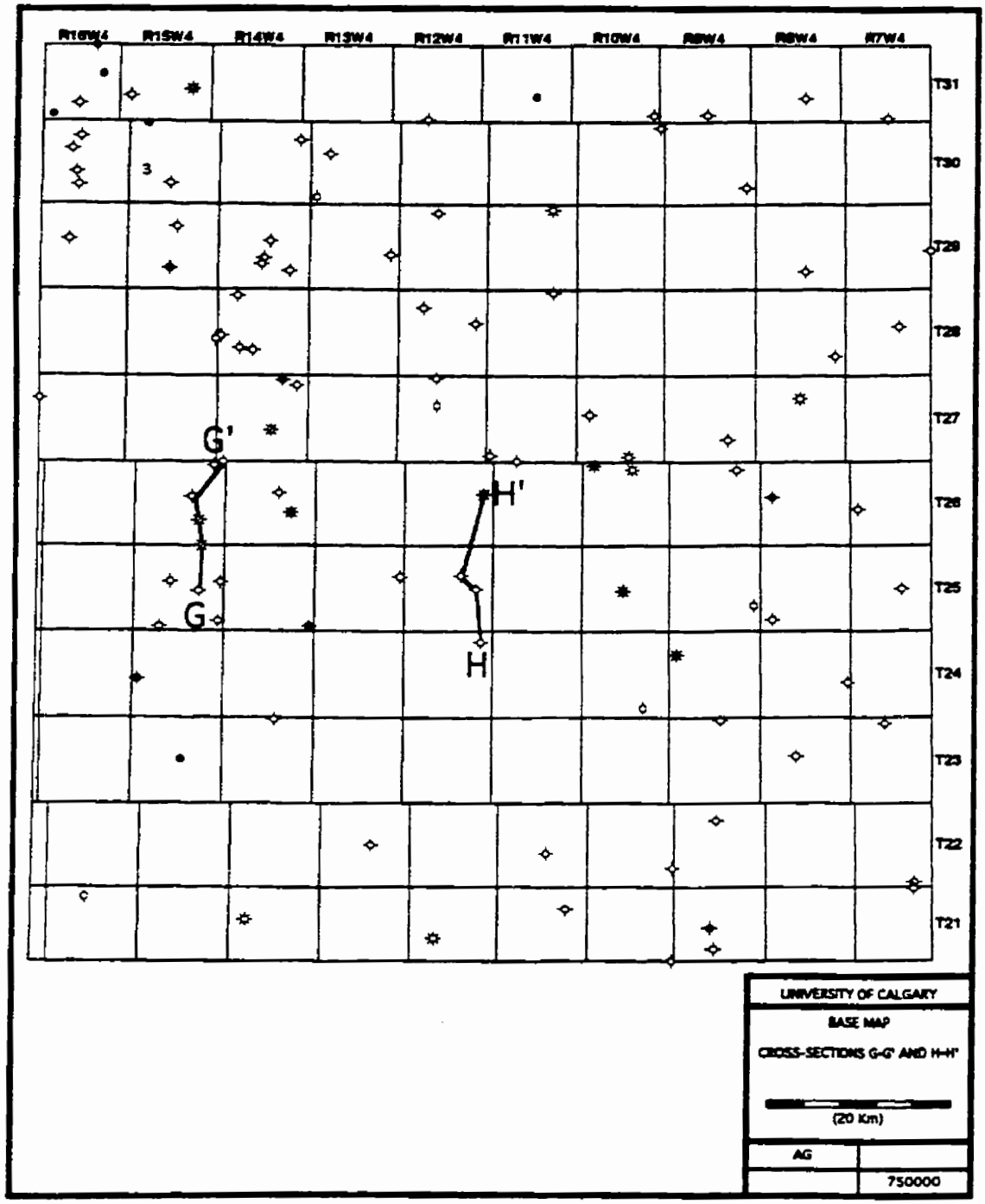


Figure 3.4. Base map for cross-sections G-G' and H-H' in Figure 3.5.

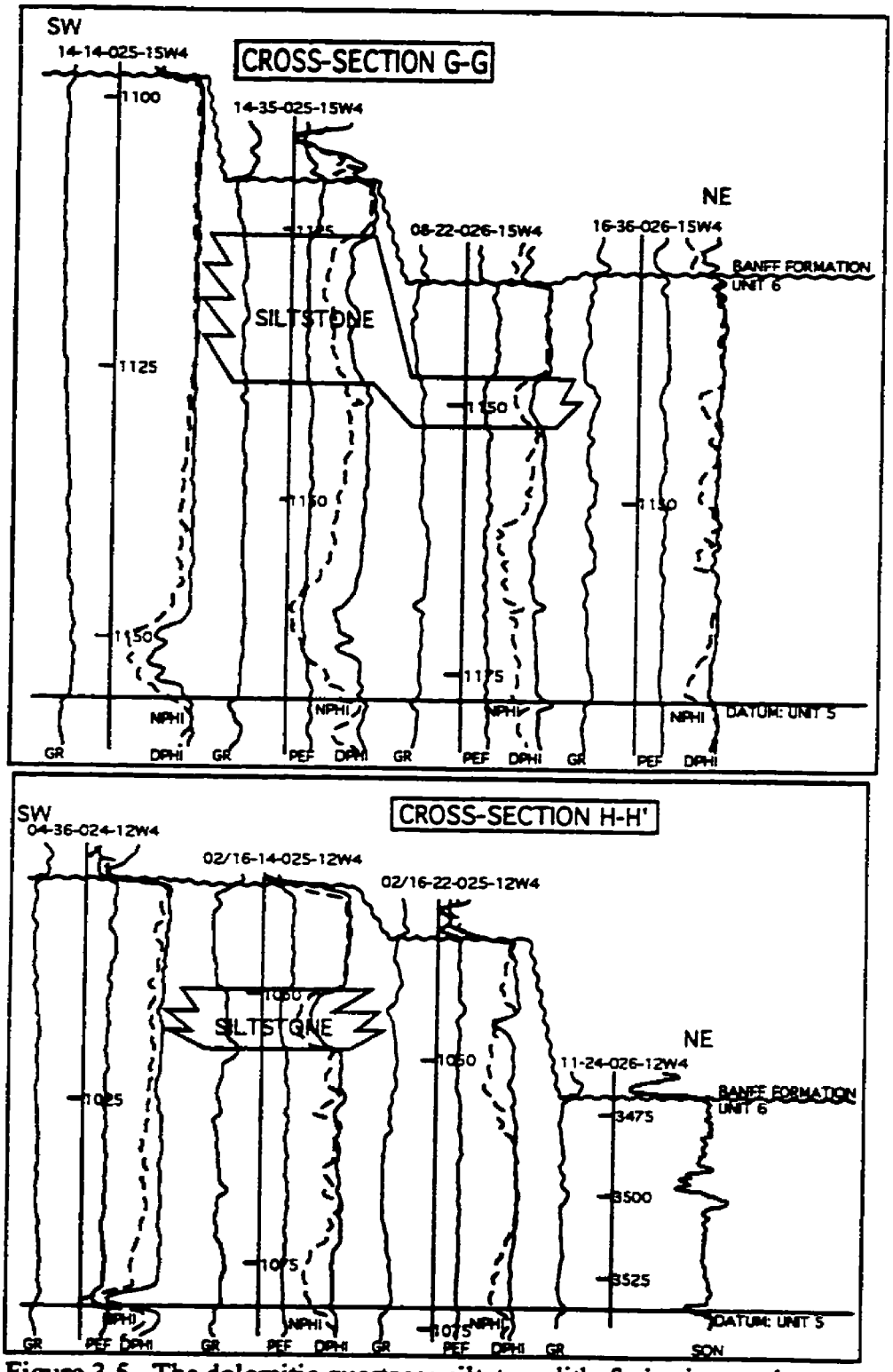


Figure 3.5. The dolomitic quartzose siltstone lithofacies is not always present in closely spaced wells. The siltstone ranges in thickness from 2-13 metres and is recognized on log profiles by relatively high gamma ray and porosity log values. PEF log values are intermediate between sandstone and limestone.

typically developed in the Cruziana ichnofacies which is located in the nearshore to coastal marine depositional environment (Pemberton et al. 1992). The dolomitic/calcareous quartzose siltstone to sandstone lithofacies is interpreted as a reworked sediment deposited in a shallow, open marine, inner ramp setting above fair-weather wave base.

The dolomitic/calcareous quartzose siltstone/sandstone lithofacies fits into Wilson's (1975) clastics-dominated areas on the normal marine open platform. The seventh facies belt is characterized by variable quantities of extensively bioturbated carbonate and clastic sediment.

The local concentration of skeletal material along the upper contact of this lithofacies is interpreted as a transgressive lag. Frayed dolomite edges, dissolution of cements and oversized pores suggest flushing by meteoric water. Dissolution of calcite is discussed in greater detail in Chapter 5 (Diagenesis), and its effects on porosity and reservoir characteristics in Chapter 6 (Petroleum Geology).

The dolomitic/calcareous quartzose siltstone/sandstone lithofacies is not penetrated by core in the southwest quadrant of the study area in Unit 2. By virtue of its position among other mid-ramp facies in Unit 2, the dolomitic/calcareous quartzose siltstone/sandstone lithofacies is interpreted as mid-ramp sediments. It is speculated that sediments were transported from the inner ramp to the mid-ramp environment by storm-generated currents. Presumably, flaser bedding is not preserved in these deposits. These sediments were likely deposited in Wilson's (1975) fourth facies belt which contains fine-grained siliciclastics deposited on the foreslope.

3.2.4 Pelleted Mudstone to Packstone

3.2.4.1 Description

The fourth lithofacies of the Banff Formation consists of light brown-gray, pelleted mudstone to wackestone to packstone. Subhorizontal, millimetre-scale, continuous and discontinuous, green shale laminae are commonly present. Shale

accounts for approximately 5% of the bulk rock composition. Bioturbation exhibits highly variable intensity, ranging from an absence of bioturbation to intensive bioturbation. Crinoids are the dominant macrofossil, with brachiopods and bryozoans present in lesser abundance. Lithologic contacts with underlying lithofacies are typically gradational. The pelleted mudstone to packstone lithofacies is locally silty and pyrite mineralization and calcite filled cavities are common.

The pelleted mudstone has a patchy appearance in thin section attributed to the occurrence of micrite pockets within a fully recrystallized micro and pseudospar rock. Sparry calcite grains are 10-55 micrometres long. Subangular quartz grains (30-60 micrometres long) are scattered throughout the matrix and constitute <5% of the bulk mineralogical composition.

Two generations of calcite cement are observed, but generally only the second generation is present. The first generation consists of pyramidal, bladed, isopachous fringe cement that crystallized along the periphery of skeletal fragments. The second generation of cement is composed of finely to coarsely crystalline, equant calcite cement that crystallized in intergranular spaces and within fossil vugs. Calcite grains in the second generation cement are typically 30-50 micrometres long and generally increase in crystal size towards the centre of fossil vugs and other voids (Plate 3b).

Microcrystalline quartz selectively replaced portions of echinoderm and brachiopod fragments. In addition, quartz overgrowth cement is locally present. Pellets are 50-100 micrometres long and are approximately 25% of the total framework components. Patchily distributed porosity is typically <1%, but rarely ranges up to 5%.

The pelleted mudstone to packstone lithofacies does not have a very diagnostic log signature. The gamma radiation ranges from 15-55 API, PEF log values are typically 4-5, and the neutron and density porosity curves are generally 0-9 limestone porosity

units apart. Neutron and density logs record 6-21 and 6-14 limestone porosity units respectively (Figure 3.2e).

3.2.4.2 Thickness and Distribution

The pelleted mudstone to packstone lithofacies is only penetrated by three cores in the Greater Cessford Area. It is preserved as part of Unit 6 and is 0-8 metres thick. This lithofacies is part of a series of metre-scale, coarsening-upward cycles. The pelleted lithofacies is probably a component of Units 3-5 but does not have a very diagnostic log signature and is thus hard to identify and differentiate from other lithofacies using geophysical well logs alone.

3.2.4.3 Depositional Environment

The abundance of pellets relative to the minor amount of skeletal debris suggests that the pelleted mudstone to packstone lithofacies is the product of a restricted, shallow subtidal, lagoonal depositional environment that is protected by the crinoidal bioclastic grainstone lithofacies shoal and bank complex. Fecal pellet sands are micritic owing to their deposition in water quieter than that in which the rocks of the barrier system were deposited. Reduced water circulation and low current activity would have inhibited fauna through elevated salinity levels (Read 1985). Presumably, bioclastic debris was swept off the shoal and bank complex and into the lagoonal environment during storm events. Pyrite mineralization suggests conditions were somewhat dysaerobic (Bathurst 1975). Fine-grained siliciclastic material may have been periodically introduced to the lagoonal system by eolian processes.

Pelleted bioclastic mudstones to packstones similar to those described herein occur in 5-15 metres of water along the western portion of the Great Pearl Barrier in the Persian Gulf (Purser and Evans 1973), in <10 metres of water along the interior of the Bahamas platform (Bathurst 1975), and in 10-30 metres of water along the Shark Bay embayment plain (Logan and Cebulski 1970). Stratigraphic relationships with other lithofacies and comparisons with modern analogues suggests that the pelleted mudstone

to packstone lithofacies was deposited in water depths of 5-25 metres (Elrick and Read 1991).

The muddier endmember of this lithofacies is the product of the more protected parts of the lagoon, while the grain-supported packstones were deposited in areas of moderate circulation. This relationship is seen along the Trucial Coast in the Persian Gulf (Purser and Evans 1973).

The pelleted mudstone to packstone lithofacies fits into Wilson's (1975) seventh and eighth standard facies belts. The pelleted packstones fit into the seventh facies belt which consists of open marine sedimentation in open lagoons and bays located behind some sort of hydraulic barrier. Water depth ranges from several metres to tens of metres and circulation is moderate. Water conditions are usually favourable for organisms and burrowing and pelleting of the sediment is common. The eighth facies belt is characterized by fine-grained sedimentation in hypersaline, restricted lagoons where wind blown clastics may be locally significant. The pelleted mudstones and wackestones fit into Wilson's (1975) eighth facies belt.

3.2.5 Crinoidal Bioclastic Wackestone to Packstone

3.2.5.1 Description

The fifth lithofacies identified in the Banff Formation consists of light to dark gray-brown, crinoidal, bioclastic, wackestone to packstone (Plates 5c, d; 7a, b). The crinoidal bioclastic wackestone to packstone lithofacies is variably dolomitized and commonly interbedded with shale. Irregular and ramose, subhorizontal shale laminae are variably rare to abundant and commonly stylolitized. Shale content ranges from 0-50% of the bulk rock composition, with 10% being typical. Bioturbation of sediments is moderate to intense. Locally, soft sediment deformation features are present along the basal contact of packstone intervals which overlie muddier sediments (Plate 5d). Slightly bulbous shaped muddy sediments project upwards into the overlying, coarser-

PLATE 7-CRINOIDAL BIOCLASTIC PACKSTONE AND CRINOIDAL BIOCLASTIC GRAINSTONE LITHOFACIES

A) CRINOIDAL BIOCLASTIC PACKSTONE. A light gray crinoidal bioclastic packstone contains irregular and ramose, millimetre- to centimetre-scale, partially stylolitized shale laminae. The crinoidal bioclastic packstone is under- and overlain by the calcareous quartzose siltstone and bioturbated silty mudstone lithofacies respectively. (1047.15-1047.36 metres, 02/16-14-025-12W4, Unit 6).

B) CRINOIDAL BIOCLASTIC PACKSTONE. A medium gray crinoidal bioclastic packstone contains subhorizontal, continuous and discontinuous, millimetre-scale shale lamina and lamina sets. This is part of a metre-scale, coarsening-upward cycle of crinoidal bioclastic wackestones and packstones. (1046.40-1046.58 metres, 02/16-22-025-12W4, Unit 6).

C) CRINOIDAL BIOCLASTIC GRAINSTONE. A light brown crinoidal bioclastic grainstone contains subhorizontal, millimetre-scale, continuous and discontinuous, green shale laminae. This is part of a metre-scale, coarsening-upward cycle consisting of the bioturbated silty mudstone lithofacies capped by the grainstone lithofacies pictured here. (1121.55-1121.73 metres, 14-35-025-15W4, Unit 6).

D) CRINOIDAL BIOCLASTIC GRAINSTONE. A massive, white, crinoidal bioclastic grainstone contains macro/micro vugular and moldic pores. The crinoidal bioclastic grainstone is the top of one of several stacked metre-scale, coarsening-upward cycles that are underlain by black, calcareous shales. (1306.15-1306.29 metres, 16-31-31-16W4, Unit 3).

Note: Coin is 21 millimetres in diameter.

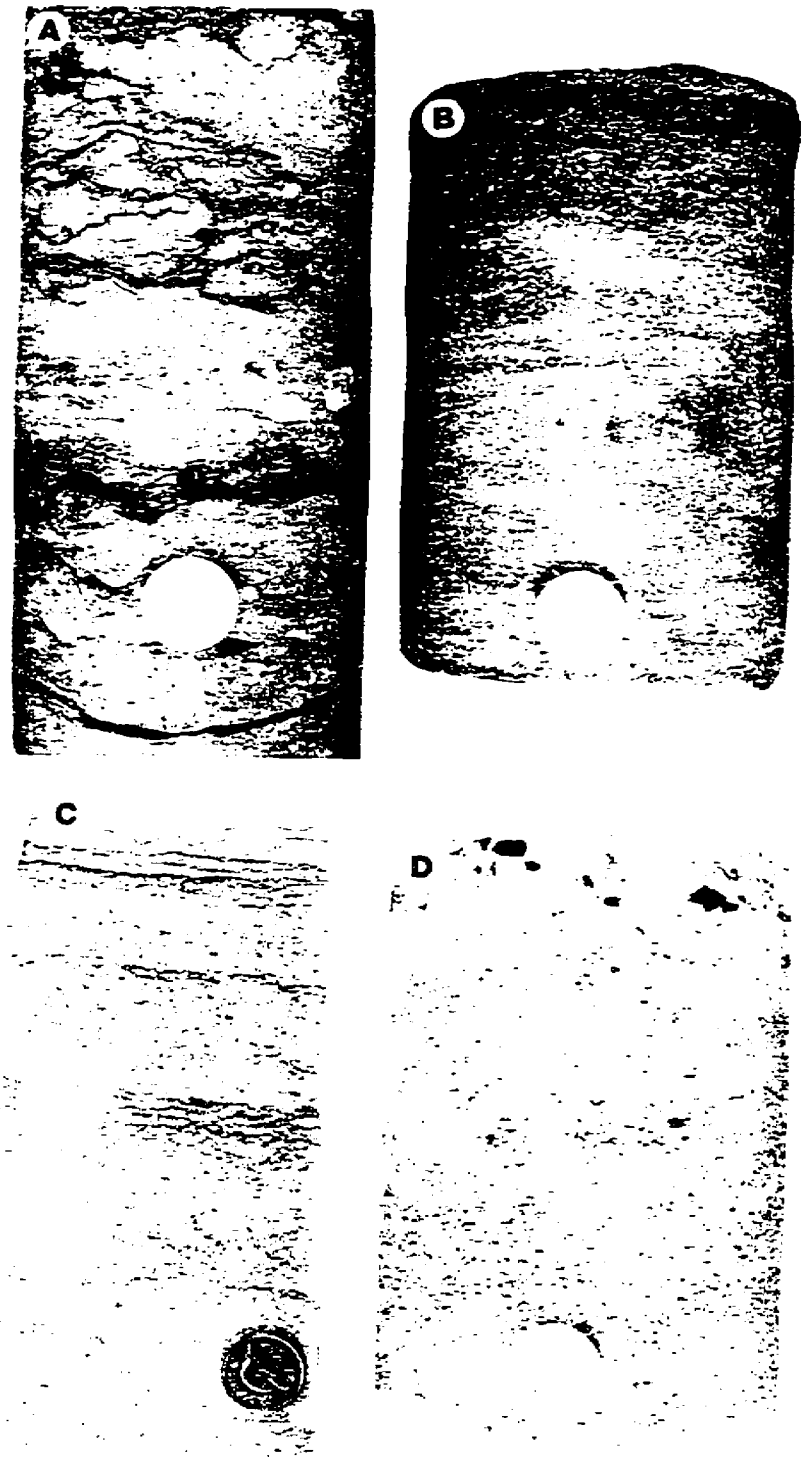


PLATE 7

grained packstone sediments. Whole and broken crinoids are the dominant bioclastic material.

Pyrite mineralization as both disseminated specks and euhedral crystals is common. Locally, dark gray wackestone clasts, calcite filled voids and fractures, stringers of carbonaceous material, whole shells filled with spar and white rimmed dark gray limestone clasts are present. Upper and lower lithologic contacts of the crinoidal bioclastic wackestone to packstone lithofacies are typically gradational. More rarely, lithologic contacts are sharp or bioturbated (Plate 2d, e).

Three generations of calcite cement are commonly developed in the crinoidal bioclastic packstones. In contrast, only one generation is usually developed in the muddier crinoidal bioclastic wackestones (Plate 3c). The first generation cement consists of inclusion-free, coarsely crystalline syntaxial overgrowths on echinoderm ossicles and other skeletal fragments. The second generation cement forms pyramidal, isopachous fringes on skeletal grains. The third generation is comprised of medium to coarsely crystalline, inclusion-free, calcite cement which infills intergranular spaces and shell interiors. The third generation cement represents 80-98% of total cements.

In decreasing order of abundance, the macrofossils in the crinoidal bioclastic wackestone and packstone lithofacies are crinoids, brachiopods, ostracods and pelecypods. Total porosity due to fracturing and secondary leaching is typically <1%. Scattered pellets and micritic envelopes around skeletal fragments are locally present. Microcrystalline quartz replaced portions of skeletal fragments and rare subangular quartz grains are observed along fracture planes and scattered in the sediment. Within wackestone lithologies, whole, delicate walled brachiopod shells are present. Locally, sutured contacts between skeletal grains are recognized.

Examination of several samples of this lithofacies with the scanning electron microscope reveals a tight rock composed of anhedral to subhedral calcite crystals. Calcite cementation has occluded any primary porosity (Plate 8 a, b).

PLATE 8-CRINOIDAL BIOCLASTIC PACKSTONE AND CRINOIDAL BIOCLASTIC GRAINSTONE LITHOFACIES

A and B) CRINOIDAL BIOCLASTIC PACKSTONE. The crinoidal bioclastic packstone lithofacies is comprised of subhedral calcite grains. Any primary porosity has been occluded by calcite cementation. (1126.00 metres, 14-35-025-15W4, Unit 6).

C and D) CRINOIDAL BIOCLASTIC GRAINSTONE. Subhedral, equant calcite grains are the main constituent of the crinoidal bioclastic grainstone lithofacies. Some inhomogeneously distributed intercrystalline porosity is present. (1297.68 metres, 16-31-030-16W4, Unit 6).

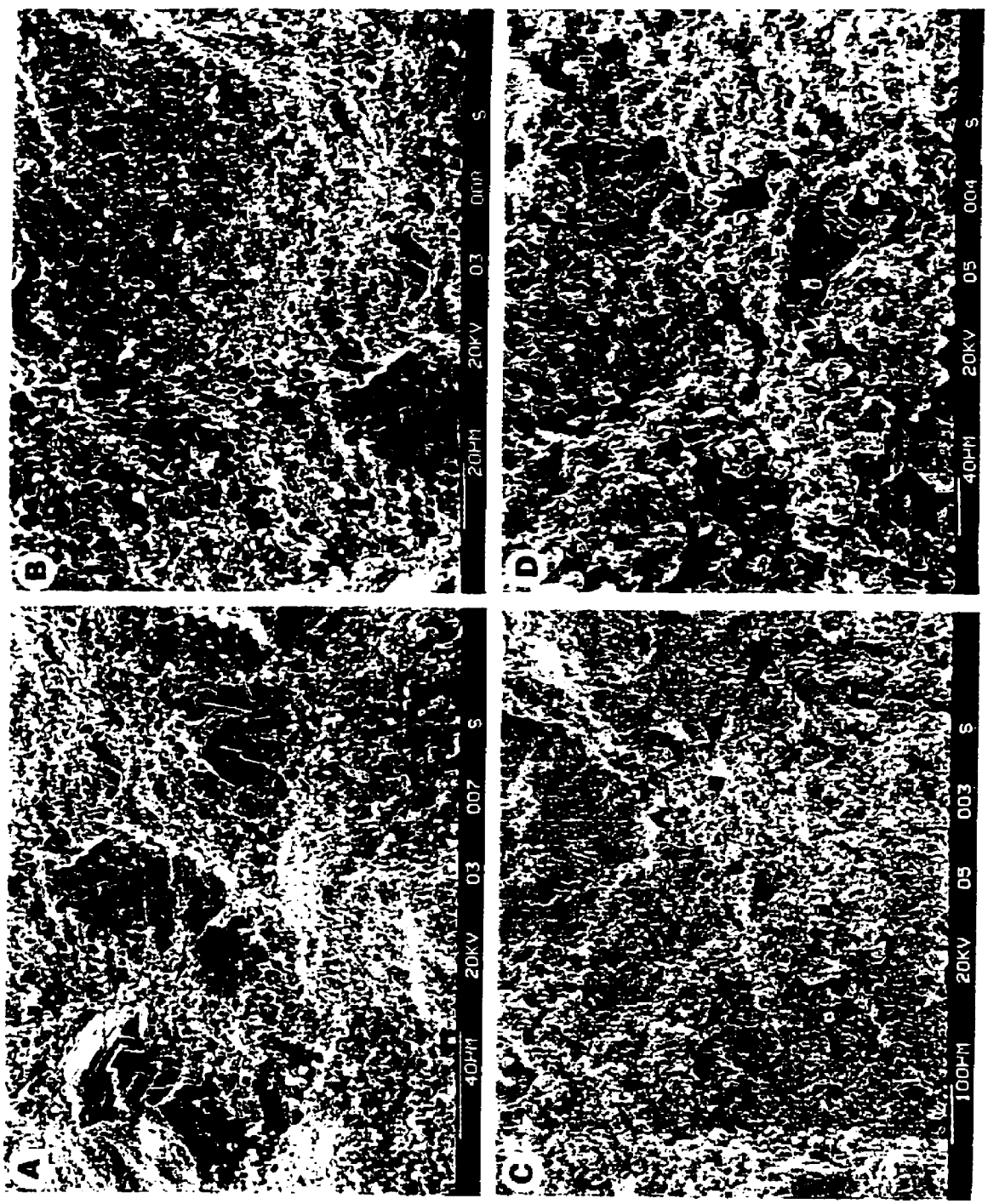

A
40µm 20KV 03 007 S
B
20µm 20KV 03 010 S
C
100µm 20KV 05 003 S
D
40µm 20KV 05 004 S

PLATE 8

The gamma ray log reading is typically lower than in the pelleted mudstone to packstone lithofacies (10-50 API) and the PEF log values are highly variable (3-5) depending on the quantities of calcite, dolomite and shale. The neutron and density porosity log separation is typically 1-10% with the density log registering 0-18 limestone porosity units (Figure 3.2b, c, e, f, g).

3.2.5.2 Thickness and Distribution

The crinoidal, bioclastic wackestone to packstone lithofacies is present in Units 2-6 and ranges from 0-14 metres thick. It is the most commonly encountered lithofacies in core and is present both alone and interbedded with the shale lithofacies.

No cores penetrate the crinoidal bioclastic wackestone to packstone lithofacies in Units 2 and 3. As a consequence, their interpretation is based entirely on geophysical well logs. This lithofacies is preserved as the upper portion of one or several, metre-scale, coarsening-upward cycles. Alternatively, the crinoidal bioclastic wackestone to packstone lithofacies is preserved as a massive sedimentary succession.

Units 4-6 consist of a massive section of crinoidal, bioclastic wackestone to packstone, or alternatively, a series of coarsening-upward, metre-scale cycles. These cycles range from a crinoidal bioclastic wackestone coarsening-upward into a packstone lithology to the same cycle capped by the crinoidal bioclastic grainstone lithofacies. These cycles are commonly stacked on top of each other and may also be shale- and/or mudstone-based. Alternatively, the crinoidal bioclastic wackestone to packstone lithofacies commonly under and/or overlies the dolomitic/calcareous quartzose siltstone to sandstone lithofacies.

3.2.5.3 Depositional Environment

The crinoidal bioclastic wackestone to packstone lithofacies represents reworking by currents and waves to varying degrees in the shallow subtidal zone. Intensive bioturbation suggests that the substrate was stable and thus more fine-grained sediment was available for infaunal organisms. This lithofacies occurs in two different

depositional environments on different parts of the Banff Formation ramp. The first is deeper water accumulations on the mid-ramp. Mid-ramp wackestones and packstones were not penetrated by core but their position in the sedimentary succession and associated facies indicate deposition below fair-weather wave base. The second depositional environment is interpreted to have been located on the inner ramp above fair-weather wave base. Crinoidal bioclastic packstones were deposited as a barrier bar complex that sheltered crinoidal bioclastic wackestones deposited behind (shoreward) the bank complex in a semi-restricted, protected marine environment where incoming waves were somewhat baffled.

Chatellier (1983) interpreted the packstone lithofacies of the Banff Formation in southwestern Alberta as the product of a complex assemblage of barrier bars and channels. He proposed that wackestones were deposited in localized low areas to form mud-filled depressions. These are similar to the barrier bars and channels along the Trucial Coast of the Persian Gulf (Purser and Evans 1973) and low areas of the Hawk Channel behind the Florida Reef Tract and the Great Pearl Bank in the Persian Gulf (Wilson and Jordan 1985). Muddy, skeletal sands lie seaward of a barrier in quieter water along the Trucial Coast, Persian Gulf (Purser and Evans 1973).

The crinoidal bioclastic wackestone to packstone lithofacies fits into three of Wilson's (1975) standard facies belts. The fourth facies belt is characterized by deposition between fair-weather and storm wave base on the mid-ramp. Bioclastic material is derived from both in situ colonies and from debris swept down the slope. Some siliciclastic material derived from the inner ramp may also be deposited out of suspension. The observations herein deviate from Wilson's (1975) model owing to an absence of the slumping and brecciation features characteristic of the model. This discrepancy arises from the fact that the model was developed for an abrupt margin, whereas this study involves a shallowly sloping ramp geometry with no sharp breaks in slope.

The sixth and seventh standard facies belts consist of winnowed platform sands and open marine deposition in bays located behind a hydraulic barrier respectively. The crinoidal bioclastic packstones are deposited in both facies belts while the crinoidal bioclastic wackestones were more often deposited in the seventh facies belt. Shallow waters several metres to tens of metres in depth, moderate circulation, and variable salinity are characteristics of the seventh belt.

3.2.6 Crinoidal Bioclastic Grainstone

3.2.6.1 Description

The highest energy lithofacies of the Banff Formation consists of white crinoidal bioclastic grainstone (Plate 7c, d). Subhorizontal, continuous and discontinuous, millimetre-scale, green shale laminae and centimetre-wide shale lamina sets are variably rare to common. Shale laminae are typically <1% of the bulk rock composition with rare occurrences as high as 20%. Cross-bedding is present in several cores, while others are devoid of sedimentary structures. The crinoidal bioclastic grainstone lithofacies has the most abundant and diverse macrofossil assemblage of the Banff Formation lithofacies. The dominant fossils are crinoids with lesser abundances of well-abraded brachiopods, bryozoans, corals, ostracods and pelecypods.

Also abundant in this lithofacies are: (1) pyrite nodules and euhedral pyrite crystals, (2) stylolites, and (3) calcite filled subvertical fractures and vugs. Locally, black argillaceous flecks and laminations, micro and macro vugs, moldic pores, intraclasts and large (up to 5 centimetres long) cracked mud nodules are present.

The crinoidal bioclastic grainstone and bioturbated mudstone lithofacies are commonly separated by a scour surface. In contrast, where the crinoidal bioclastic grainstone lithofacies overlies the dolomitic/calcareous quartzose siltstone to sandstone lithofacies, the contact is gradational.

Three generations of calcite cement are present in the crinoidal bioclastic grainstone lithofacies (Plate 9 a-d). The first generation of calcite cement consists of

PLATE 9-CRINOIDAL BIOCLASTIC GRAINSTONE LITHOFACIES

A, B and C) CRINOIDAL BIOCLASTIC GRAINSTONE. The crinoidal bioclastic grainstone lithofacies consists of skeletal fragments cemented by three generations of calcite cement. Skeletal fragments are dominated by echinoderm fragments but brachiopod, bryozoan, ostracod, pelecypod and coral fragments are all present in this sample. The first generation cement consists of pyramidal, included, isopachous fringe cement which crystallized along allochem edges (see photomicrograph C). The second generation cement consists of syntaxial overgrowths on echinoderm and brachiopod fragments. Syntaxial overgrowths are inclusion free and occur in optical continuity with single crystal grains. The third generation cement consists of equant, coarsely crystalline calcite which crystallized in intergranular spaces. Cementation completely occludes all primary porosity in this sample. (1121.47 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

D) CRINOIDAL BIOCLASTIC GRAINSTONE. This sample is cemented by the same three calcite cement generations as described for the previous photomicrograph. Green microcrystalline quartz selectively replaced portions of skeletal fragments and subround quartz grains are scattered throughout the slide. (1392.44 metres, 06-25-026-18W4, Unit 6, plane-polarized light).

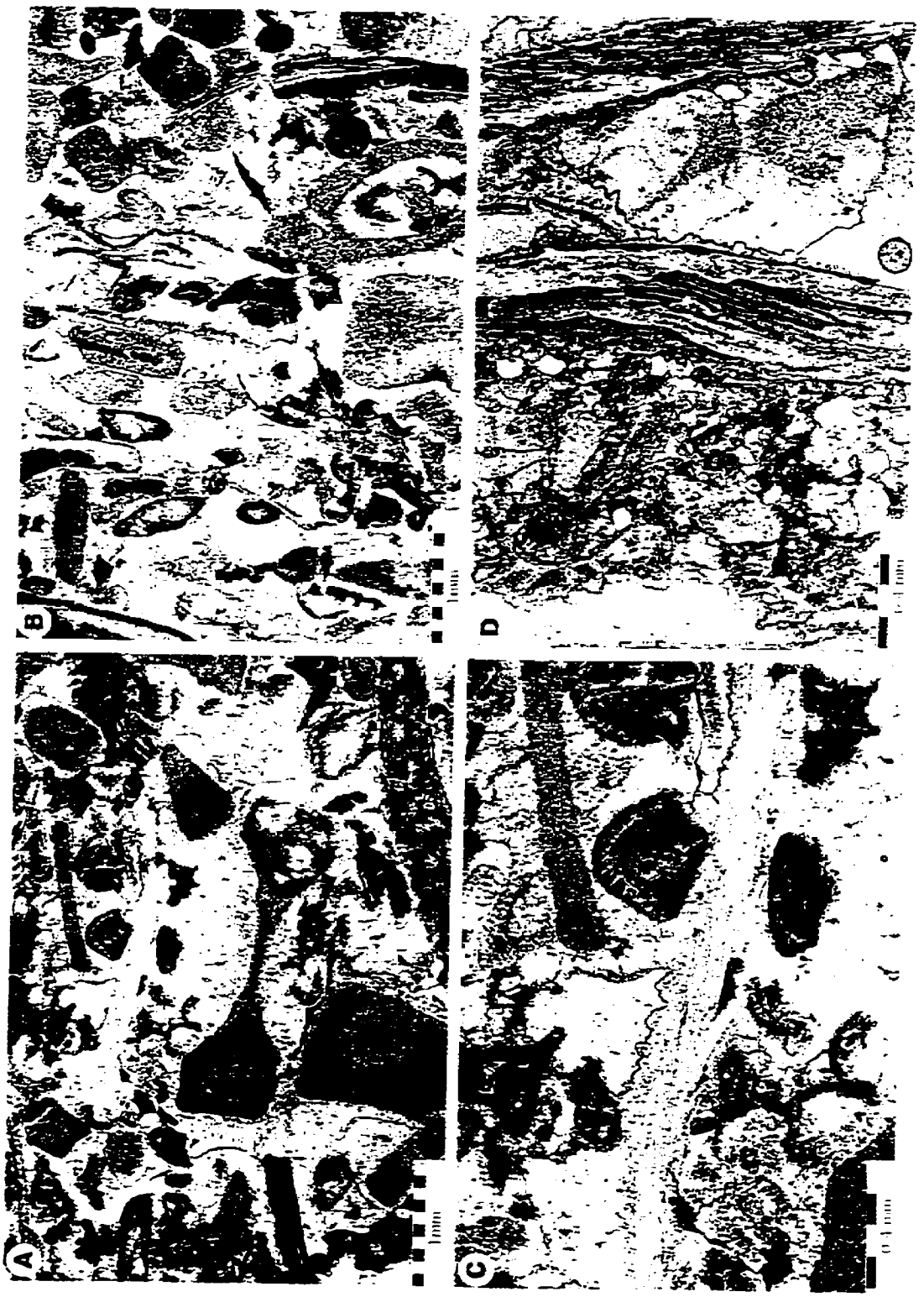


PLATE 9

syntaxial overgrowths on crinoid ossicles and other skeletal fragments. The syntaxial overgrowths are inclusion-free and in optical continuity with skeletal grains. The second generation consists of pyramidal, bladed isopachous fringe calcite cement which is developed along the periphery of skeletal grains. The fringe cement is observed overgrowing several syntaxial overgrowths which indicates that the fringe cement grew after the syntaxial overgrowth cement. The third and dominant cement generation (75-95% of total cements) consists of equant, coarsely crystalline, well-cleaved calcite cement (Plate 9c, d). The third generation cement is generally not as iron-rich as the first and second generation cements. Ghost fabrics are generated by the replacement of echinoderm fragments by third generation cement.

Porosity varies between 1 and 8%, and is the result of secondary leaching of skeletal fragments and pinpoint dissolution of bryozoans. Both moldic and vugular pores are present. Micritic envelopes are commonly developed around allochems. Microcrystalline green quartz (Plate 9d) and a black, opaque mineral (pyrite?) replaced portions of some skeletal fragments, while others are iron rich. Locally, finely crystalline dolomite cement infills obliquely oriented fractures while calcite cements fractures which cross-cut skeletal fragments.

A completely silicified (95%) crinoidal grainstone bed with chalcedony and megaquartz cements was observed in one thin section. Chalcedony cements occur between skeletal grains and along the walls of shell interiors. Megaquartz infills voids and commonly becomes coarser-grained towards the void centre.

Dominantly subhedral, equigranular calcite crystals are observed with the scanning electron microscope (Plate 8c, d). Some inhomogeneously distributed intercrystalline porosity is preserved.

The crinoidal grainstone lithofacies has a consistently low gamma radiation (3-16 API; rarely up to 30 API) and records 4.5-5 on the PEF log. Porosity log readings are highly variable due to the wide-ranging porosities encountered in these rocks. Neutron

and density porosity logs record between 0 and 30 limestone porosity units and generally overlap each other, indicating that the grainstone lithofacies is not commonly dolomitized (Figure 3.2d, f, g).

3.2.6.2 Thickness and Distribution

The crinoidal bioclastic grainstone lithofacies is present in Units 3 to 6. Individual grainstone packages range from 2-10 metres thick but these are commonly stacked to form 15-20 metre thick packages in Unit 6.

The crinoidal bioclastic grainstone lithofacies commonly caps coarsening-upward, metre-scale cycles that consist of the shale and/or bioturbated mudstone lithofacies overlain by the crinoidal bioclastic wackestone to packstone lithofacies which is in turn overlain by the crinoidal, bioclastic grainstone lithofacies. Grainstones are also present as massive stacked successions.

3.2.6.3 Depositional Environment

Crinoidal limestones have been interpreted as shallow water deposits by many authors (Choquette and Steinen 1980; Carozzi and Gerber 1984; Moore 1984; Elrick and Read 1991). Since no direct modern counterparts of shallow water crinoid banks are known, skeletal grainstone deposits found in 5-20 metres of water in Shark Bay, Australia (Hagan and Logan 1974) or along the seaward edge of the Great Pearl Barrier in the Persian Gulf (Purser and Evans 1973) are potential analogues for the crinoidal bioclastic grainstone lithofacies. These modern deposits, integrated with ancient analogues, suggest that the crinoidal bioclastic grainstone lithofacies of the Banff Formation was deposited in approximately 5-20 metre water depths. Diverse and numerous macrofossils, especially crinoids, indicate near normal salinity.

Migratory grainstone shoals may have been located on local positive areas on the inner ramp. Tucker and Wright (1990) documented shoaling on local highs due to halokinesis along the Trucial Coast, Persian Gulf. Here, skeletal grainstones are one of three principal lithofacies of the inner ramp and consist of well abraded skeletal material

derived from molluscs, echinoderms, foraminifera and corals. The grainstone lithofacies forms high energy shoals, beach barriers, tidal deltas and tidal channels and is characterized by common cross-stratification (Purser and Evans 1973). Cross-bedding in the crinoidal bioclastic grainstone lithofacies was locally observed.

The crinoidal bioclastic grainstone lithofacies fits into Wilson's (1975) sixth standard facies belt. This belt comprises high energy, winnowed, platform edge sands deposited in shoals, beaches, fans, tidal bars, and eolianite dune islands. Depth of deposition ranges from above sea level (in the case of the eolianite deposits) to 5-10 metres water depth. The crinoidal bioclastic grainstone lithofacies of the Banff Formation is interpreted to have been deposited as a barrier bar, shoal and bank complex which protected a series of bay and lagoonal depositional environments. No evidence is preserved to suggest the presence of fan, tidal bar or eolianite dune island deposits.

The crinoidal bioclastic grainstone lithofacies was substantially reworked, transported and winnowed by current and wave agitation. The micritic matrix was removed by winnowing and replaced with sparry calcite cement. During storm events, the shoal and bank complex was eroded by wave action and crinoidal and other skeletal debris was transported by migrating ripples, while finer mud was carried out in suspension to be deposited on the mid-ramp. This is one of the sources of skeletal material in the crinoidal bioclastic and pelleted mudstone to packstone lithofacies. The presence of intraclasts in the crinoidal bioclastic grainstone lithofacies suggests that local storms ripped up adjacent soft sediments, transported the clasts shoreward and deposited them on the bank complex.

3.3 FACIES ASSOCIATIONS

3.3.1 Introduction

The six lithofacies of the Banff Formation are grouped into six units which can be interpreted as depositional associations. A southwestward-deepening ramp profile is

indicated for the Banff Formation in the Greater Cessford Area. There is no evidence in the form of turbidites or slumping features for a sharp break in slope, as determined from mapping or cores. However, the profile of the Banff Formation ramp appears to have varied with time resulting in episodes of deposition when the ramp had a slightly inflected or curved profile. The geometry of the Banff Formation ramp will be discussed in greater detail in Chapter 4 (Carbonate-Siliciclastic Mixtures and a Ramp Model for the Banff Formation).

3.3.2 Unit 1

The shale and bioturbated mudstone lithofacies, deposited either alone or as a coarsening-upward cycle, comprise Unit 1 in the Greater Cessford Area. The shale and bioturbated mudstone lithofacies were deposited between fair-weather and storm wave base in an open marine setting on the mid-ramp. Much of the sediment and rare skeletal debris was derived from the inner ramp and deposited out of suspension. Shale laths in the bioturbated mudstone lithofacies indicate that Unit 1 was influenced by storm-generated currents.

3.3.3 Unit 2

Unit 2 is interpreted to have been deposited in an open marine setting on the mid- to inner ramp and consists of piles of crinoidal bioclastic wackestones and packstones and dolomitic/calcareous quartzose siltstones and sandstones isolated in bioturbated mudstones and shale. Dolomitic/calcareous quartzose siltstone/sandstone and carbonate piles are isolated in shales throughout the Greater Cessford Area. On the inner ramp, shales and argillaceous carbonates dominate. The profile of the Banff Formation carbonate ramp for Units 1 and 2 was an extremely low relief, shallowly sloping surface.

3.3.4 Unit 3

Unit 3 laterally changes from a single massive coarsening-upward cycle of bioturbated mudstones and crinoidal bioclastic wackestones and packstones deposited

on the mid-ramp to either one or a series of metre- to decimetre-scale, coarsening-upward cycles of shale, and dolomitic/calcareous quartzose siltstone and sandstone deposited along the inflected part of the inner ramp. Less commonly, the crinoidal bioclastic wackestone lithofacies overlies shale along the inflected portion of the inner ramp. Inner ramp deposits consist of massive packages of crinoidal bioclastic packstone and grainstone deposited as barrier bar, bank and shoal complexes which protected intershoal areas characterized by crinoidal bioclastic wackestone deposition. Pelleted mudstones to packstones were deposited in restricted, shallow subtidal lagoons located shoreward of the barrier bar complex.

3.3.5 Unit 4

Unit 4 consists of one or two coarsening-upward cycles of shale and crinoidal, bioclastic wackestone to packstone deposited on the mid-ramp. These grade laterally into metre-scale cycles with a high proportion of siliciclastic material deposited along the inflected portion of the Banff Formation ramp. Migratory, barrier bar, bank and shoal complexes sheltered lagoons and open bays on the inner ramp. Bioturbated silty mudstone, shale and pelleted mudstone to packstone were deposited in these lower energy environments that were baffled from wave activity. Fine-grained siliciclastic material was occasionally introduced into these depositional environments by eolian processes.

3.3.6 Unit 5

The mid-ramp sediments of Unit 5 cannot be distinguished from those of Unit 6 in the southwest quadrant of the study area. An alternative hypothesis is that Unit 5 is absent on the mid-ramp because it was never deposited there. Similar to Units 3 and 4, Unit 5 consists of metre-scale cycles deposited along the inflected portion of the inner ramp. These metre-scale cycles laterally interfinger with winnowed grainstone shoals and restricted sediments of the inner ramp.

3.3.7 Unit 6

Unit 6 laterally changes from massive bioclastic wackestones deposited on the mid-ramp to metre-scale cycles of the shale, crinoidal bioclastic wackestone to packstone, and dolomitic/calcareous quartzose siltstone to sandstone lithofacies along the inflected portion of the ramp. Bioclastic material on the mid-ramp is derived both in-situ and from debris swept down from the inner ramp. The open marine and restricted sediments of the inner ramp were removed by erosion associated with the post-Mississippian unconformity.

CHAPTER 4: CARBONATE-SILICICLASTIC MIXTURES AND A RAMP MODEL FOR THE BANFF FORMATION

4.1 INTRODUCTION

Little is known about the extent and significance of mixing and interbedding of carbonate and siliciclastic sediments in either modern or ancient systems (Doyle and Roberts 1988; Budd and Harris 1990). The range of carbonate-siliciclastic mixtures extends from a few quartz grains in a carbonate rock, to nearshore siliciclastic delta sediments laterally interfingering with carbonate ramp deposits. In many carbonate ramp systems, inner ramp deposits are carbonate-dominated, while outer ramp sediments consist of siliciclastic mudstones. Such a pattern was documented by Handford (1986), who described an updip skeletal shoal and shoreline facies passing downdip into a shale-rich, deep muddy shelf on a carbonate ramp in Arkansas.

In contrast, other systems are characterized by siliciclastic sediments on the nearshore shelf, which interfinger with carbonate sediments and reefs on the remainder of the shelf. This pattern of sedimentation was documented in Nicaragua by Roberts (1987). Yancey (1991) reported a similar pattern in the Pennsylvanian of the Midland Basin, whereby an intermediate carbonate zone is positioned between shallow nearshore and deep-water outer ramp zones of siliciclastic deposition.

Neither of these documented patterns of mixed carbonate-siliciclastic sedimentation appear comparable to the Banff Formation. Sedimentation in the Banff Formation exhibits two characteristics that are distinctly different from other carbonate ramps. Firstly, Unit 2 was deposited as piles of carbonate and quartzose siltstones and sandstones that are isolated in fine-grained siliciclastic sediments. Secondly, the siliciclastic sediments in Units 3-6 are concentrated into a medial belt that roughly parallels the paleoshoreline and that is flanked by carbonates in both the landward and seaward directions.

This chapter compares the regional sedimentology of the Banff Formation with sedimentation in the Greater Cessford Area. Carbonate-siliciclastic mixtures on ancient and modern ramps are compared and contrasted with the carbonate to siliciclastic transitions of the Banff Formation. Possible sources of siliciclastic sediment and structural influences on ramp sedimentation are evaluated. A ramp model for the Banff Formation in the Greater Cessford Area is presented at the end of the chapter.

4.2 COMPARISON WITH REGIONAL BANFF FORMATION

4.2.1 Regional Banff Formation and Established Ramp Models

This section will briefly re-iterate the regional picture and ramp models derived for the Mississippian Banff and Lodgepole Formations by previous workers. All of the studies mentioned below have already been discussed in some detail in Chapter 1, Section 1.3 (Previous Work) and Chapter 2, Section 2.1.4 (Banff and Lodgepole Formations).

It is important to differentiate between the regional work discussed below and the present study. Figure 4.1 is a schematic diagram of the passive margin, distally steepened ramp model for the Banff Formation stretching from southern Saskatchewan to southern British Columbia compiled from Chatellier (1983, 1988, 1992) and Richards et al. (1993, 1994). The current study examines a small part of the Banff Formation ramp in the eastern domain and utilizes more closely-spaced data points than in the existing regional studies. The eastern domain consists of the proximal, low gradient, homoclinal portion of the carbonate ramp which is characterized by a very shallow slope that is generally much less than one degree.

Chatellier (1983) divided the Banff Formation into three coarsening- and shallowing-upward cycles or mesosequences each comprised of: (1) lower basinal and slope rhythmic limestones, marls and shales, (2) a barrier bar, shoal and bank complex consisting of bioclastic wackestones and packstones, and (3) subtidal to supratidal

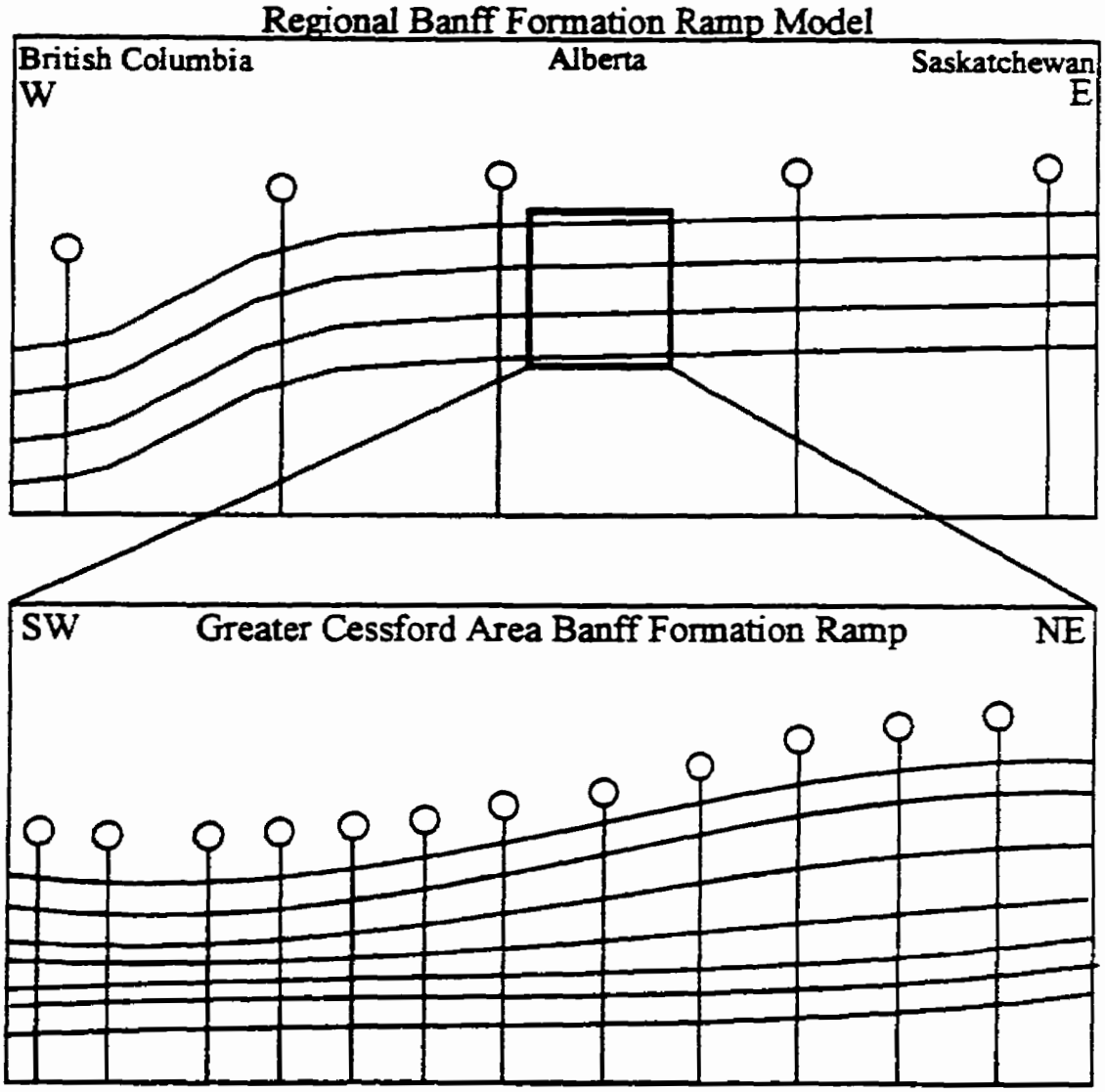


Figure 4.1 Highly schematic diagram of the Banff Formation distally steepened ramp. Location of the boundary between the western, outer ramp and eastern mid-and inner ramp environments is on Figure 1.3(a). The present study only examines a small part of the Banff Formation ramp in the eastern domain but utilizes more closely spaced data points than in existing regional studies.

terrigenous clastics. Each of these cycles was interpreted using Rich's (1951) model to represent the fondoform, clinoform and undaform respectively (Figure 1.3b, 2.1a).

The presence of sigmoidal bed surfaces which clinoform westward into the basin were interpreted from columnar sections and a seismic profile from northeastern British Columbia. Chatellier (1983) concluded that the Banff Formation was deposited on a distally steepened, tectonically controlled, westward-prograding carbonate ramp.

O'Connell (1990) mapped the Lower Banff and Pekisko Formations in the Peace River Embayment to determine the basin configurations. The shallower water facies of the middle and upper Banff Formation show little thickness variation, indicating that the main phase of basin formation and infilling occurred during the Lower Banff. Isopach maps on two lower shale units and two lower carbonate units did not show concentric bands of increasing sediment thickness but instead piles of sedimentary material. O'Connell (1990) attributed this to differential subsidence and divided the sediments into a northern (north-south trending, north of Township 90) and southern domain (west-east trending, south of Township 90). The shallower upper and middle Banff Formation successions prograded from east to west across the area. O'Connell's (1990) interpretation of a westward-prograding carbonate ramp confirms Chatellier's conclusions (1983, 1988, 1992).

Elrick and Read (1991) interpreted the Lodgepole Formation in the northwestern United States as a storm-dominated, pericratonic carbonate ramp. Subsidence rates derived from decompacted sediment thicknesses were estimated at 0.007-0.11 metres/thousand years. Slopes along the shallow ramp were estimated at <0.08 metres/kilometre, while ramp slopes increased to 0.35-0.9 metres/kilometre which is less than 0.1 degrees on the distal ramp. Three types of upward-shallowing, fifth-order, metre-scale cycles (peritidal, shallow subtidal, deep subtidal) were interpreted to have formed in response to Milankovitch sea level oscillations and were stacked to form three third to fourth-order depositional sequences (see Chapter 2).

A basal dolomite and siliciclastic lithofacies in the Lodgepole Formation overlies the Devonian-Mississippian unconformity and is comprised of dark coloured shales, quartzose siltstone/sandstone and dolostone. Elrick and Read (1991) interpreted the nonbioturbated dark shales, quartzose siltstones and dolostones as ramp slope and outer ramp deposits. In contrast, bioturbated quartzose siltstones and sandstones are interpreted as inner ramp sediments deposited in the shallow subtidal zone. The inner ramp quartzose siltstones and sandstones contain herringbone-stratification, channel scours, plane-laminations and flaser bedding indicating deposition in intertidal flats and tidal channels. Although the basal dolomite/siliciclastics lithofacies has the greatest quantity of siliciclastic sediment, traces of quartz silt are common in several other Lodgepole Formation lithofacies.

A carbonate platform model consisting of a ramp with an offshore skeletal peloidal bank was proposed for the Lodgepole Formation by Chen and Webster (1994). A basinward transition from very shallow water carbonates in central Wyoming (undeformed craton) to mud-dominated, deeper water facies in western Wyoming (secondary foreland basin) and farther west to relatively shallow water, grain-supported facies in southeast Idaho (peripheral forebulge) was recognized.

The skeletal peloidal bank developed hundreds of kilometres away from the shallow ramp fringing shoals along the transition zone between a homoclinal ramp and the Antler foreland basin. There is no evidence to support a steep shelf margin slope or a typical shelf lagoon. The inherited earliest Mississippian paleotopography had pronounced effects on Lower Mississippian carbonate sedimentation and was the major cause of the general lateral carbonate facies architecture of three broad facies zones (Chen and Webster 1994).

4.2.2 Greater Cessford Area

The Greater Cessford Area lies within the proximal part of the Banff Formation distally steepened carbonate ramp (Figure 4.1). The current study examines Banff

Formation sedimentation on a very small portion of the total geographic extent of the ramp using closely-spaced drillhole data. This is in contrast to the majority of previous workers who have concentrated on geographically large areas and utilized data points with a large distance between them.

The lower basinal and slope deposits documented by Chatellier (1983) are not observed in the Greater Cessford Area because they were deposited on the distally steepened part of the carbonate ramp which lies within the western domain. However, a barrier bar, shoal and bank complex developed in the present study area and is comprised of crinoidal, bioclastic packstones and grainstones. Chatellier's (1983) uppermost mesosequence of subtidal to supratidal clastics has largely been removed by erosion associated with the post-Mississippian unconformity in the Greater Cessford Area.

The sigmoidal bed surfaces observed on a regional scale by Chatellier (1983) and others cannot be established by correlation between relatively close-spaced wells in the Greater Cessford Area. In contrast, sediments were deposited in piles of highly variable thickness and areal extent in Units 1-5, rather than in concentric bands of increasing sediment thickness towards the basin. The sediment packages in the current study are interpreted to have prograded to the southwest which agrees with Chatellier's (1983) and Richards (1989) conclusions of westward and southwestward progradation of the Banff Formation respectively.

In the Peace River Embayment, the shallower water facies show little thickness variation indicating that the main phase of basin formation and infilling occurred during the lower Banff (O'Connell 1990). In contrast, highly variable thicknesses were encountered in Units 1-5 of the present study. No individual unit was dominant in basin infilling except for Unit 6 which prograded over the existing sediments. O'Connell (1990) recognized sediment piling in the Lower Banff Formation similar to that observed in the present study and attributed it to differential subsidence. Differential subsidence

is a possible but unlikely mechanism for the sediment piling in the Greater Cessford Area. Hydrodynamic re-working and movement of sediments is a more plausible mechanism.

The concentration of siliciclastic sediments on the inner ramp of the Lodgepole Formation (Elrick and Read 1991) is consistent with Banff Formation deposition. Sedimentologically, the inner ramp quartzose siltstones and sandstones are very similar to those in Unit 6 of the Banff Formation. Both consist of silt- and very fine-grained sand-sized quartz grains with preserved flaser bedding. Unfortunately, most of the sedimentary structures have been destroyed by bioturbation in the quartzose siltstones of Unit 6. The location of quartzose siliciclastics along the basal Lodgepole Formation unconformity is not observed in the Banff Formation sediments of the Greater Cessford Area.

The sedimentation patterns observed in the Banff Formation (carbonate-clastic-carbonate) are also present in Chen and Webster's (1994) model. However, this model was derived for a ramp hundreds of kilometres long and evokes large scale tectonic features such as the peripheral forebulge to create these patterns. Tectonism was important for establishing the initial ramp geometry in the Greater Cessford Area but would have had minimal impact on a local scale. There is no evidence to support the presence of an offshore bank similar to the peloidal skeletal barrier of Chen and Webster (1994) in the Banff Formation.

4.3 CARBONATE-SILICICLASTIC MIXTURES

4.3.1 Introduction

Carbonate-siliciclastic mixtures and lateral transitions can be divided into two broad categories. The first are mixed sediments that result from lateral facies changes or episodic and non-episodic variations in carbonate and/or siliciclastic sediment supplies. These deposits consist of laterally adjacent carbonates and siliciclastic sediments that

are contemporaneous in space and time. The second category of carbonate-siliciclastic mixtures are attributable to temporal variations in sediment supply. These variations generate deposits consisting of carbonate and siliciclastic sediments that alternate with each other through time (Budd and Harris 1990).

On the basis of both modern and ancient examples, Mount (1984) recognized four mixing processes that generate both temporally and spatially variable carbonate-siliciclastic mixtures. These are (1) punctuated mixing, (2) facies mixing, (3) in situ mixing, and (4) source mixing. These processes act in a wide range of environments around the world and throughout a large part of the geologic record. The style of mixing in both spatially and temporally variable mixtures may be influenced by climate, tectonic setting (local scale to global plates), eustatic sea level changes, sedimentation rates, sediment sources and subsidence rates (Clemmensen 1978; Purser et al. 1987). The four types of sediment mixing will be briefly discussed below.

4.3.2 Punctuated Mixing

Mixing of sediments by rare or catastrophic, high-intensity sedimentation events is termed punctuated mixing (Mount 1984). Kreisa (1981) documented the transport of nearshore siliciclastic sediments into carbonate-dominated deeper water environments by storm-generated currents. On rimmed platforms, major storms erode reefal sediments and redeposit them landward in a siliciclastic dominated lagoonal environment. Mixing may also be initiated by storm processes through the introduction of sediment from subtidal to tidal flats environments.

Periodicity is an important factor in punctuated mixing processes. Benthic communities can become well established and generate large quantities of carbonate if the influx of siliciclastic sediments is a relatively rare event. These communities can recover rapidly when disrupted by major storm events because relatively little siliciclastic material is introduced during fair-weather conditions. This relationship has been documented on some sea-marginal fans of the Read Sea (Roberts 1987; Roberts and

Murray 1988). The depositional environment of most of these ancient deposits is in subtidal environments below fair-weather wave base (Mount 1984).

4.3.3 Facies Mixing

Facies mixing generates mixed sediments that record the lateral transition between carbonate and siliciclastic sediments (Mount 1984). These types of mixtures are relatively scarce in both modern and ancient sediments. Mixing of sediments occurs along diffuse boundaries between contrasting facies and has been documented in a wide range of environments. These include (1) fore-reef, back-reef, and inter-reef settings of reef tracts; (2) the flanks of carbonate shoal complexes that shelter siliciclastic lagoons; (3) interfingering siliciclastic tidal flats and deeper subtidal carbonates; and (4) coastal dunes and tidal flats which receive eolian contributions of a different composition than the background sediments (Mount 1984).

4.3.4 In Situ Mixing

In situ mixing refers to the formation of sediment mixtures in a local environment and does not involve a lateral facies change as does facies mixing. The most prevalent sites of in situ mixing are subtidal, terrigenous, mud-dominated environments (Mount 1984). Here, siliciclastic shelf sediments mix with carbonate material derived from autochthonous or parautochthonous death assemblages of calcareous organisms. Burrowing organisms and weak tidal or ocean currents mix skeletal material with siliciclastic sediments. Stronger currents may hydraulically separate the mud and coarser skeletal grains into shell lags that contain little or no muddy material (Larsonneur et al. 1982).

4.3.5 Source Mixing

Source mixing describes the weathering of uplifted siliciclastic terranes which supplies clastic material to the otherwise carbonate-dominated shelf environment. Owing to the importance of proximity to a siliciclastic source in this process, source mixing is most common in marginal marine and nearshore environments that are close to

exposed source terranes. Source mixing is the product of erosion, transportation and depositional processes (Mount 1984).

4.3.6 Selected Examples

4.3.6.1 Introduction

Ancient and modern examples of carbonate to siliciclastic transitions and carbonate-siliciclastic mixtures are plentiful (Early and Goodell 1968; Frey and Pinet 1978; Specht and Brenner 1979; Driese 1985; D'Alvisio and Davis 1988; Friedman 1988; Hay et al. 1988; Holmes 1988; Nittrouer et al. 1988; Pilkey et al. 1988; etc.). A few examples relevant to Banff Formation sedimentation in the Greater Cessford Area are briefly discussed below.

Shinn (1973) documented eolian quartz dunes rapidly migrating out into the sea to produce a quartz sand sabkha along the Qatar Peninsula of the Arabian Gulf. The supratidal flat is 40 kilometres long, 10 kilometres wide and up to 30 metres thick. The author believes sedimentation of this type will cease in a few thousand years, resulting in the preservation of a siliciclastic sand lens in a carbonate body.

An ancient example of this type is a Middle Pennsylvanian mixture on the western coast of the United States which consists of interbedded quartz sandstone and oolitic, bioclastic, peloidal and micritic carbonate units. One depositional phase is characterized by very rapid transgression, followed by progradational subtidal carbonate shelf to shoal conditions. A second depositional phase is distinguished by the progradation of eolian and interdune sandstones across intertidal and subtidal carbonate depositional environments. The dominant controls on the development of these cycles were sea level changes associated with Gondwanaland glaciation and subsidence of the local shelf (Driese and Dott Jr. 1984).

A second ancient example of mixed carbonate-siliciclastic sediments are the Fayetteville Shale and Pitkin Limestone in Arkansas, which are Mississippian carbonate ramp deposits. Handford (1986) identified a shoaling-upward succession that consists

of a deep muddy facies overlain by an ooid-skeletal shoal and shoreface facies. The transition zone between the two facies is characterized by thin, rhythmically bedded limestone intercalated with thin, skeletal rich shale beds. Limestone interpreted as storm deposits formed by offshore transport of the shallower water carbonates. The transition from nearshore carbonates to offshore, fine-grained siliciclastics is a common phenomenon in Paleozoic rocks.

4.3.6.2 Modern Mixed Carbonate-Siliciclastic Shelves

Two modern day examples of mixed carbonate-siliciclastic sedimentation are the Lacepede and Rottnest Shelves of Australia. Both of these shelves consist of cool water carbonates mixed with siliciclastic sediments. Modern cool water carbonates are good analogues for periods in geological history such as the Mississippian when reef-builders were absent. Terrigenous clastics, Holocene carbonates, and relict carbonate are the three main types of sediments on the Lacepede Shelf (Bone et al. 1991). Fluvial and eolian siliciclastic sediments were deposited during a period of low sea level and subsequent shelf exposure. In contrast, the Rottnest Shelf consists of relict quartz and carbonate grains that were derived from the transgressive erosion of older coastal (quartz) and shelf (carbonate) sediments during Holocene sea level rise and highstand (Collins 1988).

Six major lithofacies were recognized by James et al. (1992) on the Lacepede Shelf: (1) calcareous quartz sands and (2) quartzose bryozoa/bivalve sands, both of which are shallow shelf deposits; (3) clean bryozoa sands are deposited on the middle shelf; (4) bryozoa muds cover the deep shelf, shelf edge, and top of slope; (5) pelagic muds cover the slope proper; and (6) bivalve-coral gravels are locally deposited on the upper slope.

Facies on this open shelf are the result of four processes: (1) terrigenous clastic input from land and carbonate sediment diagenesis during sea level lowstand, (2) strandline reworking during each sea level rise, stillstand and fall, (3) modern reworking

of sediment deposited during previous highstands, and (4) Holocene seafloor production (James et al. 1992). Sediments on the Lacepede shelf are dominated by a major lobe of quartzose sand in the centre of the open shelf which was deposited during the last sea level lowstand and reworked during subsequent transgression and is continuously moved by strong waves and populated by scarce bivalves today.

The Rottnest Shelf off southwestern Australia is located in a similar oceanographic setting and facies patterns resemble those of the Lacepede Shelf. The main difference between the two shelves is the lack of fluvially transported sediments onto the shelf during sea level lowstands which provides a blanket of sediment which is subsequently reworked during highstand sedimentation. Instead, sediments on the Rottnest Shelf are distributed by northward littoral transport and wave dispersal (Collins 1988). Erosional reworking of the shelf, and sorting, rounding, and abrasion of sand-sized sediment is due to waves and wave currents.

The sediments of the Rottnest Shelf are divided into a shallower Fremantle Blanket and a deeper Rottnest Blanket. The Fremantle Blanket consists of quartz grainstone, lithoskel grainstone, and algal-bryozoan grainstone. The Rottnest Blanket sediments are angular, moderately well to poorly sorted, fine- to medium-grained skeletal sands (bryozoan grainstone and skeletal wackestone) which fine seaward to silt and clay. The Rottnest Shelf is characterized by a blanket geometry with basinward thickening and fining (Collins 1988).

In contrast to the Lacepede and Rottnest Shelves, the Otway continental margin in southeastern Australia contains only minor siliciclastic material concentrated as quartzose bivalve bryozoan gravels on the shallow shelf. Little siliciclastic material is transported to the shelf due to a lack of major drainage conduits. However, similar to the other two Australian shelves, facies form a series of broad, shore-parallel linear belts with gradational boundaries. Deposition of carbonate sediment is largely controlled by wave energy and local swell, storm and tidal current conditions (Boreen et al. 1993).

4.3.6.3 Mixed Carbonate-Siliciclastic Sedimentation in the Western Canada Sedimentary Basin

Mixed carbonate-siliciclastic sedimentation is common throughout the Western Canada Sedimentary Basin, yet little is known about the source and mechanics of its deposition. Several examples are discussed below in decreasing order of age.

Cyclic carbonate-clastic deposits in the Upper Devonian Winterburn Group record an overall shallowing and filling of the basin (Switzer et al. 1994). The Nisku Formation lies at the base of the Winterburn Group. The progradational stage of the Nisku Formation is represented by basinward building of carbonate and fine-grained clastic sediment wedges under diminishing accommodation space. Reworking of these lowstand siliciclastics during a relative sea level rise resulted in the dispersal of silts and clays that form most of the Calmar Formation. In the subsurface, the Calmar Formation consists variably of quartz siltstone, green shale, silty shale, dolomite and shallow marine carbonates which have been interpreted variously as marginal marine, coastal plain, and fluvial deltaic deposits (Gilhooly 1987).

A second example is the Graminia Silt which is the upper siltstone or sandstone of the Graminia Formation. The most probable source for the Graminia silts is detrital material originally deposited discontinuously in the basin during a preceding relative sea level lowstand. The widespread distribution of silt in the Graminia Formation is interpreted to be due to reworking of detrital and/or windblown material during transgression of the Devonian sea which led to subsequent Wabamun Group deposition (Switzer et al. 1994).

A third example is the Lower Carboniferous Mount Head Formation, part of the Rundle Group which overlies the Banff Formation. It consists of carbonates and mixed carbonate-siliciclastic rocks deposited on a high energy, westward-deepening ramp. Swells partition the ramp into three major subdivisions: (1) a shallow, wave-swept zone of carbonate production but little carbonate accumulation, (2) a middle, wave-swept

zone of significant carbonate production and accumulation, and (3) a deeper, muddy zone of significant carbonate production and accumulation (Brandley 1993).

Sabkha-related facies in the Mount Head Formation contain abundant quantities of silt and fine-grained quartz sand in a carbonate mudstone. Siliciclastic content is typically 10% but ranges from 0-70% (Brandley 1993). Brandley (1993) concluded that the majority of the siliciclastic sediment is fluvially-derived from the north and northeast with minor contributions of silt from dust storms.

The Middle Jurassic lower Gravelbourg and Reston Formations constitute a fourth example of mixed carbonate-siliciclastic sedimentation in the Western Canada Sedimentary Basin. These formations consist of a heterogeneous mixture of shallow marine sandstones, limestones and shales deposited in a complex pattern in the Williston Basin. Poulton et al. (1994) suggest that cratonic sources provided the siliciclastic sediments.

Permian strata of the Western Canada Sedimentary Basin are a fifth example, consisting of phosphatic marine siliciclastics and silty to sandy carbonates. In particular, the Belloy Formation is subdivided into an eastern assemblage of shallow marine sandstone and dolostone and a western assemblage of deeper marine limestone and siltstone. The eastern assemblage lies outside and along the margins of the Fort St. John Graben. Henderson et al. (1994) suggest that the sandstones represent shoreline-related facies developed along the basin margins and that the dolostones are proximal shallow-marine rocks. The western facies siltstones and limestones are interpreted as deeper outer shelf to slope deposits (Henderson et al. 1994).

4.3.7 Banff Formation in the Greater Cessford Area

Both temporal and spatial variations in the Greater Cessford Area are responsible for the mixed carbonate-siliciclastic deposits of the Banff Formation. Units 1 and 2 contain mixtures as a result of spatial and temporal variability. These range from lateral changes between carbonate piles and siliciclastic sediments to temporal

variations between shales and overlying silty mudstones. In Units 3-6, a lateral change from carbonate to mixed carbonate-siliciclastic sediments back into cleaner carbonate is observed. Temporal variations are evident in the deposition of quartzose siltstones within a predominantly carbonate succession where it is under- and overlain by carbonates.

Punctuated mixing in the form of high intensity sedimentation events and storm-generated currents may have been a very important process for transporting siliciclastic sediments from the inner ramp to the mid-ramp environment during the deposition of Unit 2. Storm-generated currents and other hydrodynamic forces were extremely important in transporting and distributing sediment over the carbonate ramp in all six units.

Mixed sediments generated by facies mixing along the boundaries between the medial siliciclastic belt and the two carbonate belts is clearly illustrated by log signatures but not penetrated by core in the Greater Cessford Area. These deposits would consist of silty carbonate mudstones and silty crinoidal bioclastic wackestones and packstones.

In situ mixing was a relatively minor mixing process operating on the Banff Formation ramp. Extensive bioturbation of siliciclastic sediment and macrofossils generated mixed sediments in the bioturbated mudstone and dolomitic/calcareous quartzose siltstone/sandstone lithofacies.

Source mixing was the dominant mixing process acting in the Greater Cessford Area. Siliciclastic material is interpreted to have been eroded from the craton and transported onto the ramp by both fluvial and eolian processes. Storm- and tidal-generated currents laterally transported siliciclastic material to the Greater Cessford Area.

The blanket-like geometries of the sediments on the Lacepede, Rottnest and Otway Shelves in Australia are not consistent with the unit geometries of the Banff Formation. However, the importance of wave currents in distributing both carbonate

and siliciclastic sediments in these modern environments is evident. Wave currents were extremely important in the winnowing, erosion and transportation of both carbonate and siliciclastic sediments in the Banff Formation.

Siliciclastic sediments were introduced during sea level lowstand on the Lacepede Shelf in Australia and in the Calmar and Graminia Formations of the Western Canada Sedimentary Basin. It is doubtful that the siliciclastic sediments of the Banff Formation were introduced during a lowstand because the entire Banff Formation is a shallowing-upward sequence starting from an initial transgression at the base. There is no evidence to support an exposed shelf during a sea level lowstand in the Greater Cessford Area.

4.4 SOURCE OF SILICICLASTIC SEDIMENT

4.4.1 Introduction and Background

Two types of detrital siliceous grains are commonly found in carbonate deposits (Wilson 1975). The first type consists of rounded, frosted, quartz grains from coastal dune and beach sand reworked in the shallow marine environment. Zones of these siliceous grains are widely known in the Lower Ordovician platform which is composed of shallow shelf and intertidal deposits surrounding the Canadian Shield. Siliciclastic grains have been documented in areas hundreds of kilometres from the original sandy coastlines of the large carbonate-producing sea which lay across the shield. The Persian Gulf shelf has up to 10% of such grains distributed from large sand dunes into the sea along the coast of the Qatar Peninsula (Shinn 1973). Quartz sand is so resistant that it may be widely distributed in the carbonate environment without appreciable abrasion or solution.

The second type of siliceous grains are silt-size, angular quartz and feldspars which are windblown. The Holocene sedimentary regime of the Persian Gulf is a modern day analogue, where vast dust storms in the Gulf are capable of blowing silt and clay size material a distance of 40 kilometres across the sea. A large portion of the fine

terrigenous and carbonate material of the axial part of the Persian Gulf east of the Qatar Peninsula is wind-blown (Wilson 1975).

Konopka and Dott (1983) studied alternating siliciclastic and carbonate deposition in Middle Pennsylvanian rocks in Central Utah. Very fine-grained and fine-grained quartzose siliciclastics, fossiliferous wackestones and packstones and carbonate-siliciclastic mixtures are present. Sandstone deposition is dominated by eolian processes and shallow marine currents related to the Pennsylvanian wind regime. Subaerial and marginal marine deposition is dominated by siliciclastic sands with carbonate deposition limited to open marine environments. The cyclicity is a function of glacio-eustatic sea level fluctuations, tectonically induced rapid episodic subsidence, high rate of carbonate production, and facies shifts between carbonate and clastics partly controlled by wind influenced delivery of siliciclastic sand and silt (Konopka and Dott 1983).

Permian regressive peritidal to shallow marine carbonate sequences in west Texas and New Mexico contain thin quartzose sand bodies (Mazzullo et al. 1985). A lack of diagnostic sedimentary and biogenic features makes the origin of these sands difficult to decipher. Facies relationships and comparisons with Quaternary depositional systems were used to determine that the successions are dominated by progradational eolian sheet sediments deposited on arid, wind-dominated, exposed flats adjoining deep basins. The sand bodies represent rapid rates of sand accumulation that interrupted longer periods of highstand carbonate sedimentation.

Fluvially delivered sediment to the shallow shelf or inner ramp has been documented by a number of authors in the Great Barrier Reef province of Australia (Belperio and Searle 1988) and on the North Puerto Rico shelf (Pilkey et al. 1988). Siliciclastics were also fluvially transported to the Lacepede Shelf in Australia (James et al. 1992) and the Mount Head Formation in the Western Canada Sedimentary Basin (Brandley 1993).

4.4.2 Source of Siliciclastic Sediments in the Banff Formation

All six units of the Banff Formation contain varying quantities of siliciclastic sediments. The clastic component ranges from a few scattered quartz grains to thick quartzose siltstone to sandstone successions. It is speculated that the origin of sand- and silt-sized terrigenous quartz in each of the 6 units is dominantly fluvial with significant contributions from eolian sources.

There is no evidence preserved in the Banff Formation of river deltas or channel deposits which would express themselves by the presence of clay layers, freshwater fauna and fining-upward log profiles (Shinn 1973). However, this evidence, even if initially present, has likely been eroded away.

Richards (1989) suggests that the Banff Formation received fluvially-transported silicicilastic sediment from the north and northeast during the Tournaisian. The fine-grained nature of the siliciclastic sediments suggests that they were deposited far from any tectonic highland. The northwest-trending Severn Arch and north-trending Wisconsin Arch were also important sources of clastic detritus in southern Alberta. Western-derived sediments are not common in most of the Banff Formation in southern Alberta but are important in the western domain of the Banff Formation in southeastern British Columbia (Savoy and Mountjoy 1995).

The idea of silt-sized quartz particles being transported to the edge of the Mississippian seaway by winds was first proposed by Martin (1969). Eolian processes are interpreted to have been responsible for silt emplacement in some of the muddier lithologies but the Banff Formation inner ramp was dominated by carbonate material which suggests that a significant source of siliciclastic material was not available. It seems more probable that most of the siliciclastic material was derived from the craton and transported from northern Alberta, or alternatively, introduced from areas that were being or had been glaciated and were supplying silt and clay material to eolian systems (Brandley 1993).

The source of siliciclastic sediments in the Banff Formation is difficult to verify. The siliciclastic sediments in Unit 2 may be outliers of the Bakken Formation deposited east of the Sweetgrass Arch. This would suggest an eastern source for the quartzose siltstones and sandstones documented in Unit 2. In contrast, craton-derived siliciclastic sediments from the north and northeast transported into the Greater Cessford Area by currents is a more probable source of clastics in the medial belt in Units 3-6 (Figure 4.2). Rare quartz grains were commonly blown into the muddier, nearshore lithofacies which include the pelleted mudstones to packstones and crinoidal bioclastic wackestones and packstones.

4.5 STRUCTURAL INFLUENCES ON RAMP SEDIMENTATION

The Banff Formation was deposited in a cratonic-interior basin which is a broad, persistent depression that is located adjacent to orogens (Burchette and Wright 1992). Cratonic-interior basins are characterized by slow overall rates of flexural subsidence which generates gentle depositional gradients and mostly shallow basinal water depths. The Devonian and Mississippian rocks of the Western Canada Sedimentary Basin form a series of stacked ramp sequences which constitute a major proportion of the cratonic-interior basin fill (Richards et al. 1994).

The western cratonic platform contains a broad, northeast-trending uplift in the vicinity of the Laramide Sweetgrass Arch (Richards et al. 1993). This uplift is never discussed in any detail and is rarely mentioned in the published literature. In some interpretations, the present-day Sweetgrass Arch overlaps the southeast corner of the Greater Cessford Area.

The Sweetgrass Arch is composed of three broad arches; the northwest plunging South Arch, the northwest striking Kevin Sunburst Dome, and the northeast plunging Bow Island Arch which separates the Alberta and Williston Basins (Podruski 1988). The Bow Island Arch is located in southeastern Alberta and was not a positive feature

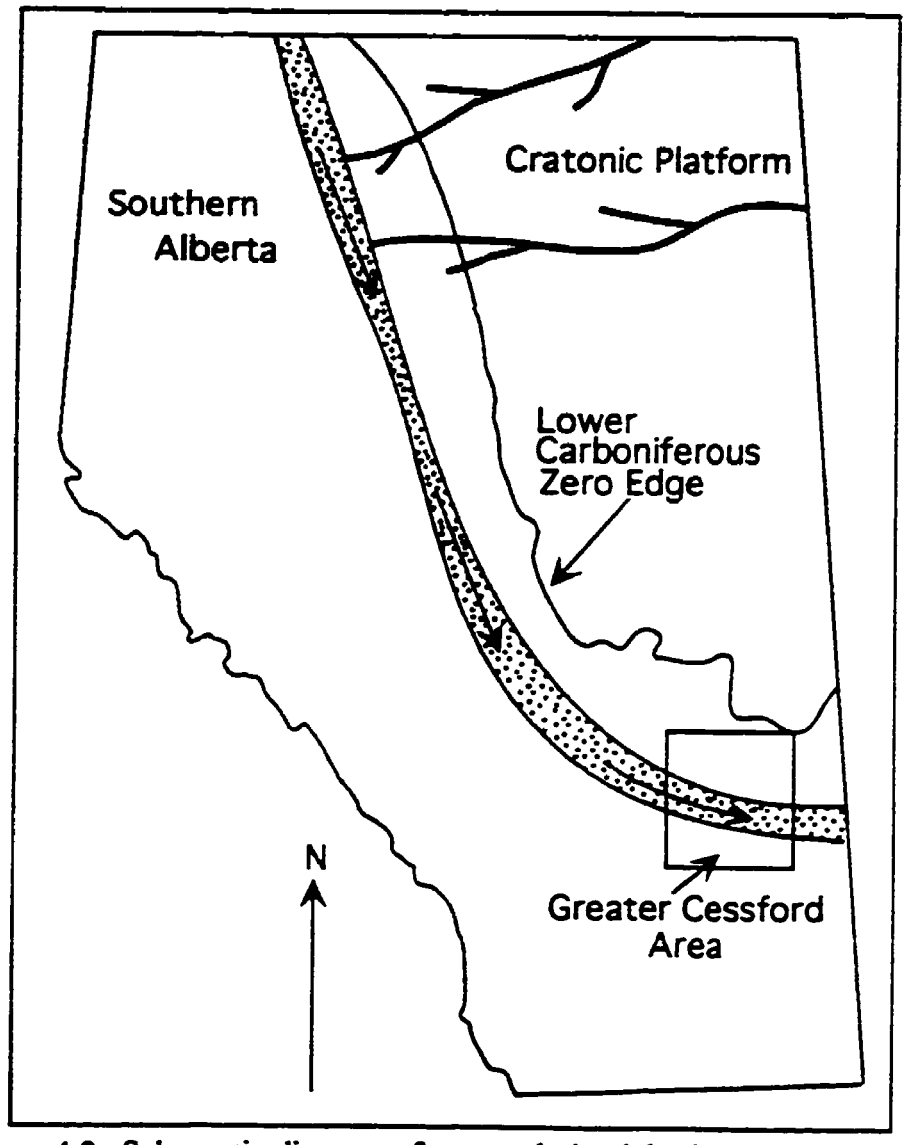


Figure 4.2. Schematic diagram of craton-derived detritus transported to a clastics belt by fluvial processes. Lateral longshore currents along the Banff Formation ramp transported the clastic sediments into the study area.

prior to the Laramide with the possible exception of the Jurassic (Hayes 1983). No major depositional or erosional thinning occurred across southern Alberta except for in the Tertiary (Podruski 1988).

Podruski (1988) suggests that the subtle facies changes that do occur within Phanerozoic strata cannot be correlated to the present Bow Island Arch and that most evidence points to only Paleogene uplift of the present Bow Island Arch relative to the Alberta and Williston Basins. The Bow Island Arch was not active during the deposition of the Banff Formation, but possible uplift during the Jurassic may have influenced diagenetic processes (Pasternack 1988; Dolson 1990).

Tectonism on a regional scale was important for establishing shallow gradients conducive to carbonate ramp sedimentation. Locally, there is no evidence of differential subsidence as there was in the Peace River Embayment as a mechanism for differential piling of sediment.

The Devonian Wabamun Group salts are widely distributed in southeastern Alberta (Meijer Drees 1986; Brown and Anderson 1990). These salts have been extensively dissolved and are preserved as isolated to contiguous remnants of varying thickness and areal extent (Anderson et al. 1990). The typical composition of the Wabamun Group in the Greater Cessford Area is approximately 38-60% salt, 21.5% dolomite, 4-20% anhydrite and <4% limestone (Halbertsma 1994).

Synsedimentary salt dissolution of underlying Wabamun sediments may have been the cause of differential sedimentation in the Banff Formation in the Greater Cessford Area. However, Oliver and Cowper (1983) propose that the dissolution of rock salts in the Wabamun Formation was initiated by regional faulting and fracturing during the mid-Late Cretaceous. The fault and fracture planes provide conduits between salt beds and adjacent aquifers which initiates leaching and subsidence. Anderson and Brown (1992) confirmed these results and suggested that dissolution was later accentuated by glacial loading and unloading.

It is difficult to demonstrate the effects of salt dissolution on Banff Formation sedimentation in the Greater Cessford Area due to sparse drilling down to the Devonian. However, previous workers have suggested that salt dissolution was initiated in the Mesozoic (Oliver and Cowper 1983; Anderson and Brown 1992) rather than in the Paleozoic and thus this mechanism was not likely the cause of differential sedimentation in the present study.

4.6 BANFF FORMATION RAMP MODEL FOR THE GREATER CESSFORD AREA

4.6.1 Introduction

Carbonate ramp development is dependent on a number of important variables: antecedent slope, water depth, climate, sediment production, composition and source, base level changes, presence/absence of framebuilders, wind direction and velocity, coastal orientation, and oceanographic regime (Ahr 1989; Burchette and Wright 1992). Sedimentation patterns are dependent on temperature, carbonate saturation, salinity, water depth, nature of water currents, light penetration, water turbidity, nature of sediment substrate, and rates of relative sea level changes (Miall 1990). Subsidence rates and water circulation patterns depend strongly on the structural setting, and, in turn, control the thickness, configuration, and content of carbonate depositional systems.

A southwest-deepening ramp profile is indicated for the Banff Formation in the Greater Cessford Area. Carbonate ramps rarely maintain a single geometry for long periods of geologic time (Carozzi 1989). There is no evidence for a sharp break in slope either from mapping or the cores in the form of turbidites, brecciation or slumping features. However, the profile of the Banff Formation ramp appears to have varied with time. The Banff Formation ramp evolved from a very low gradient sloping surface during deposition of Units 1 and 2 to a surface with a slightly inflected or curved profile

during deposition of Units 3-6, and finally into the Pekisko Formation carbonate rimmed shelf (Richards et al. 1993).

4.6.2 Climate

Paleogeographic reconstructions indicate that the Greater Cessford Area was located between 10° south and 25° north latitude during the Tournaisian (see Chapter 1) (Scotese 1984; Van der Zwan 1985; Van der Voo 1988; Witzke and Heckel 1988; Ziegler 1988; Golonka et al. 1994; Metcalfe 1994). An arid to semi-arid climate with high temperatures and low precipitation is suggested by comparison with modern analogues located in this sub-equatorial location. High levels of run-off due to a sparsely vegetated shoreline may have carried siliciclastic sediments into the carbonate ramp system. Dominant dry, offshore paleowinds were to the southwest (Parrish 1982) and strong monsoonal storms may have been frequent during the summer (Wright 1990). Storm activity was important for transporting debris and fine sediment within the carbonate ramp environment. Dominant southerly winds would have transported some silt-sized quartz sediment from the inner ramp in the northeast to the mid-ramp environment in the southwest.

4.6.3 Depositional Environments

4.6.3.1 Units 1 and 2

Unit 1 consists of shale and bioturbated mudstones deposited in an open marine setting on the mid-ramp below fair-weather wave base. Rare skeletal debris was transported in suspension by storm events from the inner to mid-ramp environment.

Unit 2 is interpreted to have been deposited in an open marine setting on the mid- to inner ramp and consists of piles of carbonate and quartzose siltstones and sandstones isolated in shale (Figure 4.3). Quartzose siltstone/sandstone and carbonate piles are isolated in shales throughout the Greater Cessford Area. On the innermost ramp, shales and argillaceous carbonates dominate. The profile of the Banff Formation carbonate ramp for Units 1 and 2 was an extremely low relief, shallowly sloping surface.

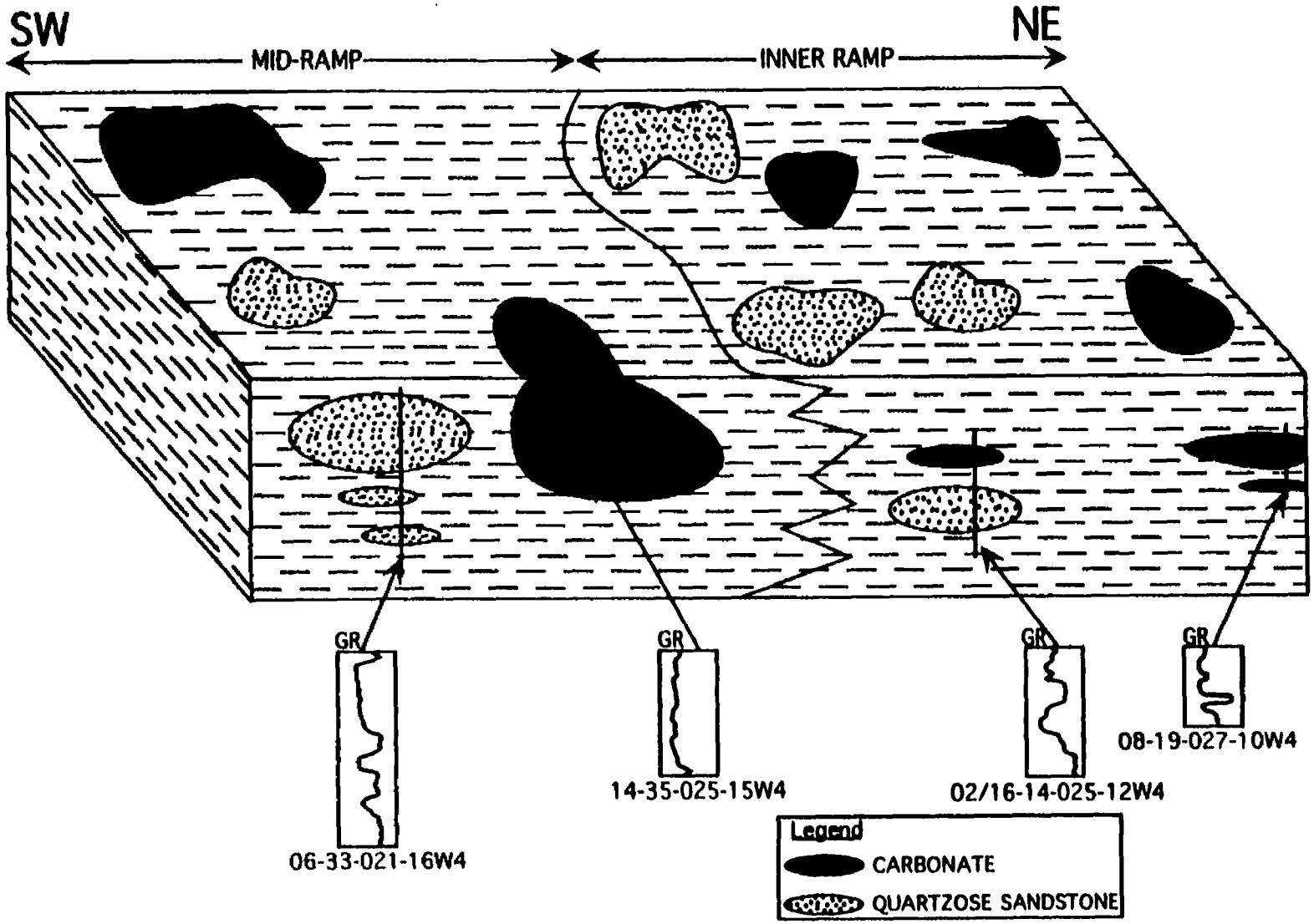


Figure 4.3. Unit 2 consists of carbonate and quartzose sandstone isolated in shale deposited in an open marine setting on both the inner and mid-ramp.

4.6.3.2 Units 3-6

In contrast to Units 1 and 2, Units 3-6 are dominated by carbonates in the southwest (seaward) and northeast (landward) parts of the Greater Cessford Area separated by a medial siliciclastic belt (Figure 4.4). The ramp profile changed between Units 2 and 3 from a uniformly sloping, low gradient surface to an inflected surface with a slightly greater gradient.

The mid-ramp sediments of Units 3-6 consist of massive bioturbated mudstones and crinoidal bioclastic wackestones and packstones deposited in quiet, normal salinity water. Fine detritus was transported from the inner ramp and deposited from suspension on the mid-ramp. Siliciclastic sediments were concentrated along the inflected portion of the ramp by bottom currents. This is discussed in more detail in the next section.

Open and restricted marine sedimentation characterizes the inner ramp deposits of Units 3-6. Pelleted mudstones to packstones and shales were deposited in restricted, shallow subtidal lagoons and open bays that were protected by a series of migratory crinoidal bioclastic packstone and grainstone barrier bars and shoals. During storm events, the shoal and bank complex was eroded by wave action and skeletal debris was transported by migrating ripples, while the finer mud was carried out in suspension to be deposited on the mid-ramp. The bioturbated mudstone and crinoidal bioclastic wackestone lithofacies were deposited in muddier, intershoal areas.

4.6.4 Siliciclastic Sediments

4.6.4.1 Distribution of Siliciclastic Sediments

Determining the source of the abundant siliciclastic sediments in the Banff Formation is problematic. Siliciclastic sediments are present in Unit 2 as quartzose sandstones and siltstones. Quartzose siltstones and sandstones are distributed in piles isolated in shale throughout the Greater Cessford Area. The dominance of carbonate in the innermost ramp sediments located in the northeast quadrant and the presence of

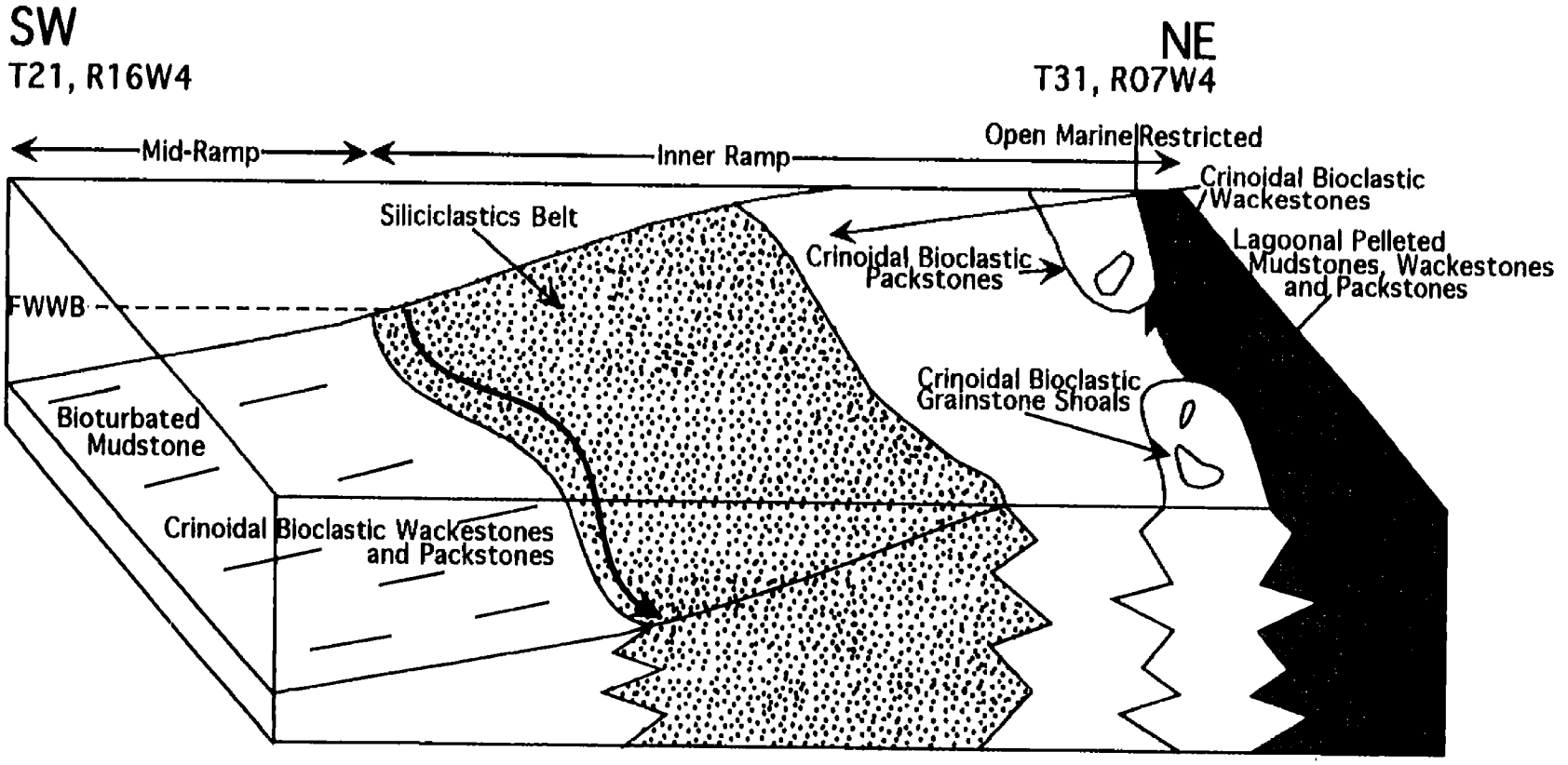


Figure 4.4. Block diagram of the mid- and inner ramp depositional environments showing relationships between the lithofacies in Units 3-6 of the Banff Formation. A medial siliciclastics belt deposited on the inner ramp separates mid-ramp bioturbated mudstones and crinoidal bioclastic wackestones and packstones from inner ramp crinoidal bioclastic grainstone and packstone shoals, lagoonal pelleted mudstones to packstones and shales, and intershoal crinoidal bioclastic wackestones. Longshore currents and other hydrodynamic processes were extremely important in the transportation and piling of sediments in the ramp environment.

quartzose siltstones/sandstones with flaser bedding on the east side of the Greater Cessford Area suggest that the siliciclastic sediments in Unit 2 were derived from the east. A fundamental change in the direction of the source of siliciclastics and the hydrodynamic regime between Unit 2 and Units 3-6 is suggested by the change from lithological piling in Unit 2 to a concentration of clastic sediment in a west-northwest to east-southeast oriented belt in Units 3-6.

The sedimentation of siliciclastics in a medial belt in Units 3-6 could be due to differential tectonism, the development of a physical barrier, or a subtle change in the ramp profile. Differential tectonism creates a series of highs and lows into which siliciclastic sediments are concentrated and is usually discussed in a regional sense. No evidence of tectonism of this kind is indicated for the Greater Cessford Area. The second possibility involves the trapping of siliciclastic sediment behind or in front of some sort of physical barrier. No evidence from mapping, cores or logs supports the presence of a physical barrier. A subtle change in the profile of the Banff Formation carbonate ramp is interpreted to be the mechanism which concentrated clastic sediments into the medial belt.

4.6.4.2 Sediment Movement Mechanisms and Bottom Currents

Hydrodynamic piling, reworking and distribution of sediments was an extremely important process for all six of the Banff Formation units, and Unit 2 in particular. It appears that none of these units aggraded to a single base level and thus did not develop a horizontal, platform surface. Wilson (1975) recognized piling of carbonate sediment by mechanical movement as an accessory process that forms and shapes carbonate accumulations. The volume of sediment preserved is a function of the production rate plus stabilization and piling processes, minus any removal processes operating. Each unit of the Banff Formation appears to fill in the surface left by the deposition of the previous unit. This results in thicker piles of sediment overlying thinner piles on the underlying layer.

The roles of long-shore currents in transporting material laterally from one area to another in the offshore zones of carbonate ramps, or of storm-generated currents in transporting material from the shoreline to the mid- or outer-ramp are largely unevaluated (Burchette and Wright 1992), but are potentially of major importance in the Greater Cessford Area. Storm-generated currents and waves are interpreted to have moved large quantities of siliciclastic material on the Banff Formation carbonate ramp.

The siliciclastic belt in Units 3-6 is interpreted as a series of bottom current deposits distributed along a slight inflection on the inner ramp. A contourite is any contour-current deposit and usually consists of fine sand or coarse silt deposited on the continental rise by contour following bottom currents (Bates and Jackson 1980; Hollister 1990, 1993). Contourites are generally well sorted, normal or reversed graded, and have sharp upper and lower contacts (Faugeres and Stow 1990; Shanmugam et al. 1993).

The original definition of sediment deposited from thermohaline driven bottom currents flowing parallel to bathymetric contours has been used in the literature to include any bottom current derived sediments deposited not only in the deep marine realm, but also in the shallow marine and lacustrine environments (Faugeres and Stow 1993). Faugeres and Stow (1993) suggest that the term "contourite" should be restricted to deep water (>500 metres) sediments deposited or significantly reworked by stable geostrophic currents, and that the term "bottom current deposits" be used for shallower water deposits. Currents in shallow waters have originated from a number of sources including internal waves and tides, wind, and fluvial driven lacustrine currents (Faugeres and Stow 1993).

Many of the sedimentological characteristics of the Banff Formation quartzose siliciclastics match the criteria utilized for identifying bottom current deposits: (1) composed predominantly of silt, (2) sharp upper and lower contacts, (3) well sorted, (4) inverse size grading (coarsens-upward), and (5) flaser bedding. Diagnostic sedimentary

structures such as cross-bedding, lenticular ripples, and current ripples may have been destroyed by intensive bioturbation.

4.7 SUMMARY

The Banff Formation in the Greater Cessford Area represents deposition on a southwestward-prograding carbonate ramp. The profile of the carbonate ramp is interpreted to have evolved from a low gradient slope onto which Units 1 and 2 were deposited into a surface with a subtle inflection or bend in its vertical profile. A medial siliciclastic belt separated by two carbonate belts was concentrated along this margin by lateral bottom currents. The Banff Formation ramp was succeeded by the rimmed shelf deposits of the Pekisko Formation.

The source of siliciclastic sediment in Unit 2 is speculated to be from the east. In contrast, the large influx of siliciclastic sediments in Units 3-6 are derived primarily from the craton in the north and northeast, augmented by eolian sources. Longshore currents and storm processes transported and concentrated clastics along the inflection belt of the Banff Formation carbonate ramp. Hydrodynamic piling of sediment was an important process in all six units, but especially in Unit 2 where carbonate and quartzose sandstone piles are isolated in shales.

CHAPTER 5: DIAGENESIS

5.1 INTRODUCTION

The purpose of this chapter is to describe and interpret the diagenetic fabrics and textures observed in the lithofacies of the Banff Formation. The role that organisms, cementation, dissolution, replacement, neomorphism, and physical compaction play are amalgamated at the end of the chapter into a paragenetic sequence. The extent to which diagenesis controlled the reservoir characteristics of the dolomitic/calcareous quartzose siltstone/sandstone and crinoidal bioclastic grainstone lithofacies is discussed in Chapter 6 (Petroleum Geology).

Analysis of diagenetic processes in the Banff Formation was not the main objective of this study. The diagenetic processes and products discussed in this chapter are based on core work as well as thin section and scanning electron microscopy. Further work in the form of cathodoluminescence and isotopes is required to substantiate the findings of this chapter.

The sedimentology of the residual deposits associated with the post-Mississippian unconformity, as well as the Detrital and Ellerslie Formations is discussed. In addition, diagenetic effects associated with the unconformity are considered.

5.2 BIOLOGICAL DIAGENESIS

Bioturbation of unlaminated sediments by organisms is a very early or penecontemporaneous process associated with the accumulation and deposition of sediments. Moderate to intensive bioturbation is common in all of the lithofacies with the exception of the shales, which are not bioturbated to only partially so. Evidence of bioturbation in core and thin section is provided by a mottled appearance (Plate 1c),

swirled distribution of lithologies (Plate 3a, c, d), and disrupted sedimentary structures (Plate 5b).

Allochems from the grain-supported lithofacies commonly have micritic envelopes around their exterior wall (Plate 10a). Grain micritization occurs in poorly agitated or stagnant water conditions when allochems are repeatedly bored by endolithic algae or fungi and the borings later infilled by fine sediment (Tucker and Wright 1990).

5.3 CEMENTS

Five types of cement are preserved in the lithofacies of the Banff Formation. These are: (1) syntaxial overgrowth calcite, (2) isopachous, bladed calcite, (3) equant, finely to coarsely crystalline calcite, (4) blocky dolomite, and (5) polycrystalline quartz.

5.3.1 Syntaxial Overgrowth Cement

Syntaxial overgrowths commonly occur in the crinoidal bioclastic packstone to grainstone lithofacies, predominantly on echinoderm fragments (ossicles, plates and spines in that order), but also on brachiopod and other skeletal fragments (Plates 9a; 10b). The syntaxial overgrowths are inclusion-free and coarsely to very coarsely crystalline calcite. Overgrowths tend to form on grains that do not have micritic envelopes.

Tucker and Wright (1990) propose that syntaxial overgrowths are the product of a marine or shallow burial environment where cements were precipitated from seawater circulating through interconnected, interparticle pores.

5.3.2 Isopachous Bladed Calcite Cement

An isopachous, bladed, occasionally iron-rich, pyramidal calcite cement fringe is commonly present along the edges of allochems and around the interior of internal cavities (Plates 3d; 9c and d; 10b and c). The crystals form perpendicular to grain surfaces and are equigranular for any particular thin section. The isopachous calcite

cement commonly overgrows the syntaxial overgrowth cement which suggests that it is the later cementation phase (Plate 9a, c).

The isopachous, bladed calcite cement is commonly developed in the grain-supported lithofacies. It may also crystallize around rare skeletal fragments in the crinoidal bioclastic wackestone lithofacies. These lithofacies are the product of a moderate- to high-energy environment where reworking and winnowing by wave agitation and currents was constant. Seawater is forced into the sediment by waves, tides, and currents, resulting in the passage of sufficient oversaturated pore water to precipitate cement on grains. The relatively rapid formation of these cements with shallow burial essentially eliminates the occurrence of physical compaction (Heckel 1983).

Evidence for a marine source for the bladed calcite cement is provided by its formation of isopachous fringes around grains and cavity walls and its succession by sparry calcite in all cases (Tucker and Wright 1990; Tucker 1991).

5.3.3 Equant Finely to Coarsely Crystalline Calcite Cement

The most dominant cement consists of equant, finely to coarsely crystalline, well cleaved calcite cement (Plates 9a-d; 10a-c). This generation of calcite cement commonly accounts for 75-100% of the total cements in a given sample. Calcite grains are typically 35-50 micrometres long and commonly increase in size towards the centre of infilled cavities. Equant, blocky cement crystallizes in interskeletal and intraskeletal pores. This generation of calcite cement generally occludes any primary porosity.

The equant calcite cement is a first generation cement in the crinoidal bioclastic wackestone and pelleted wackestone lithofacies. In contrast, this equant cement succeeds both the calcite overgrowth and fringe cements in the crinoidal bioclastic packstone to grainstone lithofacies. Ghost fabrics are generated by the replacement of echinoderm fragments in grainstones.

PLATE 10-DIAGENETIC FEATURES

A) A crinoidal bioclastic grainstone consists of skeletal fragments and two generations of calcite cement. Isopachous fringe calcite cement has crystallized along skeletal grain edges and coarsely crystalline calcite cement has infilled intergranular voids. Micritic envelopes are commonly developed around skeletal fragments. (1174.85 metres, 06-22-026-16W4, Unit 6, plane-polarized light).

B) Syntaxial overgrowth cement is well developed on fragmented crinoids in this photomicrograph of a crinoidal bioclastic grainstone. Isopachous fringe and coarsely crystalline calcite cements are also present. Note increasing calcite crystal size towards void centres (especially in leached out shell just left of centre of photomicrograph). (1121.47 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

C) Two well developed generations of calcite cement are present in this crinoidal, bioclastic grainstone. The first generation consists of a pyramidal, isopachous fringe cement which crystallized along the edges of allochem fragments. A second, coarsely crystalline calcite cement infills intergranular spaces and other voids and commonly increases in grain size towards the centre of these voids. (1126.00 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

D) Microcrystalline quartz has replaced almost all echinoderm and other skeletal fragments in this crinoidal, bioclastic grainstone. Megaquartz cement infills the central void and succeeds a fibrous fringe of chalcedony cement. Quartz grain size increases towards the void centre. (1168.63 metres, 06-22-026-16W4, Unit 6, crossed polars light).

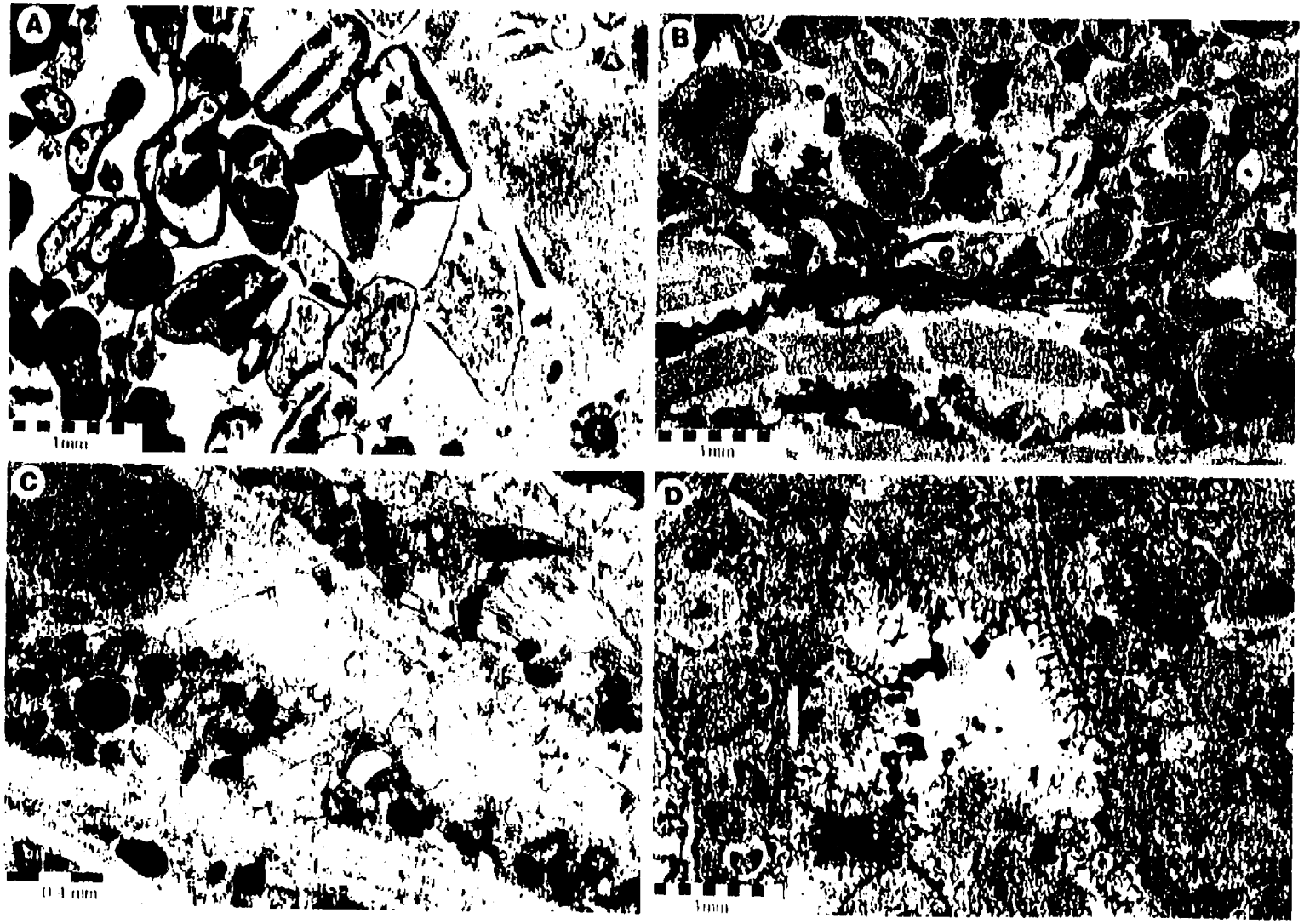


PLATE 10

Precipitation of equant, calcite cement is interpreted to be in the meteoric phreatic zone as indicated by the larger crystal size and clear, blocky crystals low in iron (Tucker 1991).

5.3.4 Blocky Dolomite Cement

Blocky, subhedral dolomite rhombs locally crystallize in intercrystalline pores and fractures which cross-cut allochems and cement in the crinoidal bioclastic grainstone lithofacies. Dolomite rhombs range from 15-60 micrometres long.

This generation of cement post-dates any matrix dolomitization and is a product of the burial environment. Dolomitizing fluids may have been generated during compaction of matrix dolomites (Tucker 1991).

5.3.5 Quartz Cement

Microquartz, megaquartz and chalcedonic quartz cements are the least abundant of the five cements. Microquartz has crystallized in skeletal pores and tectonic fractures. Megaquartz cement infills voids and locally succeeds a fibrous fringe of chalcedony cement. Grain size commonly increases away from the allochem wall and towards the centre of the void (Plate 10d).

The quartz cements are the last to crystallize of the five cement varieties. Evidence for this is provided by the crystallization of quartz in fractures which cross-cut all pre-existing fabrics.

Locally, chalecedony and megaquartz have almost completely silicified a crinoidal bioclastic grainstone bed. Chalcedony cements were preserved between skeletal grains and along the walls of shell interiors. Megaquartz infilled voids and replaced portions of skeletal fragments. Quartz has cemented and replaced approximately 95% of the rock (Plate 10d).

5.4 DISSOLUTION

The partial or complete removal of unstable carbonate material is an extremely important process in the alteration of pores in both the crinoidal bioclastic grainstone and dolomitic/calcareous quartzose siltstone to sandstone lithofacies (Plate 6a-d). Both the creation of new pore space and the enlargement of existing pore space result. In addition to the lithofacies just described, some evidence of dissolution along fractures is noted in the other lithofacies.

Partially and completely leached cements, leached shell interiors, vugular and oversized pores, as well as corroded grain edges when examined under the scanning electron microscope are evidence of dissolution (Plate 4d). Irregular distribution of the bladed, isopachous cement in some lithofacies may also be a consequence of dissolution.

5.5 REPLACEMENT

Replacement of portions of echinoderm and other skeletal fragments, as well as leached cements is prevalent in many of the lithofacies. The timing of replacement processes relative to other diagenetic processes is very difficult to determine.

5.5.1 Dolomite Replacement

Microcrystalline to very finely crystalline, unimodal, planar, subhedral to euhedral dolomite rhombs are typically 45 micrometres long and have inclusion-rich centres which contrast with relatively clear crystal exteriors. Dolomite has replaced the micrite matrix in many of the Banff Formation lithofacies and extends into the original pore space.

5.5.2 Silica Replacement

Three varieties of silica replacement are preserved in the Banff Formation lithofacies. These are (1) megaquartz, (2) microcrystalline quartz, and (3) chalcedonic quartz. Echinoderm ossicles are commonly replaced by green megaquartz and microcrystalline quartz, and more rarely by fibrous chalcedony in the crinoidal bioclastic

and pelleted wackestone to packstone lithofacies (Plate 9a, d; 10d). Quartz replacement of skeletal fragments ranges from 0-80% with 20% replacement typical.

5.5.3 Hematite Replacement

Hematite replacement is restricted to the uppermost few metres of the Banff Formation and is observed within the crinoidal bioclastic wackestone to packstone and bioturbated mudstone lithofacies. It appears as a reddish uniform to patchily distributed stain (Plate 2d; 5c). An alternative pattern of hematite replacement is the staining of thin horizontal layers and laminae a reddish maroon. Red zones range in thickness from several millimetres to metres and alternate with green weathering rocks of the same lithofacies. Red and purple colours are due to the presence of ferric oxide or hematite as grain coatings and intergrowths with clay particles (Moore 1989).

Only 0.1% iron is needed to impart a bright red colour to sediments (Tucker 1991). This alternating red to green weathering suggests that changing sea levels placed the sedimentary succession in alternating oxidizing and reducing conditions in a restricted lagoonal environment. During relative sea level highs, good circulation would induce a well-oxygenated environment which favours the precipitation of hematite. In contrast, low sea level stands with restricted water circulation would create reducing conditions which produced the green zones. The green colour develops from the reduction of hematite by migrating pore waters (Tucker 1991).

Boreski (1978) recognized this alternating red and green weathering in the Banff Formation west of the Greater Cessford Area. He suggests that the red and green weathering could have taken place at or near the water table soon after deposition or during emergence and subaerial weathering. Oxidation of iron to hematite would have taken place above the water table and the reduction of iron oxide would have occurred below the water table. Iron in its more soluble ferrous state could be incorporated into clays and impart a green colour to the sediment which would result in the same alternating red and green weathering.

5.5.4 Pyrite Replacement

Evidence for pyrite mineralization includes rusty weathering, the presence of disseminated pyrite specks, and the occurrence of euhedral pyrite crystals. Pyrite mineralization is commonly encountered in the bioturbated mudstone, dolomitic/calcareous quartzose siltstone/sandstone, crinoidal bioclastic wackestone to packstone, and crinoidal bioclastic grainstone lithofacies. Pyrite is indicative of reducing conditions in a somewhat dysaerobic environment (Greensmith 1989).

5.5.5 Hydrocarbons

Hydrocarbons in the form of bituminous residue and oil stain occur predominantly in the dolomitic/calcareous quartzose siltstone/sandstone and crinoidal bioclastic grainstone lithofacies. Hydrocarbons tend to accumulate along fractures and in stylolites (Plate 11a). Podruski et al. (1988) estimate that the migration and entrapment of hydrocarbons in the Banff Formation occurred in the late Cretaceous to Tertiary.

5.6 NEOMORPHISM

Neomorphism was an important process in the bioturbated mudstone and pelleted mudstone lithofacies. Aggrading neomorphism yielded a mosaic of microspar crystals (5-10 micrometres long) and coarser pseudospar crystals (>30 micrometres long) (Plate 11b). The presence of skeletal debris floating in coarse spar also indicates neomorphism. Neomorphism may have taken place during early meteoric or burial diagenesis. Alternatively, but less likely, neomorphism may be the result of weathering (Tucker and Wright 1990).

Micrite crystals are observed in the pore space of the dolomitic/calcareous quartzose siltstone/sandstone lithofacies at high magnification. Since this lithofacies lacks any micritic matrix, the micrite must have been sufficiently lithified at the time of sediment accumulation to escape removal by currents. It is impossible to determine if

PLATE 11-DIAGENETIC FEATURES

A) A bitumen filled fracture cross-cuts the calcareous quartzose siltstone lithofacies. (1077.10 metres, 16-06-025-08W4, Unit 3, plane-polarized light).

B) Neomorphozed, bioturbated, silty mudstone consists of micrite pockets within a wholly recrystallized micro and pseudospar rock. (1045.20 metres, 02/16-14-025-12W4, Unit 6, plane-polarized light).

C) Microsutured boundary between two echinoderm fragments in a crinoidal, bioclastic packstone. (1086.59 metres, 02/06-15-029-10W4, Unit 5, plane-polarized light).

D) Subhorizontal fracturing creates <1% porosity in the dolomitic quartzose siltstone lithofacies. (1134.00 metres, 14-35-025-15W4, Unit 6, plane-polarized light).

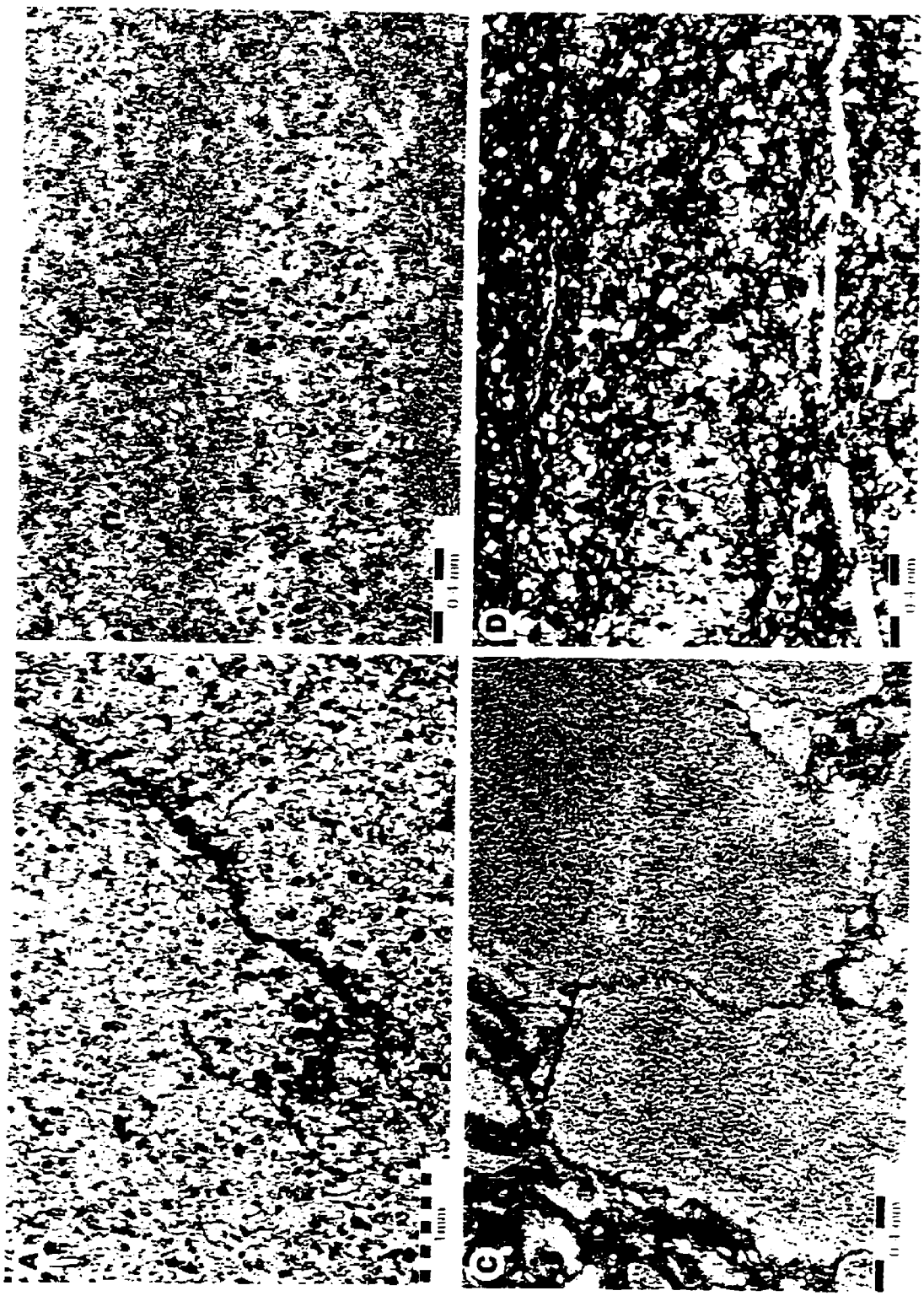


PLATE 11

the lithification of micrite was due to the precipitation of microcrystalline cement or resulted from the neomorphism of lime mud.

5.7 STYLOLITES AND OTHER PRESSURE SOLUTION FEATURES

Horizontal, sutured and non-sutured stylolites cut across allochems, matrix and cement in all of the grain-supported lithofacies. Rare microsutured boundaries are locally observed between echinoderm fragments (Plate 11c). In the muddier lithofacies, smooth, undulose and anastomozing dissolution seams of insoluble residue are present. Flaser bedding is locally preserved in core in the dolomitic/calcareous quartzose siltstone/sandstone lithofacies (Plate 5b).

Stylolites and dissolution seams are the product of pressure solution in the burial environment due to chemical compaction (Tucker 1991). Pressure solution is the volume reduction of a rock by dissolution processes resulting from uniaxial, linear compressive stresses due to overburden pressures. Less soluble green and black clays, pyrite, and hydrocarbons commonly accumulated along stylolitic boundaries as more soluble carbonate sediments were dissolved and removed (Reijers and Hsu 1986).

5.8 PHYSICAL COMPACTION

Fracturing and rare compacted (collapsed and/or broken) skeletal fragments in thin section are evidence for physical mechanical compaction. For the majority of the rocks in the Banff Formation, compaction was not a major process as illustrated by the preservation of delicate fossils and lack of overpacking of grains. The presence of one to three cement generations that completely occluded pore space provided a rigid framework that was resistant to compaction.

Late tectonic fractures attributed to burial or exposure on the unconformity surface cross-cut existing allochems, matrix and cement (Plate 11d). These fractures are

often filled with calcite, dolomite, or quartz, while others are unfilled or only partially occluded with cement linings.

5.9 PARAGENETIC SEQUENCE

A complex series of diagenetic processes in a variety of depositional and post-depositional environments has created an intricate diagenetic fabric with considerable overprinting. Every Banff Formation lithofacies was deposited in the marine realm. Some were exposed to subaerial and meteoric diagenetic processes before being compacted and buried, while others were buried directly from the marine realm itself.

A tentative paragenetic sequence is presented in Figure 5.1. The earliest diagenetic processes were bioturbation and boring concurrent with or soon after deposition of the original sediments. This was followed by cementation in the marine zone, commonly followed by cementation in the meteoric phreatic zone and then compacted. Dissolution and dolomitization were important diagenetic processes in the creation of secondary porosity. The final diagenetic event was the emplacement of hydrocarbons. Dissolution, physical compaction, pressure solution, neomorphism and replacement by several different minerals were diagenetic processes that were ongoing throughout the history of the sediment.

5.10 SEDIMENTATION AND DIAGENESIS ASSOCIATED WITH THE POST-MISSISSIPPIAN UNCONFORMITY

5.10.1 Introduction

Permian, Triassic, and Jurassic sediments have all been removed by erosion in the Greater Cessford Area. As a result, a series of heavily weathered residual sediments separate the Banff Formation from the overlying Detrital and Ellerslie Formations. These deposits are picked as either the top of the Banff Formation or the base of the Detrital Formation. For the purposes of this study, the residual sediments are referred

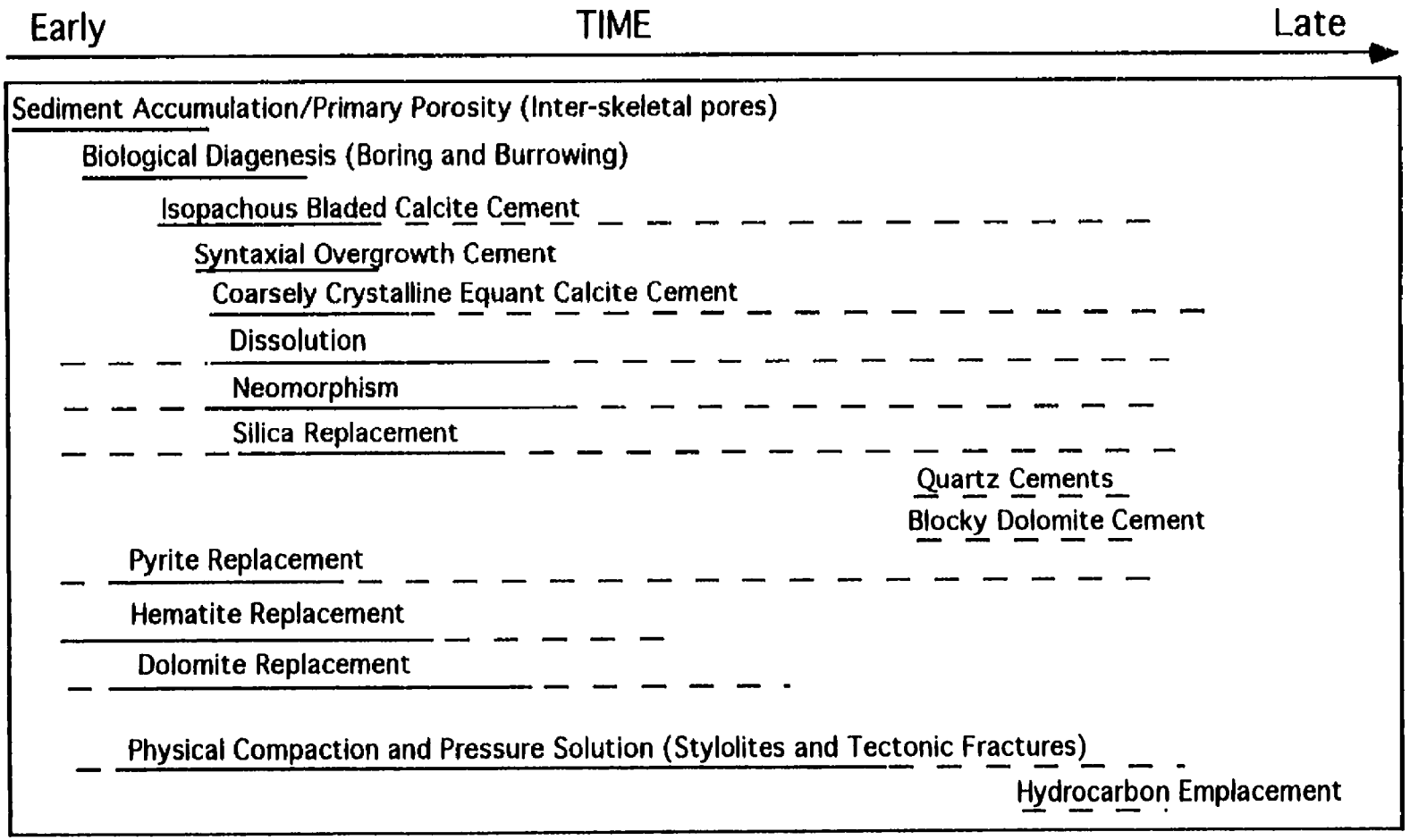


Figure 5.1. Paragenetic sequence for the Banff Formation.

to as a "transition" or "altered" zone between the carbonates of the Banff Formation and the breccias of the Detrital Formation or silty sandstones of the Ellerslie Formation.

5.10.2 Sub-Unconformity Banff Formation Residual Deposits

The transition zone between the Banff Formation and the overlying Lower Cretaceous sediments consists of heterogeneous green (dominant colour), red and orange weathering shales with tripolitic chert clasts of millimetre- to centimetre-scale length. Chert clasts generally account for 10-15% of the bulk rock composition. The interiors of the clasts are either featureless, mottled, or have developed Liesegang rings. Alternatively, the transition zone consists of a heterogeneous, light green mudstone with subhorizontal, continuous and discontinuous, millimetre-scale, dark green shale laminae.

Parts of the transition zone are intensively bioturbated. Slickensides are developed in shalier parts of the interval. Scattered skeletal fragments in highly variable proportions consist predominantly of crinoid ossicles and spines, as well as brachiopod shells. Locally, crinoidal grainstone and microcrystalline carbonate clasts from the underlying Banff Formation are dispersed in the shale and mudstone lithologies. Some of these clasts have vugular pores.

The transition zone is commonly fragmented and the contact with the upper Banff Formation is rarely preserved. Where it is preserved in two cores, the contact is marked by either (1) a series of cracks or fissures where green shale is penetrating into the underlying Banff Formation in one (Plate 12a), or (2) a sharp contact in the other. The top of the Banff Formation is readily identified in core by the dramatic lithology change from green shales and mudstones to a white to gray carbonate rock.

The transition zone is present wherever the siliciclastic Detrital and/or Ellerslie Formations directly overlie the Banff Formation instead of the carbonates of the Pekisko Formation (example Figure 2.15). The transition zones examined in core were 2-6 metres thick and commonly overlay the crinoidal, bioclastic grainstone lithofacies. Less

PLATE 12-TRANSITION ZONE, DETRITAL AND ELLERSLIE FORMATIONS

A) Green shale penetrates underlying light brown gray, crinoidal, bioclastic wackestone at the top of the Banff Formation through a series of cracks. (1167.86-1168.03 metres, 06-22-026-16W4, Unit 6).

B) DETRITAL FORMATION. A medium green-gray shale contains scattered tripolitic chert clasts and skeletal fragments. (1165.19-1165.36 metres, 06-22-026-16W4, Unit 6).

C) DETRITAL FORMATION. Maroon weathering shales contain opaque white chert clasts. Development of Liesegang rings in a central chert clast is due to rhythmic precipitation within a fluid saturated rock. (4464'4''-4462'2'', 10-32-028-16W4, Unit 6).

D) ELLERSLIE FORMATION. The Ellerslie Formation commonly consists of massive, light gray, well sorted, silty sandstones as pictured here. (1158.39-1158.52 metres, 06-22-026-16W4, Unit 6).

Note: Coin is 21 millimetres in diameter.

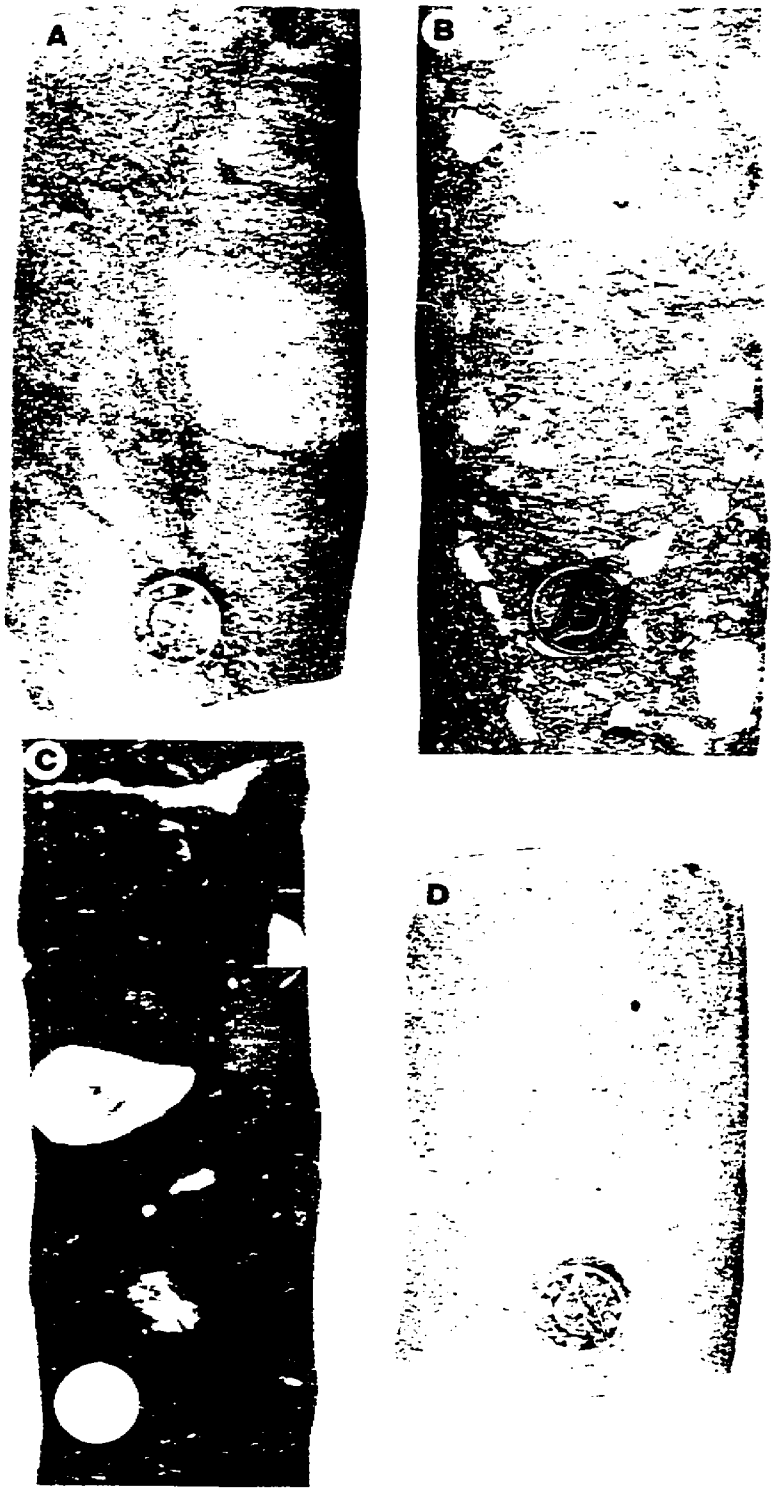


PLATE 12

commonly, the transition zone overlies the bioturbated mudstone and crinoidal, bioclastic wackestone to packstone lithofacies.

The transition zone is the product of heavily subaerially reworked terrigenous material derived from the craton and carbonate material derived from the underlying Banff Formation. This material was deposited in depressions on top of the Banff Formation unconformity surface.

5.10.3 Detrital Formation

The Detrital Formation consists of a heavily weathered green breccia with matrix- supported, opaque, white, leached, microporous, tripolitic chert clasts ranging from millimetre-length to widths in excess of the width of the core (Plate 12b, c). The matrix is composed of frosted quartz grains floating in silty shale. Rare scattered skeletal fragments are dominated by crinoids and brachiopods. Slickensides, rusty, red and maroon weathering, green shale laths, discontinuous fractures and Liesegang rings in chert clasts are commonly present. Alternatively, the Detrital Formation consists of a light gray brown breccia composed of tripolitic chert clasts in an opaque, kaolinitic white clay matrix.

The Detrital Formation ranges from 0-40 metres thick (averages 20 metres thick) in the Greater Cessford Area (Poulton et al. 1994). In the cores examined, it varied from 1-11 metres thick. The Detrital Formation was deposited on top of the Pekisko Formation in the southwest portion of the study area and is not present in the northernmost central part of the Greater Cessford Area.

The Detrital Formation has an irregular distribution, being restricted to depressions on the pre-Cretaceous erosional surface (Glass 1981). The patchy distribution is consistent with an origin as largely craton-sourced, little transported terrigenous material deposited in topographic lows. Paleosols may have formed on topographic highs. The distribution of the Detrital Formation suggests preservation partly in pre-existing ancient valley systems (Poulton et al. 1994).

5.10.4 Ellerslie Formation

The Ellerslie Formation overlies the Detrital Formation and is a massive, brown-gray, fine-grained silty sandstone in the Greater Cessford Area (Plate 12d). It is a well-sorted sediment consisting of subangular quartz grains in a white clay matrix. Rare tripolitic chert clasts ranging from millimetre- to centimetre-scale commonly have Liesegang rings. Locally, larger chert clasts have been leached. Rare skeletal fragments are incorporated into the base of the Ellerslie Formation. Patchily distributed rusty weathering and sub-vertical fracturing are commonly present.

The Lower Mannville was deposited over the entire Greater Cessford Area and is approximately 20-40 metres thick (Hayes et al. 1994). The Ellerslie Formation is up to 10 metres thick in the cores examined. The Ellerslie Formation is conformably overlain by the Ostracod Zone and underlain by the Detrital Formation (Glass 1981).

The Ellerslie Formation silty sandstones are the product of northward flowing rivers occupying a network of incised valley systems. Fluvial Ellerslie Formation and associated Lower Mannville Group strata accumulated in the valleys, while the intervening highlands remained emergent. Much of the Ellerslie fill is interpreted to have been deposited under brackish water conditions by Hayes et al. (1994). Quartzose sediments were supplied to the valley systems from the Precambrian Shield.

5.10.5 Diagenesis

Diagenesis related to the post-Mississippian unconformity is restricted to silica and hematite replacement within the uppermost few metres of the Banff Formation, as well as in the transition zone and Detrital Formation.

In contrast to the megaquartz, microquartz, and microcrystalline quartz replacement in the Banff Formation, silica replacement is in the form of white, Tripolitic chert nodules in the transition zone and Detrital Formation sediments. The Liesegang rings in the chert clasts are the product of rhythmic precipitation within a fluid-saturated rock prior to clast incorporation into the Banff Formation transition zone

rocks. Fluid flow may have been localized through joints or other fracture-related features (Miall 1990).

The most visible change is the red and green colouration of the transition zone and Detrital Formation sediments. The mechanisms for this colour pattern have been discussed in the hematite replacement section.

Dolomitization and dissolution of the Banff Formation lithofacies were likely enhanced by proximity to the post-Mississippian unconformity. Unfortunately, no simple relationship could be derived between these two diagenetic processes and proximity to the unconformity from this cursory study of diagenetic textures and processes.

5.11 SUMMARY

Diagenesis of the Banff Formation included the processes of (1) conversion of lime mud to mudstone, (2) primary and secondary porosity development, (3) marine, meteoric and burial cementation, (4) dolomitization, (5) mineral replacement, (6) stylolitization, and (7) fracturing. The effects of these diagenetic processes on reservoir characteristics are discussed in the following chapter.

The post-Mississippian unconformity is overlain by a series of residual deposits which include the Banff Formation transition zone and the Detrital Formation. These, in turn, are overlain by the Cretaceous silty sandstones of the Ellerslie Formation. Diagenesis related to the unconformity is restricted to silica replacement in the form of chert clasts and hematite replacement which imparts a red and green colour to the sediments. Proximity of upper Banff Formation sediments to the post-Mississippian unconformity may have enhanced dissolution and dolomitization processes.

CHAPTER 6: PETROLEUM GEOLOGY

6.1 INTRODUCTION

It has been estimated that Lower Carboniferous rocks account for 18% of the total initial in place oil reserves in the Western Canada Sedimentary Basin (Podruski et al. 1988). Most of these reserves are located in the Pekisko and Turner Valley Formations along their respective subcrop edges in unconformity traps. The majority of Lower Carboniferous reserves are in such subcrop pools. Structural and stratigraphic traps are of secondary importance.

Carboniferous reservoirs are typically grainstones and packstones that were dolomitized during several periods of erosion. Seals are variably provided by cementation at the upper Carboniferous unconformity or by restricted marine, subtidal to supratidal carbonate-evaporite successions that commonly cap each Carboniferous cycle. Deep-water source rocks are located below and down-dip from oil pools and it is estimated that migration and entrapment occurred in the late Cretaceous to Tertiary (Podruski et al. 1988). The deep water shales of the Exshaw and Banff Formations are possible source rocks for overlying Carboniferous successions. All of the Carboniferous pools have associated gas.

Podruski et al. (1988) established three play types for the Banff Formation on the Alberta Shelf. The first play type includes all pools in the Banff Formation in structural and combination stratigraphic-structural traps and extends across Southern Alberta from the Sweetgrass Arch to the eastern edge of the disturbed belt. Its northern extent is defined by the limit of normal faults. The southeastern corner of the Greater Cessford Area lies within these boundaries. Structural traps are formed by block faults and anticlines related to Laramide tectonics which also induced fracturing in shelf carbonate rocks. Porosity was enhanced by both fracturing and unconformity-related processes. Impermeable carbonates in overlying Carboniferous rocks constitute the seal.

Net pay between 2 and 30 metres thick and 5-16% porosity is typical for this play type.

The other two play types are related to the Banff Formation subcrop edge in southern and central Alberta. They include pools in unconformity or stratigraphic traps in carbonate shelf rocks. Lime and dolomitic packstones and grainstones form the reservoir in traps near the subcrop edge. Mesozoic shales and Banff Formation limestones act as seals. The Mesozoic shales may also be the source rock. Other possible source rocks include the Exshaw and Banff Formation shales. Net pay ranges from 3-30 metres with porosities from 10-20%. The Watts field discussed below is an example of this play type.

6.2 EXISTING PRODUCTION

Production from the Banff Formation in the Greater Cessford Area is presently confined to 88 wells in seven fields (Figure 6.1). Crude oil is produced from the Cessford, Coyote, Dowling Lake, Pearl, Sunnynook, Watts and Wildunn Creek Fields (Figure 6.2). The Cessford and Watts Fields are also gas producers. Oil and gas initial established reserves, pay thickness and porosity data for these fields is presented in Tables 6.1 and 6.2.

Cursory examination of Table 6.1 quickly reveals that the Banff Formation does not have prolific reserves in most of the Greater Cessford Area. A number of pools have been abandoned in the late 1980's and early 1990's. These include three pools from each of the Cessford and Watts Fields, two pools from the Coyote field, and a single pool from each of the Dowling Lake and Sunnynook fields.

In contrast to the other producing fields, the Watts and Cessford fields located in the northwest corner and west to south-central part of the Greater Cessford Area respectively contain substantial quantities of oil. With a combined initial established recoverable reserves of $1.1 \times 10^6 m^3$ in all of the Banff Formation pools, the Watts field is

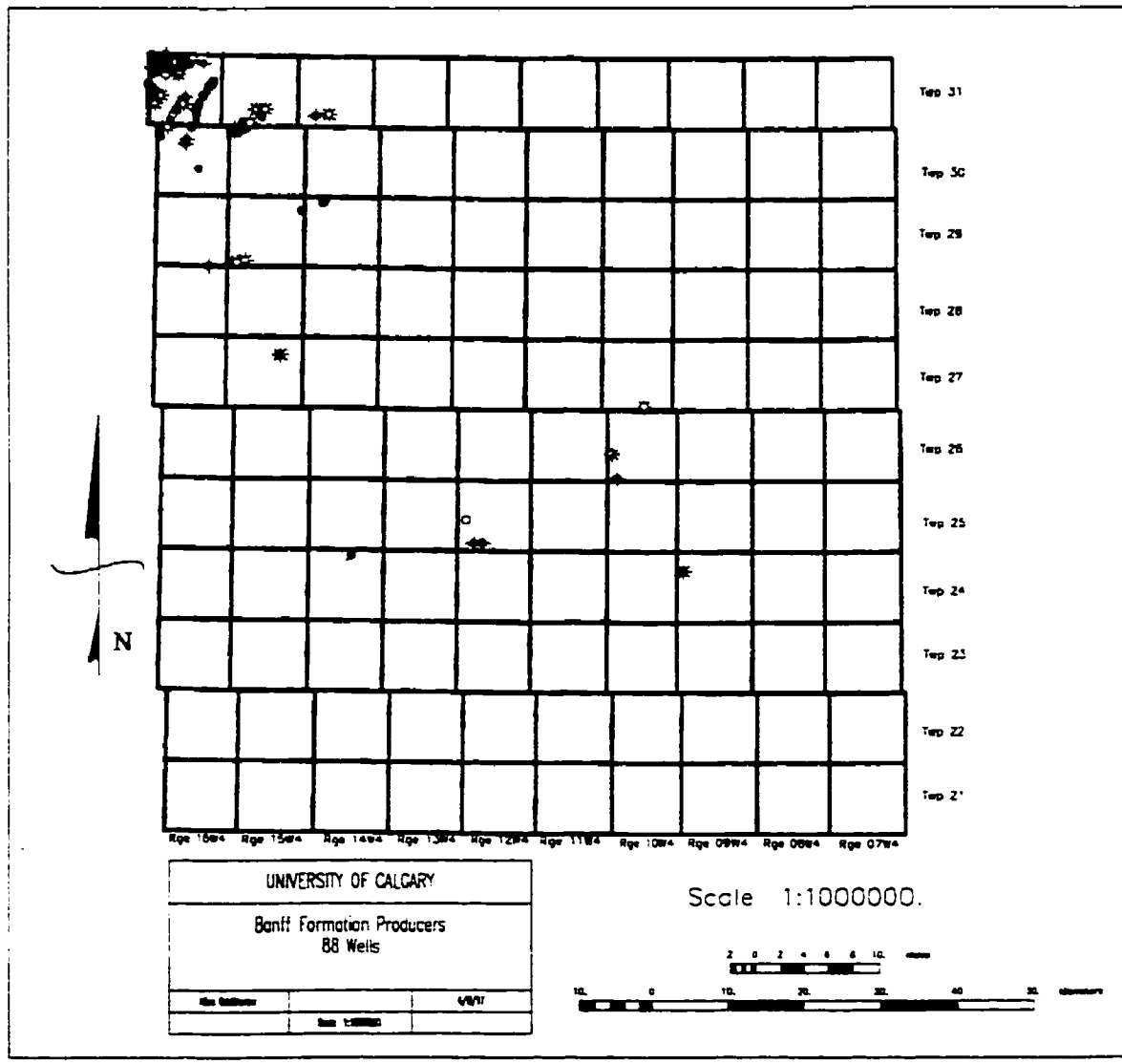


Figure 6.1. Producing wells in the Greater Cessford Area.

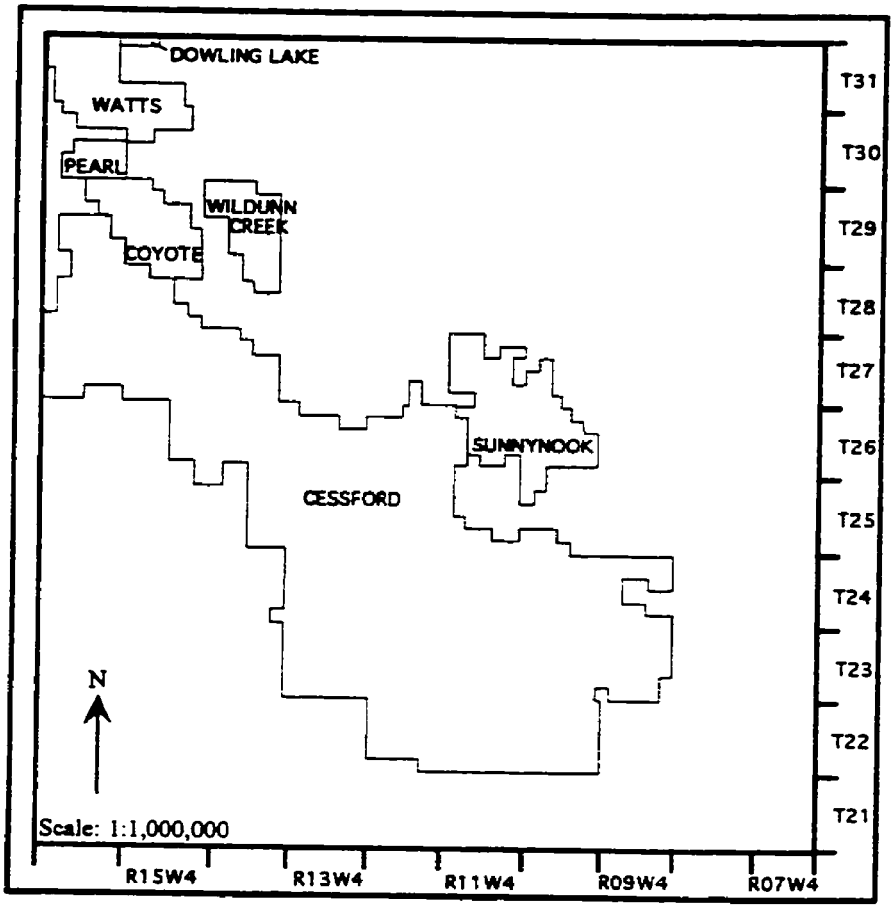


Figure 6.2: Banff Formation producing fields.

OIL

FIELD	POOL	INITIAL ESTABLISHED RESERVES (103M3)	AVERAGE PAY THICKNESS (M)	POROSITY (%)
CESSFORD	BANFF B	425	3.92	14.5
	BANFF E	12.5	2.2	16
	BANFF F	0.1	8.5	5
	BANFF H	0.1	4.5	8
	BANFF I	10.1	4.5	16
	BANFF J	0.1	7	14
COYOTE	BANFF A	0.3	3	8
	BANFF B	0.1	26.8	7
DOWLING LAKE	BANFF A	0.1	4.7	3.5
PEARL	BANFF A	11	2.13	6
SUNNYNOOK	BANFF C	0.1	4	6
WATTS	BANFF A	5	4.86	3.5
	BANFF C	27.9	4.71	7
	BANFF D	82.9	5.72	6
	BANFF G	0.4	6.3	4.5
	BANFF H	447	7.96	8
	BANFF I	144	14.18	5.4
	BANFF J	4.1	7	3
	BANFF L	40	6.6	8
	BANFF M	76	5.64	5
	BANFF N	32.2	16	5
	BANFF O	23.9	7.5	6
	BANFF P	0.1	6.3	4
	BANFF Q	25.2	11	4
	BANFF W	11.6	9.5	6
	BANFF X	14.8	27	5
	BANFF Y	24.1	14.28	5
	BANFF Z	42.1	12.56	4
	BANFF AA	12.8	9.6	6.5
	BANFF DD	24.7	21	6.5
WILDUNN CREEK	BANFF A	15.8	3.9	8

Source: Alberta Energy and Utilities Board 1995.

Table 6.1. Relevant oil data for fields in the Greater Cessford Area.

GAS

FIELD	POOL	INITIAL ESTABLISHED RESERVES (106M3)	AVERAGE PAY THICKNESS (M)	POROSITY (%)
CESSFORD	BANFF B ASSOC	347	2.53	15.1
	BANFF B SOLN	179		
	BANFF B ASSOC	2	0.73	14
	BANFF ASSOC	5	0.94	15.1
WATTS	BANFF D SOLN	28		
	BANFF D ASSOC	298	3.63	12.6

Source: Alberta Energy and Utilities Board 1995.

Table 6.2. Relevant gas data for fields in the Greater Cessford Area.

the eighth largest oil producer from the Banff/Bakken Formations in Western Canada (Richards et al. 1994). Recoverable gas reserves in the Banff/Bakken Formations are relatively small, and thus interest in the Banff Formation is predominantly oil-related.

Current oil and gas production from the Banff Formation in the Greater Cessford Area is from crinoidal grainstones located near the top of the Banff succession. Dolomitized quartzose siltstones are producing oil west of the study area.

6.3 POROSITY AND PERMEABILITYDEVELOPMENT

Original primary porosity was presumably quite high in siltstone, packstone and grainstone lithologies, and low in mudstones, wackestones and some packstones. Most of this primary porosity was reduced or occluded by cementation in the early stages of diagenesis. Later dissolution may have enhanced any remaining primary porosity, but more importantly, created secondary porosity. Dolomitization was also an important porosity-generating diagenetic process in some lithologies.

Porosity-permeability cross-plots were generated using core analyses from logged wells for the dolomitic/calcareous quartzose siltstone and sandstone lithofacies in Units 2, 3 and 6 and for the crinoidal bioclastic grainstone lithofacies in Units 3-6 (Figures 6.3-6.4). A second set of cross-plots were created for the dolomitic quartzose siltstones in Unit 6 and the crinoidal bioclastic grainstone lithofacies using horizontal, vertical and maximum permeabilities (Figure 6.5). The core analyses in Units 2 and 3 only reported maximum permeability values.

The quartzose siltstones and sandstones in Units 2 and 3 are generally dolomitized and have good porosity and permeability. Secondary, leached, intergranular, solution-enlarged porosity is minor compared to the porosity generated by dolomitization (Plate 6a, b). Average core porosities and permeabilities are 15% and 20 millidarcys respectively (Figure 6.3a). Drillstem test results over this interval recovered

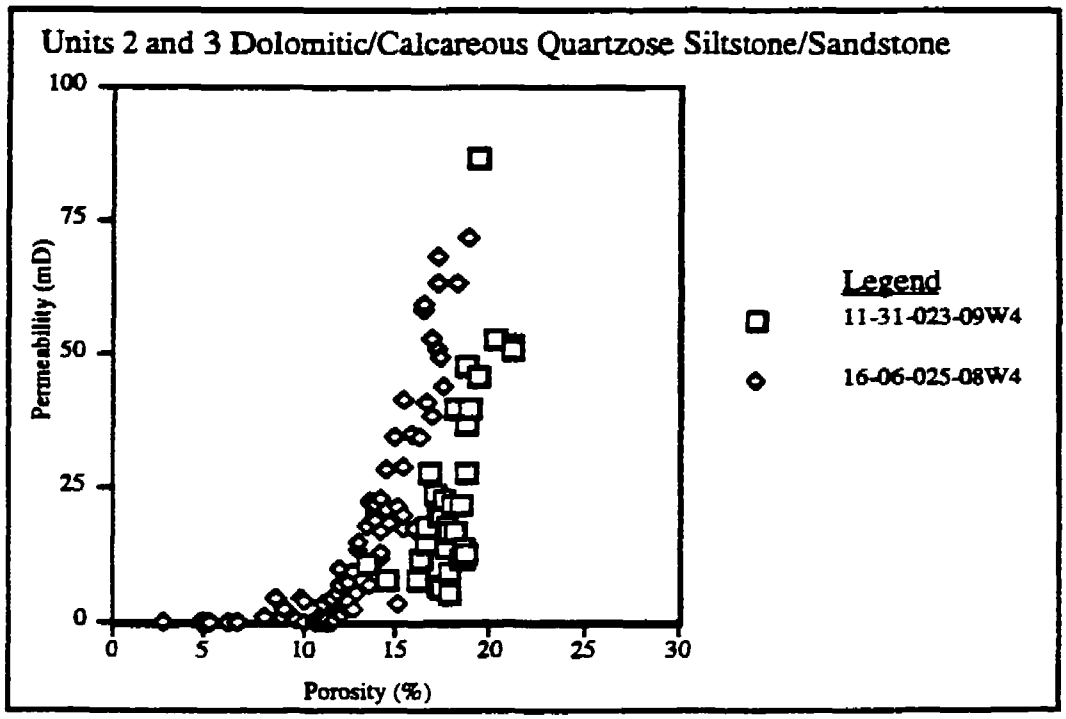


Figure 6.3 (a). Porosity-permeability cross-plot for the dolomitic/calcareous siltstones and sandstones in Units 2 and 3.

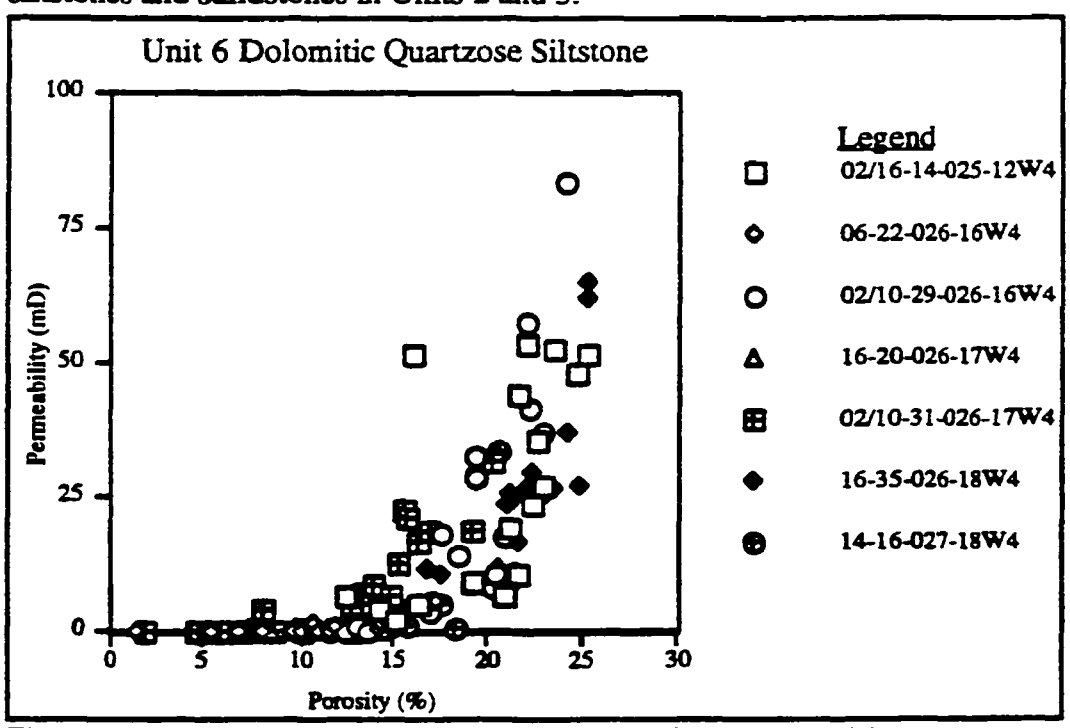


Figure 6.3 (b). Porosity-permeability cross-plot for the dolomitic quartzose siltstones in Unit 6.

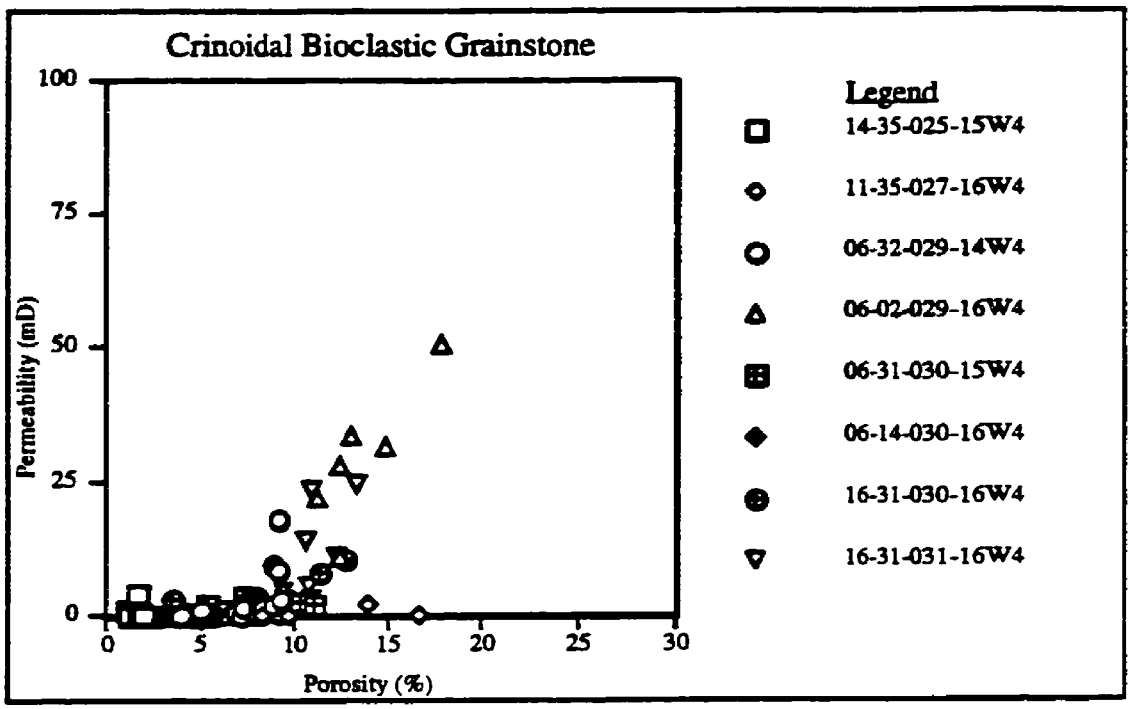


Figure 6.4 (a). Porosity-permeability cross-plot of the crinoidal bioclastic grainstones in Units 3-6.

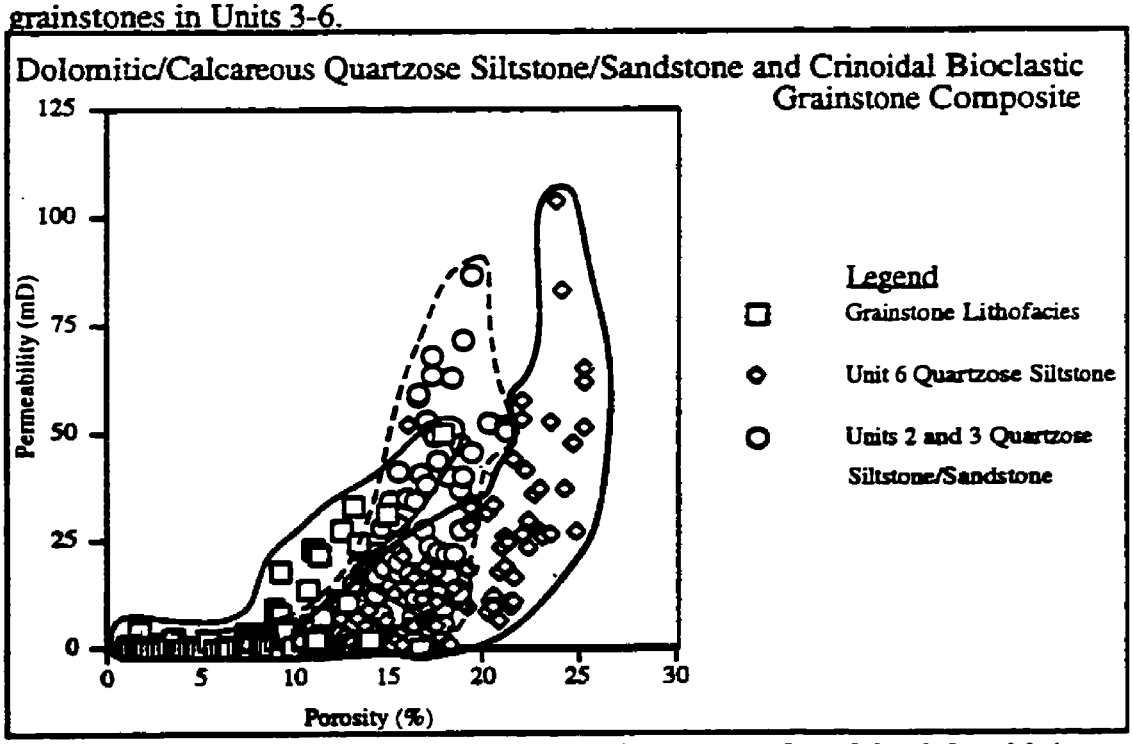


Figure 6.4 (b). Composite porosity-permeability cross-plot of the dolomitic/ calcareous quartzose siltstones/sandstones and crinoidal bioclastic grainstone lithofacies.

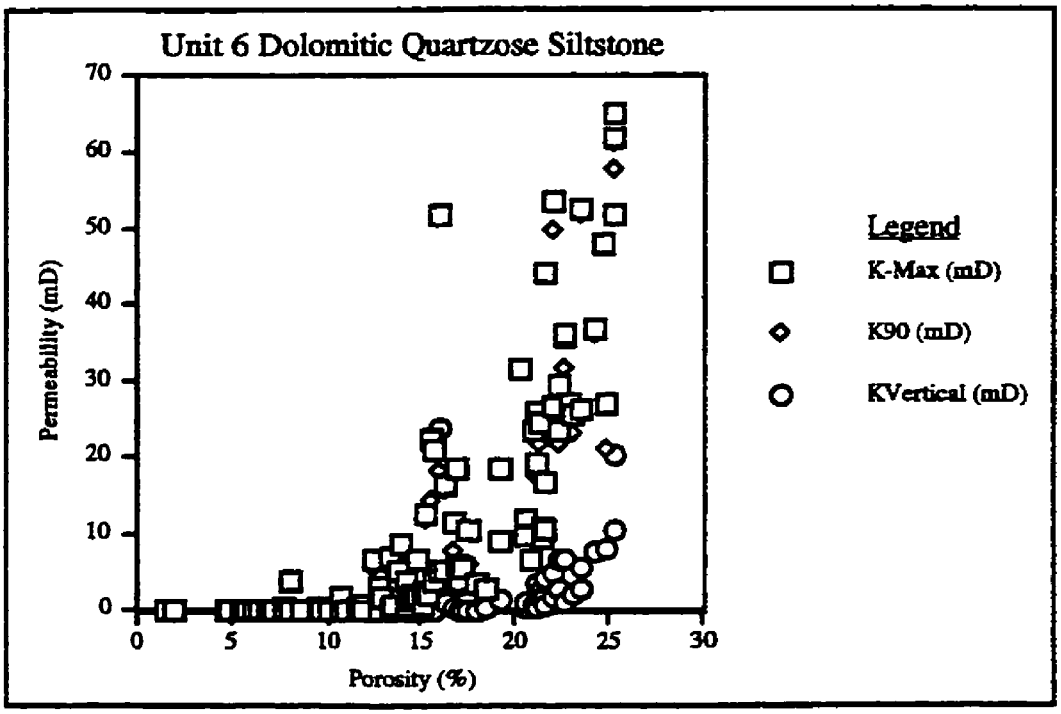


Figure 6.5 (a). Porosity-permeability cross-plot contrasts horizontal, vertical and maximum permeabilities. Data for this plot is from the following well locations: 02/16-14-025-12W4, 06-22-026-16W4, 02/10-31-026-17W4 and 16-35-026-18W4.

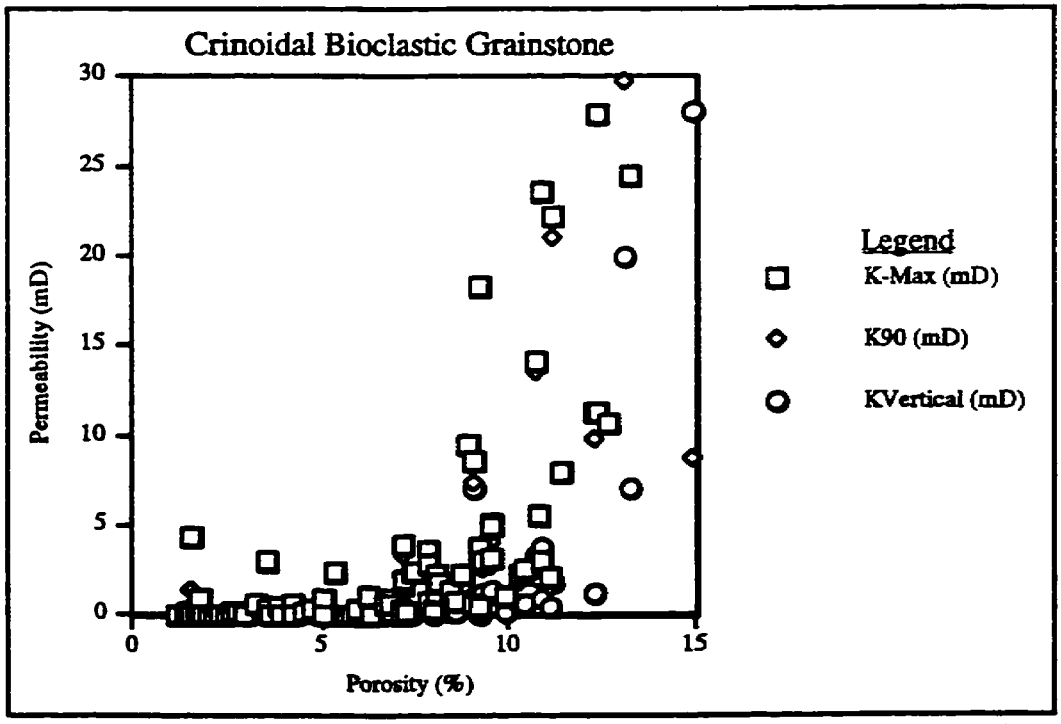


Figure 6.5 (b). Porosity-permeability cross-plot contrasts horizontal, vertical and maximum permeabilities. Data for this plot is from the following well locations: 14-35-025-15W4, 06-32-029-14W4, 06-02-029-16W4, 06-31-030-15W4, 06-14-030-16W4, 16-31-030-16W4 and 16-31-031-16W4.

mud and water. The less porous siltstones and fine-grained sandstones contain a higher proportion of shale lamina.

Similarly, the dolomitic quartzose siltstones in Unit 6 have average porosities of approximately 15% resulting from dolomitization and secondary leaching. Average permeabilities of approximately 18 millidarcies are measured (Figure 6.3b). The two producing wells (02/10-31-026-17W4 and 16-35-026-18W4) lie west of the study area and have slightly elevated permeabilities (23 millidarcies). Three wells in the Greater Cessford Area (02/16-14-025-12W4, 06-22-026-16W4 and 02/10-29-026-16W4) recovered oil-cut mud and/or water from drillstem tests and were perforated over the siltstone interval. The first and third wells have average porosities of 21% and permeabilities of 25 millidarcies. The lack of production from this horizon may lie in the relative thinness of the siltstone package (<5 metres thick) and the absence of hydrocarbons. In contrast, 06-22-026-16W4 has good porosities with consistently poor permeabilities that are typically <1 millidarcy.

The horizontal permeability in the Unit 6 dolomitic quartzose siltstones is generally two to three times greater than the vertical permeability (Figure 6.5a). Porosity is inhomogeneously distributed (Plate 6c, d). Permeameter measurements conducted on this lithofacies in a core from 14-35-025-15W4 indicate that calcareous cemented zones have very poor permeability (<1 millidarcy) in contrast to adjacent, less cemented areas (up to 17 millidarcys).

Dolomitization is the most important process in the generation of intercrystalline porosity in the quartzose siltstones and sandstones. Euhedral dolomite rhombs are typically 40-50 micrometres long. The resultant porosity and permeability of potential reservoir rocks is directly proportional to the degree of dolomitization.

In addition, leached and frayed dolomite edges observed using the scanning electron microscope in this lithofacies suggest enhancement of porosity through flushing

by meteoric water (Plate 4c, d). All leaching is considered to have taken place in the undersaturated zones of the meteoric phreatic and vadose zones.

The crinoidal bioclastic grainstone lithofacies is occasionally dolomitized and has average porosity and permeability values of approximately 7% and 1 millidarcy respectively (Figure 6.4a). Producing wells do not deviate very far from these average values and are not always dolomitized. In the crinoidal bioclastic grainstone lithofacies, the horizontal permeability is equal to or slightly greater than the vertical permeability (between 0 and 30 millidarcys) (Figure 6.5b). In contrast to the quartzose siltstone and sandstone lithofacies, secondary leaching of calcite and the generation of vugular pores is more important than dolomitization in the creation of porosity (Plate 7d). Although dolomitization of the crinoidal bioclastic grainstone lithofacies may in some way be related to the post-Mississippian unconformity, no simple relationship exists between the degree of dolomitization and proximity to the unconformity. Putnam et al. (1995) came to a similar conclusion with respect to dolomitization and proximity to the unconformity in the Banff Formation in southwestern Alberta.

Crinoidal bioclastic grainstones are the product of a high energy, shoaling environment as discussed in Chapter 3. High intergranular primary porosity was occluded by three generations of calcite cement. Secondary, leached, intergranular, solution-enlarged porosity is extremely important in this lithofacies. The producing grainstones are located underneath the Banff Formation subcrop edge which has elevated porosity attributed to the migration of meteoric waters. The development of moldic and vuggy porosity is required for the lithofacies to produce.

The composite cross-plot illustrates the relatively low porosities and permeabilities of the crinoidal bioclastic grainstone lithofacies (0-18%, 0-50 millidarcys) compared to the siliciclastic lithofacies (0-26%, 0-105 millidarcys) (Figure 6.4b). The dolomitized siltstones in Unit 6 have superior porosities and similar permeabilities to the siltstones and sandstones in Units 2 and 3. Dolomitization may have been texturally

controlled in the Greater Cessford Area. The quartzose siltstone and sandstone lithofacies was dolomitized preferentially relative to cemented grainstones.

6.5 SUMMARY

There are three potential reservoirs in the Banff Formation within the Greater Cessford Area: (1) crinoidal bioclastic grainstones in Units 3-6, (2) dolomitic quartzose siltstones in Unit 6, and (3) dolomitic/calcareous quartzose siltstones/sandstones in Units 2 and 3. The grainstones are presently producing in the Watts and Cessford fields. In contrast, the dolomitic/calcareous quartzose siltstones/sandstones in Units 2, 3 and 6 are not presently producing in the Greater Cessford Area. However, current production from the quartzose siltstones/sandstones occurs outside the study area.

Crinoidal grainstones are the most important reservoir rocks in the study area. Vugular and moldic porosity account for the reservoir quality of these lithofacies, and are attributable to secondary leaching of calcite. Dolomitization is of secondary importance in this lithofacies. The Banff Formation dolomitic quartzose siltstone in Unit 6 is a shallow water facies locally developed in the Greater Cessford Area. It is a fine-grained, low permeability unit with drillstem test results indicative of limited reservoir potential. The commonly dolomitized quartzose siltstones and sandstones of Units 2 and 3 have good porosity and permeability but limited hydrocarbon quantities in the Greater Cessford Area. Dolomitization of the quartzose siltstones and sandstones is the primary method of porosity generation within this lithofacies.

CHAPTER 7: SUMMARY AND CONCLUSIONS

7.1 SETTING

The Lower Mississippian Banff Formation consists of a shallowing- and coarsening-upward succession of carbonates and fine-grained siliciclastics deposited on a southwestward-deepening ramp in the Greater Cessford Area. The Banff Formation overlies the black shales of the Exshaw Formation and is in turn overlain by skeletal grainstones and cherty packstones of the Pekisko Formation in the southwest and by the Detrital Formation breccias in the remainder of the study area. The Greater Cessford Area is part of the proximal, low gradient, homoclinal portion of the regional, tectonically controlled, westward-prograding Banff Formation carbonate ramp.

The Greater Cessford Area was located on the western edge of the North American continental landmass immediately preceding the amalgamation of the supercontinent Pangea. The location of the study area at this time is broadly constrained to have been between 10° south and 25° north latitude. Comparison with modern day analogues in the Persian Gulf suggest that the Greater Cessford Area was characterized by an arid to semi-arid tropical desert climate with little precipitation and seasonally fluctuating temperatures. Wind and storm activity were frequent as a result of a tropical monsoonal circulation system.

7.2 SIGNIFICANCE

The significance of this study lies in its nine fundamental outcomes. Firstly, the study recognizes six fourth- or fifth-order units in the Banff Formation and correlates them across the ramp. This complements previous studies, which have concentrated on the correlation of third-order cycles in large geographic areas. Where fourth- and fifth-order cycles have been identified in the literature, there has previously been no attempt to correlate them. Secondly, a previously undocumented dolomitic quartzose siltstone

succession in the upper Banff Formation is identified and mapped. Previous identification of this unit may have been hindered by PEF log values that are commonly intermediate between sandstone and limestone. Thirdly, this study is one of the first to recognize the occurrence of sediment piling, whereby the five lowermost units of the Banff Formation are deposited in sediment piles of highly variable size, shape, thickness and areal extent as a result of differential sedimentation. Fourthly, this study documents lithological piling in Unit 2 consisting of carbonate piles isolated in fine-grained siliciclastics, a relationship that has not been previously described in the literature. The fifth outcome of this study is the documentation of a medial belt consisting of siliciclastics flanked by carbonates in the landward and seaward directions in Units 3 to 6, a relationship that has not been previously reported in the literature. Sixthly, the interpretation of this medial siliciclastics belt as a series of bottom current deposits highlights the importance of longshore currents and other hydrodynamic processes in the movement of sediment on carbonate ramps. The seventh result is the establishment of a change in the ramp geometry from a homogeneously shallowly sloping surface during deposition of Units 1 and 2 to a ramp with a slight inflection during deposition of Units 3 to 6. The Banff Formation in the eastern domain has previously been documented as a homoclinal ramp with no implication of changes in slope. The eighth point of significance in this study is its presentation of a brief summary of diagenetic processes and residual deposits associated with the post-Mississippian unconformity. Lastly, this study summarizes potential reservoirs in the Banff Formation.

7.3 CORRELATION OF UNITS

The prevailing approach to establishing the geometry and stratigraphy of carbonate ramps has been the construction of a number of regional cross-sections across entire ramp systems. Gently dipping clinoforms that prograde toward the basin are the result of such regional-scale correlation and imply that unit sedimentation is of relatively

uniform thickness and lithology over vast geographic areas. In order to provide a more accurate characterization of the variations in geometry of smaller-scale successions, the Banff Formation in this study is divided into six cyclic, shoaling-upward units. The six units are recognized and correlated by the study of geophysical well logs and the identification of distinct breaks in the gamma ray curve.

The sigmoidal and parallel bed surfaces observed on a regional scale by previous workers cannot be established by correlation between relatively close-spaced wells in the Greater Cessford Area. In contrast, cross-sections and isopach maps indicate that differential sedimentation has resulted in piles of sediment with highly variable shape, size, thickness and areal extent in all but the uppermost unit. The uppermost unit consists of broad, evenly-spaced sediment belts that are roughly parallel to the paleoshoreline.

7.4 SEDIMENTOLOGY

Six lithofacies are identified in the Banff Formation. These are (1) shale, (2) bioturbated mudstone, (3) dolomitic/calcareous quartzose siltstone/sandstone, (4) pelleted mudstone to packstone, (5) crinoidal bioclastic wackestone to packstone, and (6) crinoidal bioclastic grainstone lithofacies.

Unit 1 consists of the shale and bioturbated mudstone lithofacies deposited in an open marine setting on the mid-ramp. Rare skeletal debris was derived from the inner ramp and deposited out of suspension. Unit 2 comprises piles of crinoidal bioclastic wackestones and packstones, as well as quartzose siltstones and sandstones, isolated in shales and bioturbated mudstones deposited on the mid- and inner ramp. Units 3 to 6 consist of crinoidal bioclastic wackestones and packstones deposited below fair-weather wave-base on the mid-ramp in the southwest part of the Greater Cessford Area. These grade laterally into quartzose siltstones and sandstones, in addition to crinoidal bioclastic wackestones and packstones deposited along the inflected part of the inner

ramp. Inner ramp deposits located in the northeast consist of massive packages of crinoidal bioclastic packstones and grainstones deposited as barrier bar, bank and shoal complexes separated by intershoal crinoidal bioclastic wackestone sediments. The barrier bar complex protected a series of open bay and restricted lagoonal depositional environments in which bioturbated mudstones, shales and pelleted mudstones to packstones were deposited.

7.5 RAMP MODEL

Sedimentation in the Banff Formation is distinct from sedimentation on other carbonate ramps in two ways. Firstly, Unit 2 was deposited as piles of carbonate isolated in fine-grained siliciclastics. Secondly, the siliciclastic sediments in Units 3-6 are concentrated into a medial belt that roughly parallels the paleoshoreline and is flanked by carbonates in both the landward and seaward directions. It is conceivable that these two features would be noted in a number of other carbonate ramps if they were to be examined in the same detail and with the same data density as the current study.

The profile of the Banff Formation ramp changed over time from a low gradient sloping surface during the deposition of Units 1 and 2 to a surface with a slightly inflected or curved profile during the deposition of Units 3-6. Hydrodynamic processes were extremely important in the distribution of sediments in all six units. The medial siliciclastic belt is interpreted as a series of bottom current deposits distributed along a slight inflection on the inner ramp. Siliciclastics were primarily derived from the craton in the north and northeast and laterally transported by longshore currents into the Greater Cessford Area. Wind-blown silt was a secondary source of siliciclastic sediments. Punctuated, facies, in situ, and source mixing processes were operating in the ramp system with source mixing as the dominant process.

7.6 DIAGENESIS

Diagenesis of the Banff Formation included the processes of (1) conversion of lime mud to mudstone, (2) primary and secondary porosity development, (3) marine, meteoric and burial cementation, (4) dolomitization, (5) mineral replacement, (6) stylolitization, and (7) fracturing.

The post-Mississippian unconformity is overlain by a series of heavily weathered residual deposits which separate the Banff Formation from the overlying stratigraphy. These sediments are either picked as the top of the Banff Formation or included in the base of the Detrital Formation. Diagenesis related to the unconformity is restricted to silica replacement in the form of chert clasts, and hematite replacement which imparts a red and green colour to the sediments. No simple relationship could be derived between dolomitization and dissolution and proximity to the unconformity.

7.7 PETROLEUM GEOLOGY

Three potential Banff Formation reservoirs are present in the Greater Cessford Area: (1) dolomitic quartzose siltstones in Unit 6, (2) dolomitic/calcareous quartzose siltstones/sandstones in Units 2 and 3, and (3) crinoidal bioclastic grainstones in Units 3-6. The dolomitic quartzose siltstone in Unit 6 is a shallow water facies locally developed in the Greater Cessford Area. Low permeability and drillstem test results indicate poor reservoir potential. The quartzose siltstones and sandstones of Units 2 and 3 have good porosity and permeability but limited hydrocarbon quantities in the Greater Cessford Area. In contrast to the siliciclastic reservoirs, expansion of existing production in the crinoidal bioclastic grainstones has the greatest potential.

REFERENCES

Ahr, W.M., 1973. The carbonate ramp: an alternative to the Shelf Model. Transactions of the Gulf Coast Association of Geological Societies 23rd Annual Convention, p. 221-225.

Ahr, W.M., 1989. Sedimentary and Tectonic Controls on the Development of an Early Mississippian Carbonate Ramp, Sacramento Mountains Area, New Mexico. *In* Crevello, P.D., Wilson, J.L., Sarg, J.F. and Read, J.F. (Eds.). Controls on Carbonate Platform and Basin Development. Society of Economic Paleontologists and Mineralogists, Special Publication 44, p. 203-212.

Alberta Energy and Utilities Board, 1995. Alberta's Reserves of crude oil, oil sands, gas, natural gas liquids and sulphur. Statistical Series 96-18, Calgary, Alberta, 574p.

Allan, J.A., 1913. Rocky Mountain section between Banff, Alberta and Golden, B.C., along the Canadian Pacific Railway. Geological Survey of Canada Summary Report, Session Paper 26, p. 165-176.

Anderson, N.L. and Brown, R.J., 1992. Dissolution and deformation of rock salt, Stettler area, southeastern Alberta. Canadian Journal of Exploration Geophysics, 28(2), p. 128-136.

Anderson, N.L., Chapman, J., and Brown, R.J., 1990. Palaeo-reconstruction of the Wabamun Group Salt, southern Alberta. Technical Programme and Abstracts of Papers - European Association of Exploration Geophysicists, 52, p. 189-190.

Asquith, G.B., 1982. Basic Well Log Analysis for Geologists. American Association of Petroleum Geologists, Methods in Exploration No. 3, Tulsa, Oklahoma, 216p.

Asquith, G.B., 1985. Handbook of Log Evaluation Techniques for Carbonate Reservoirs. American Association of Petroleum Geologists Methods in Exploration No. 5, Tulsa, Oklahoma, 47p.

Bamber, E.W., Macqueen, R.W. and Ollerenshaw, N.C., 1981. Mississippian stratigraphy and sedimentology, Canyon Creek (Moose Mountain), Alberta. Geological Association of Canada, Field Guides to Geology and Mineral Deposits, Calgary, Alberta, p. 177-194.

Bamber, E.W., Macqueen, R.W. and Richards, B.C., 1980. Facies Relationships at the Mississippian Carbonate Platform Margin, Western Canada. Geological Survey of Canada, Open File 674, 32p.

Bamber, E.W., Macqueen, R.W. and Richards, B.C., 1984. Facies Relationships at the Mississippian carbonate platform margin, western Canada. *In* Belt, E.S. and Macqueen, R.W. (Eds.). Nuevieme Congress International de Stratigraphie et de Geologie du Carbonifere, Part 3: Sedimentology and Geochemistry, V.3, p. 461-478.

Bardossy, G., 1994. Carboniferous to Jurassic Bauxite Deposits as Paleoclimatic and Paleogeographic Indicators. *In* Embry, A.F. and Beauchamp, B. (Eds.). Pangea: Global Environments and Resources. Canadian Society of Petroleum Geologists, Memoir 17, p. 283-293.

Bates, R.L. and Jackson, J.A., (Eds.), 1980. Glossary of Geology. Second Edition. American Geological Institute, Falls Church, Virginia, 749 p.

Bathurst, R.G.C., 1975. Carbonate Sediments and their Diagenesis. 2nd Edition. Developments in Sedimentology 12, Elsevier Scientific Publishing Company, New York, 658p.

Bayliss, P., 1986. Quantitative Analysis of Sedimentary Minerals by Powder X-Ray Diffraction. Powder Diffraction, 1(2), p. 37-39.

Bayliss, P., Erd, D.C., Mrose, M.E., Sabina, A.P., and Smith, D.K. (Eds.), 1986. Mineral Powder Diffraction File. JCPDS International Center for Diffraction Data. Swarthmore, Pennsylvania. V.1 Data Book. V.2 Search Manual. V.3 Group Data Book.

Beales, F.W., 1950. The Late Paleozoic formations of southwestern Alberta. Geological Survey of Canada Paper 50-27, 72p.

Belperio, A.P. and Searle, D.E., 1988. Terrigenous and Carbonate Sedimentation in the Great Barrier Reef Province. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 143-174.

Bloy, G.R., Hadley, M.G. and Curtis, B.V., 1989. The Development of Porosity in Carbonate Reservoirs. Canadian Society of Petroleum Geologists Continuing Education Short Course, 454p.

Bond, G.C. and Kominz, M.A., 1991. Disentangling middle Paleozoic sea level and tectonic events in cratonic margins and cratonic basins of North America. Journal of Geophysical Research-Solid Earth and Planets, 96 (B4), p. 6619-6639.

Bone, Y., James, N.P., Von der Borch, C.C. and Gostin, V., 1991. Modern Cool-Water Siliciclastic/Carbonate Sediments, Lacepede Shelf, South Australia. American Association of Petroleum Geologists Bulletin, 75(3), p. 545.

Boreen, T., James, N., Wilson, C. and Heggie, D., 1993. Surficial cool-water carbonate sediments on the Otway continental margin, southeastern Australia. Marine Geology, 112, p. 35-56.

Boreski, C.V., 1978. Sedimentation and Diagenesis of the Mississippian Carbonates of the Twining Oil Field, Alberta. University of Calgary Master of Science Thesis, 163p.

Brandley, R.T., 1993. Carbonate and Siliciclastic Deposition on a Cold- and Warm-Water Wave-Swept Ramp: Lower Carboniferous Mount Head Formation, Southwestern Alberta and Southeastern British Columbia. University of Calgary Ph.D. Thesis, 488p.

Brock, J., 1984. Analyzing Your Logs Volume 1: Fundamentals of Open Hole Log Interpretation. Petro-Media Inc., Tyler, Texas, 234p.

Brown, R.J. and Anderson, N.L., 1990. Dissolution of the Wabamun salts - a seismic perspective. Technical Programme and Abstracts of Papers - European Association of Exploration Geophysicists, 52, p. 33.

Budd, D.A. and Harris, P.M. (Eds.), 1990. Carbonate-Siliciclastic Mixtures. Society of Economic Paleontologists and Mineralogists, Reprint Series 14, 272p.

Burchette, T.P. and Wright, V.P., 1992. Carbonate ramp depositional systems. Sedimentary Geology, 79, p. 3-57.

Calvet, F., Tucker, M.E. and Henton, J.M., 1990. Middle Triassic carbonate ramp systems in the Catalan Basin, northeast Spain: facies, systems tracts, sequences and controls. *In* Tucker, M.E., Wilson, J.L., Crevello, P.D., Sarg, J.R. and Read, J.F. (Eds.). Carbonate Platforms: Facies, Sequences and Evolution. Special Publication of the International Association of Sedimentology, 9, p. 79-108.

Carozzi, A.V., 1989. Carbonate Rock Depositional Models. Prentice Hall, New Jersey, 604p.

Carozzi, A.V. and Gerber, M.S., 1984. Crinoid arenite banks and crinoid wacke inertia flows: a depositional model for the Burlington Limestone (Middle Mississippian), Illinois, Iowa, and Missouri, USA. International Congress on Carboniferous Stratigraphy and Geology, 9(3), p. 452-460.

Carter, J.L., 1987. Lower Carboniferous Brachiopods from the Banff Formation of Western Alberta. Geological Survey of Canada Bulletin 378, Energy, Mines and Resources Canada, 183p.

Chatellier, J.Y., 1983. Sedimentology of the Mississippian Banff Formation in SW Alberta Mountains and Plains. University of Calgary Masters Thesis, 159p.

Chatellier, J.Y., 1988. Carboniferous Carbonate Ramp, The Banff Formation, Alberta, Canada. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 12, p. 569-599.

Chatellier, J.Y., 1992. Structurally controlled diagenesis of a carbonate ramp (Banff Formation, Alberta, Canada). Sedimentary Geology, 79, p. 77-90.

Chen, X. and Webster, G., 1994. Sedimentology, Tectonic Control and Evolution of a Lower Mississippian Carbonate Ramp with Offshore Bank, Central Wyoming to Eastern Idaho and Northeastern Utah, U.S.A.. *In* Embry, A.F. and Beauchamp, B. (Eds.). Pangea: Global Environments and Resources. Canadian Society of Petroleum Geologists Memoir 17, p. 557-587.

Clark, L.M. 1949. Geology of the Rocky Mountain Front Ranges near Bow River, Alberta. American Association of Petroleum Geologists Bulletin, 33(4), p. 614-633.

Clemmensen, L.B., 1978. Lacustrine Facies and Stromatolites from the Middle Triassic of East Greenland. Journal of Sedimentary Petrology, 48(4), p. 1111-1128.

Collins, L.B., 1988. Sediments and history of the Rottnest Shelf, southwest Australia: a swell-dominated, non-tropical carbonate margin. Sedimentary Geology, 60, p. 15-49.

Cutler, W.G., 1983. Stratigraphy and sedimentology of the Upper Devonian Grosmont Formation, northern Alberta. Bulletin of Canadian Petroleum Geology, 31, p. 282-235.

D'Alvisio-Guerrieri, G.M., and Davis, R.A., 1988. Infilling of Coastal Lagoons by Terrigenous Siliciclastic and Marine Carbonate Sediment: Vieques, Puerto Rico. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 207-230.

Dolson, J., 1990. Unconformities in Exploration, Examples from Lower Cretaceous through Mississippian Strata, Central and Northern Rocky Mountains. American Association of Petroleum Geologists Bulletin Abstracts, 74 (8), p. 1321.

Douglas, R.J.W., 1953. Carboniferous stratigraphy in the southern Foothills of Alberta. Alberta Society of Petroleum Geology Guidebook, Third Annual Field Conference, p. 68-88.

Douglas, R.J.W. and Harker, P., 1958. Mississippian succession in Mount Head area, Alberta. *In* Goodman, A.J. (Ed.). Jurassic and Carboniferous of Western Canada. American Association of Petroleum Geologists Symposium, p. 177-189.

Doyle, L.J. and Roberts, H.H. (eds.), 1988. Carbonate-Clastic Transitions. Developments in Sedimentology No. 42, Elsevier, New York, 304p.

Driese, S.G., 1985. Interdune Pond Carbonates, Weber Sandstone (Pennsylvanian-Permian), Northern Utah and Colorado. Journal of Sedimentary Petrology, 55(2), p. 187-195.

Driese, S.G. and Dott Jr., R.H., 1984. Model for Sandstone-Carbonate "Cyclothems" Based on Upper Member of Morgan Formation (Middle Pennsylvanian) of Northern Utah and Colorado. American Association of Petroleum Geologists Bulletin, 68(5), p. 574-597.

Dunham, R.J., 1962. Classification of carbonate rocks according to depositional texture. *In* Ham, W.E. (Ed.). Classification of Carbonate Rocks. American Association of Petroleum Geologists, Memoir 1, p.108-121.

Early, C.F. and Goodell, H.G., 1968. The Sediments of Card Sound, Florida. Journal of Sedimentary Petrology, 38(4), p. 985-999.

Elrick, M. and Read, J.F., 1991. Cyclic ramp-to-basin carbonate deposits, Lower Mississippian, Wyoming and Montana: A Combined Field and Computer Modeling Study. Journal of Sedimentary Petrology, 61(7), p. 1194-1224.

Elrick, M., Read, J.F. and Coruh, C., 1991. Short-term paleoclimatic fluctuations expressed in lower Mississippian ramp-slope deposits, southwestern Montana. Geology, 19, p. 799-802.

Ethier, V.G., 1970. Probability theory applied to sedimentary sequences: a study of the Banff Formation (Mississippian) of the southern Canadian Rocky Mountains. University of Calgary Master of Science Thesis, 121p.

Faugeres, J., and Stow, D., 1993. Bottom-current-controlled sedimentation: a synthesis of the contourite problem. Sedimentary Geology, 82, p. 287-297.

Francis, J.E., 1994. Palaeoclimates of Pangea-Geological Evidence. *In* Embry, A.F. and Beauchamp, B. (Eds.). Pangea: Global Environments and Resources. Canadian Society of Petroleum Geologists Memoir 17, p. 265-274.

Frey, R.W. and Pinet, P.R., 1978. Calcium-Carbonate Content of Surficial Sands Seaward of Altamaha and Doboy Sounds, Georgia. Journal of Sedimentary Geology, 48(4), p. 1249-1256.

Friedman, G.M., 1988. Histories of Coexisting Reefs and Terrigenous Sediments: the Gulf of Elat (Red Sea), Java Sea, and Neogene Basin of the Negev, Israel. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 77-97.

Gallup, W.B., 1951. Geology of Turner Valley oil and gas field, Alberta, Canada. American Association of Petroleum Geologists Bulletin, 35(4), p. 797-821.

Georgi, D.T., Harville, D.G., Phillips, C., and Ostroff, G.M., 1993. Extrapolation of Core Permeability Data with Wireline Logs to Uncored Intervals. *In* Western Atlas, Core Laboratories. Profile Permeameter Handbook.

Georgi, D.T. and Jones, S.C., 1992. Application of Pressure-Decay Profile Permeametry to Reservoir Description. Paper SPENC 9212:1-12, presented at the 16th Annual International Conference and Exhibition: Society of Petroleum Engineers (Nigeria Council), Lagos, Nigeria, August 26-27.

Gilhooly, M.G., 1987. Sedimentology and geologic history of the Upper Devonian (Frasnian) uppermost Ireton and Nisku Formations, Bashaw area, Alberta. University of Calgary Master of Science Thesis, 210p.

Ginsburg, R.N. and James, N.P., 1974. Holocene carbonate sediments of continental shelves. *In* Burk, C.A. and Drake, C.L., (Eds.). The Geology of Continental Margins. Springer-Verlag, Berlin, p. 137-155.

Glass, D.J. (Ed.), 1981. Lexicon of Canadian Stratigraphy. V.4 Western Canada. Canadian Society of Petroleum Geologists, Calgary, 772p.

Glatiotis, D., 1994. Instructions for Scintag X-Ray Diffractometer. Department of Geology & Geophysics, University of Calgary, 5p.

Golonka, J., Ross, M.I., and Scotese, C.R., 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps. *In* Embry, A.F., Beauchamp, B. and Glass, D.J. (Eds.). Pangea: global environments and resources. Canadian Society of Petroleum Geologists Memoir 17, p. 1-47.

Green, R., 1962. Zonal Relationships in Lower Mississippian Rocks of Alberta. Journal of the Alberta Society of Petroleum Geologists, 10(6), p. 292-307.

Greensmith, J.T., 1989. Petrology of the Sedimentary Rocks (7th Edition). Unwin Hyman Ltd., Oxford, 262p.

Hagan, G.M. and Logan, B.W., 1974. Development of Carbonate Banks and Hypersaline Basins, Shark Bay, Western Australia. *In* Logan, B.W., Read, J.F., Hagan, G.M., Hoffman, P., Brown, R.G., Woods, P.J., and Gebelein, C.D.. Evolution and Diagenesis of Quaternary Carbonate Sequences, Shark Bay, Western Australia. American Association of Petroleum Geologists Memoir 22, Tulsa, Oklahoma, p. 61-139.

Halbertsma, H.L., 1994. Devonian Wabamun Group of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 13, p. 203-220.

Handford, C.R., 1986. Facies and Bedding Sequences in Shelf-Storm-Deposited Carbonates-Fayetteville Shale and Pitkin Limestone (Mississippian), Arkansas. Journal of Sedimentary Petrology, 56(1), p. 123-137.

Handford, C.R. and Loucks, R.G., 1993. Carbonate depositional sequences and systems tracts: response of carbonate platforms to relative sea-level changes. *In* Loucks, R.G. and Sarg, J.F. (Eds.). Carbonate Sequence Stratigraphy: Recent Developments and Applications. American Association of Petroleum Geologists Memoir 57, p. 3-41.

Hanneman, D.L., 1977. Paleoecological Study of the Banff Formation, Ram Mountain, Alberta. University of Calgary Master of Science Thesis, 150p.

Haq, B.U., Hardenbol, J., and Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic (250 million years ago to present). Science 235, p. 1156-1167.

Hardy, R. and Tucker, M., 1988. X-ray powder diffraction of sediments. *In* Tucker, M. (Ed.). Techniques in Sedimentology. Blackwell Scientific Publications, London, p. 191-228.

Harker, P. and McLaren, D.J., 1958. The Devonian-Mississippian boundary in the Alberta Rocky Mountains. *In* Goodman, A.J. (Ed.). Jurassic and Carboniferous of Western Canada. American Association of Petroleum Geologists Symposium, p. 244-253.

Harris, J.M. and Langan, R.T., 1997. Crosswell Seismic Fills the Gap. American Association of Petroleum Geologists Explorer, p. 10-12.

Hay, W.M., Rosol, M.J., Jory, D.E., Sloan, J.L., III, 1988. Plate Tectonic Control of Global Patterns of Detrital and Carbonate Sedimentation. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 1-34.

Hayes, B.J.R., 1983. Stratigraphy and petroleum potential of the Swift Formation (Upper Jurassic), southern Alberta and north-central Montana. Bulletin of Canadian Petroleum Geology, 31, p. 37-52.

Hayes, B.J.R., Christopher, J.E., Rosenthal, L., Los, G., McKercher, B., Minkin, D., Tremblay, Y.M., and Fennell, J., 1994. Cretaceous Mannville Group of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 19, p. 317-334.

Hays, M.D., 1985. Conodonts of the Bakken Formation (Devonian and Mississippian), Williston Basin North Dakota. The Mountain Geologist, 22, p. 64-77.

Heckel, P.H., 1983. Diagenetic Model for Carbonate Rocks in Midcontinent Pennsylvanian Eustatic Cyclothems. Journal of Sedimentary Petrology, 53 (3), p. 733-759.

Henderson, C.M., Richards, B.C., and Barclay, J.E., 1994. Permian Strata of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 15, p. 251-258.

Hollister, C.D., 1990. The Origin of the Concept of Contourites. 13th International Sedimentological Congress Abstracts, 13, p. 229.

Hollister, C.D., 1993. The concept of deep-sea contourites. Sedimentary Geology, 82, p. 5-11.

Holmes, C.W., 1988. Carbonate to Siliciclastic Periplatform Sediments: Southwest Florida. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 271-287.

James, N.P., Bone, Y., Von der Borch, C.C., and Gostin, V.A., 1992. Modern carbonate and terrigenous clastic sediments on a cool water, high energy, mid-latitude shelf: Lacepede, southern Australia. Sedimentology, 39, p. 877-903.

Jones, S.C., 1992. The Profile Permeameter: A New, Fast, Accurate Minipermeameter. Paper SPE 24757:973-983, presented at the 67th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Washington, DC, USA, October 4-7.

Kindle, E.M., 1924. Standard Paleozoic section of the Rocky Mountains near Banff, Alberta. Pan-American Geologist, 42(2), p. 113-124.

Konopka, E.H., and Dott, R.H., 1983. Sandstone-Carbonate Repetitive Alternations: Butterfield Peaks Formation (Middle Pennsylvanian), Oquirrh Group, Central Utah. American Association of Petroleum Geologists Bulletin, 67 (3), p. 496-497.

Kreisa, R.D., 1981. Storm-generated sedimentary structures in subtidal marine facies with examples from the Middle and Upper Ordovician of Southwestern Virginia. Journal of Sedimentary Petrology, 51, p. 823-848.

Larsonneur, C., Bouyssee, P., and Auffre, J., 1982. The superficial sediments of the English Channel and its western approaches. Sedimentology, 29, p. 851-864.

Logan, B.W. and Cebulski, D.E., 1970. Sedimentary environments of Shark bay, Western Australia. American Association of Petroleum Geologists Memoir 13, p. 1-37.

Macauley, G., Penner, D.G., Procter, R.M. and Tisdall, W.H., 1964. Carboniferous. *In* McGrossan, R.G. and Glaister, R.P. (Eds.). Geological History of Western Canada. Alberta Society of Petroleum Geologists, 232p.

Macqueen, R.W. and Bamber, E.W., 1967. Stratigraphy of Banff Formation and Lower Rundle Group (Mississippian), Southwestern Alberta. Geological Survey of Canada Paper 67-47, Department of Energy, Mines and Resources, 37p.

Macqueen, R.W. and Bamber, E.W., 1974. Lower Carboniferous Stratigraphy, biostratigraphy, and sedimentology, Moose Dome, Rocky Mountain Foothills. Canadian Society of Petroleum Geologists Field Trip, 16p.

Macqueen, R.W., Bamber, E.W. and Mamet, B.L., 1972. Lower Carboniferous Stratigraphy and Sedimentology of the Southern Canadian Rocky Mountains. XXIV International Geological Congress, Montreal Quebec, Field Excursion C17, 62p.

Macqueen, R.W. and Sandberg, C.A., 1970. Stratigraphy, age, and interregional correlation of the Exshaw Formation, Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, 18(1), p. 32-66.

Mamet, B.L. and Mason, D., 1968. Foraminiferal zonation of the Lower Carboniferous Connor Lakes section, British Columbia. Bulletin of Canadian Petroleum Geology, 16(2), p. 147-166.

Martin, H.L., 1967a. Mississippian subsurface geology, Rocky Mountain House area, Alberta. Geological Survey of Canada, Paper No. 65-27, 16p.

Martin, H.L., 1967b. Mississippian subsurface geology in the Pembina area. Geological Survey of Canada Paper No. 66-22, 17p.

Martin, H.L., 1969. The Banff and Exshaw Formations in the Wabamun Lake Area, Alberta (83G). Paper 69-7, Geological Survey of Canada, Department of Energy, Mines and Resources, 24p.

Mazzullo, S.J., Massullo, J., and Harris, P.M., 1985. Significance of Eolian Quartzose Sheet Sands on Emergent Carbonate Shelves: Permian of West Texas-New Mexico. American Association of Petroleum Geologists Bulletin, 69 (2), p. 284.

McConnell, R.G., 1887. Report on the geologic structure of a portion of the Rocky Mountains. Geological Survey of Canada Annual Report, V.2, 1886, Pt. D. p. 1-41.

Meijer Drees, N.C., 1986. Evaporitic deposits of western Canada. Geological Survey of Canada Paper 85-20.

Metcalfe, I., 1994. Late Paleozoic and Mesozoic Paleogeography of Eastern Pangea and Tethys. *In* Embry, A.F. and Beauchamp, B. (Eds.). Pangea: Global Environments and Resources. Canadian Society of Petroleum Geologists Memoir 17, p. 97-111.

Miall, A.D., 1990. Principles of Sedimentary Basin Analysis. Springer-Verlag, New York, 668p.

Middleton, G.V., 1963. Facies variation in Mississippian of Elbow Valley Area, Alberta, Canada. American Association of Petroleum Geologists Bulletin, 47(10), p. 1813-1827.

Miller, J., 1988. Microscopical Techniques: I. Slices, slides, stains and peels. *In* Tucker, M. (Ed.). Techniques in Sedimentology. Blackwell Scientific Publications, London, p. 86-107.

Moore, C.H., 1989. Carbonate Diagenesis and Porosity. Developments in Sedimentology 46, Elsevier Science Publishers, 338p.

Moore, D., 1984. Devonian and Mississippian stratigraphy and depositional environments in Big Hatchet Mountains of southwestern New Mexico. American Association of Petroleum Geologists Bulletin, 68(4), p. 509.

Moore, D.M. and Reynolds, Jr., R.C., 1989. X-Ray Diffraction and the Identification and Analysis of Clay Minerals. Oxford University Press, Oxford, 332p.

Moore, P.F., 1958. Late Paleozoic Stratigraphy in the Rocky Mountains and Foothills of Alberta - a critical historical review. *In* Goodman, A.J. (Ed.). Jurassic and Carboniferous of Western Canada. American Association of Petroleum Geologists Symposium, p. 145-176.

Mount, J.F., 1984. Mixing of siliciclastic and carbonate sediments in shallow shelf environments. Geology, 12, p. 432-435.

Mount, J.F., 1985. Mixed siliciclastic and carbonate sediments: a proposed first-order textural and compositional classification. Sedimentology, 32, p. 435-442.

Nelson, S.J. and Rudy, H.R., 1959. Stratigraphic position of the Shunda Formation. Journal of the Alberta Society of Petroleum Geologists, 7(11), p. 257-259.

Nelson, S.J. 1961. Mississippian faunas of western Canada. Geological Association of Canada, Special Paper No. 2., 39p.

Nittrouer, C.A., Bergenback, B.E., DeMaster, D.J., and Kircht, S.A., 1988. Accumulation of Mixed Carbonate and Siliciclastic Muds on the Continental Shelf of Eastern Spain. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 251-269.

O'Connell, S., 1990. The development of the Lower Carboniferous Peace River Embayment as determined from Banff and Pekisko formation depositional patterns. Bulletin of Canadian Petroleum Geology, 38A, p. 93-114.

Oliver, T.A. and Cowper, N.W., 1983. Wabamun salt removal and shale compaction effects, Rumsey area, Alberta. Bulletin of Canadian Petroleum Geology, 31, p. 161-168.

Oswald, D.H., 1968. Mississippian stratigraphy of the Nordegg area. Alberta Society of Petroleum Geologists Guidebook, Sixteenth Annual Field Conference, p. 42-47.

Parrish, J.T., 1982. Upwelling and Petroleum Source Beds, With Reference to Paleozoic. American Association of Petroleum Geologists Bulletin, 66(6), p. 750-774.

Parrish, J.T., 1993. Climate of the supercontinent Pangea. Journal of Geology, 101, p. 215-233.

Pasternack, I., 1988. Nature and Distribution of Mississippian Sun River Dolomite Porosity, West Flank of the Sweetgrass Arch, Northwestern Montana. *In* Goolsby, S.M. and Longman, M.W., (Eds.). Occurrence and Petrophysical Properties of Carbonate Reservoirs in the Rocky Mountain Region. The Rocky Mountain Association of Geologists, Denver, Colorado, p. 129-138.

Pemberton, S.G., MacEachern, J.A. and Frey, R.W., 1992. Trace fossil facies models: environmental and allostratigraphic significance. *In* Walker, R.G. and James, N.P. (Eds.). Facies Models. Geological Association of Canada, p. 47-72.

Penner, D.G., 1958. Mississippian stratigraphy of southern Alberta plains. *In* Goodman, A.J. (Ed.). Jurassic and Carboniferous of Western Canada. American Association of Petroleum Geologists Symposium. p. 260-288.

Peterson, F., 1988. A synthesis of the Jurassic system in the southern Rocky Mountain region. *In* Sloss, L.L. (Ed.), Sedimentary Cover-North American Craton; U.S.. Geological Society of America, The Geology of North America, V. D-2, p. 65-76.

Petryk, A.A., Mamet, B.L. and Macqueen, R.W., 1979. Preliminary foraminiferal zonation, Rundle Group and uppermost Banff Formation (Lower Carboniferous), southwestern Alberta. Bulletin of Canadian Petroleum Geology, 18(1), p. 84-103.

Pilkey, O.H., Bush, D.M., and Rodriguez, R.W., 1988. Carbonate Terrigenous Sedimentation on the North Puerto Rico Shelf. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 231-250.

Podruski, J.A., 1988. Contrasting Character of the Peace River and Sweetgrass Arches, Western Canada Sedimentary Basin. Geoscience Canada, 15 (2), p. 94-97.

Podruski, J.A., Barclay, J.E., Hamblin, A.P., Lee, P.J., Osadetz, K.G., Procter, R.M., and Taylor, G.C., 1988. Conventional Oil Resources of Western Canada. Geological Survey of Canada Paper 87-26, 149p.

Posamentier, H.W., Jervey, M.T., and Vail, P.R., 1988. Eustatic controls on clastic deposition. *In* Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., and Van Wagoner, J.C. (Eds.). Sea level changes: an integrated approach. Society of Economic Paleontologists and Mineralogists Special Publication 42, p. 109-154.

Poulton, T.P., Christopher, J.E., Hayes, B.J.R., Losert, J., Tittemore, J., and Gilchrist, R.D., 1994. Jurassic and Lowermost Cretaceous Strata of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 18, p. 297-316.

Precht, W.F. and Shepard, W., 1988. The structure, sedimentology and diagenesis of some Waulsortian carbonate buildups of Mississippian age from Montana. *In* Geldsetzer, H.J., James, N.P., and Tebbutt, G.E., (Eds.). Reefs, Canada and Adjacent Areas. Canadian Society of Petroleum Geologists, Memoir 13, p. 682-687.

Purser, B.H. and Evans, G., 1973. Regional Sedimentation along the Trucial Coast, SE Persian Gulf. *In* Purser, B.H. (Ed.). The Persian Gulf. Springer-Verlag, New York, p. 211-231.

Purser, B.H. and Seibold, E., 1973. The Principal Environmental Factors Influencing Holocene Sedimentation and Diagenesis in the Persian Gulf. *In* Purser, B.H. (Ed.). The Persian Gulf. Springer-Verlag, New York, p. 1-9.

Purser, B.H., Soliman, M. and M'Rabet, A., 1987. Carbonate, Evaporite, Siliciclastic Transitions in Quaternary Rift Sediments of the Northwestern Red Sea. Sedimentary Geology, 53, p. 247-267.

Putnam, P.E., Klovan, J.E., Hedinger, A.S., Hopkins, J.C., and Ward, G.S., 1995. The Mississippian succession in the plains region of southwestern Alberta and northwestern Montana: stratigraphic and structural architecture, trapping styles and future opportunities. Canadian Society of Petroleum Geologists, 22(8), p. 3-4.

Read, J.F., 1982. Carbonate Platforms of Passive (Extensional) Continental Margins: Types, Characteristics and Evolution. Tectonophysics, 81, p. 195-212.

Read, J.F., 1985. Carbonate Platform Facies Models. The American Association of Petroleum Geologists Bulletin, 69(1), p. 1-21.

Reijers, T.J.A., and Hsu, K.J., (Eds.), 1986. Manual of Carbonate Sedimentology: A Lexicographical Approach. Academic Press, Toronto, 302p.

Rich, J.L., 1951. Three critical environments of deposition, and criteria for recognition of rocks deposited in each of them. Geological Society of America Bulletin, 62, p. 1-20.

Richards, B.C., 1989. Upper Kaskaskia Sequence: Uppermost Devonian and Lower Carboniferous. *In* Ricketts, B.D. (Ed.). Western Canada Sedimentary Basin: A Case History. Canadian Society of Petroleum Geologists, Calgary, Ch. 9, p. 165-201.

Richards, B.C., Bamber, E.W., Higgins, A.C., and Utting, J., 1993. Carboniferous; Subchapter 4E. *In* Stott, D.F. and Aitken, J.D. (Eds.). Sedimentary Cover of the Craton in Canada. Geological Survey of Canada, Geology of Canada, No. 5, p. 202-271.

Richards, B.C., Barclay, J.E., Bryan, D., Hartling, A., Henderson, C.M., and Hinds, R.C., 1994. Carboniferous Strata of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 14, p. 221-250.

Richards, B.C. and Higgins, A.C., 1988. Devonian-Carboniferous boundary beds of the Palliser and Exshaw formations at Jura Creek, Rocky Mountains, southwestern Alberta. *In* McMillan, N.J., Embry, A.F., and Glass, D.J. (Eds.). Devonian of the World. Canadian Society of Petroleum Geologists Memoir 14, V.2, p. 399-412.

Roberts, H.H., 1987. Modern Carbonate-Siliciclastic Transitions: Humid and Arid Tropical Examples. Sedimentary Geology, 50, p. 25-65.

Roberts, H.H. and Murray, S.P., 1988. Gulfs of Northern Red Sea: Depositional Settings of Distinct Siliciclastic-Carbonate Interfaces. *In* Doyle, L.J. and Roberts, H.H. (Eds.). Carbonate-Clastic Transitions. Developments in Sedimentology 42, Elsevier, New York, p. 99-142.

Ross, C.A. and Ross, J.R.P., 1988. Late Paleozoic Transgressive-Regressive Deposition. *In* Wilgus, C.K. (Ed.). Sea-Level Changes-An Integrated Approach. Society of Economic Paleontologists and Mineralogists Special Publication No. 42, p. 227-247.

Rowley, D.B., Raymond, A., Parrish, J.T., Lottes, A.L., Scotese, C.R. and Ziegler, A.M., 1985. Carboniferous paleogeographic, phytogeographic, and paleoclimatic reconstructions. International Journal of Coal Geology, 5, p. 7-42.

Rutherford, R., 1984. A Student's Handbook to the Cambridge Stereoscan 250. Department of Geology & Geophysics, University of Calgary, 20p.

Sando, W.J., Bamber, E.W., and Richards, B.C., 1990. The rugose coral *Ankhelasma*-index to Visean (Lower Carboniferous) shelf margin in the western interior of North America. *In* Shorter Contributions of Paleontology and Stratigraphy. United States Geological Survey, Bulletin 1895, p. B1-B29.

Sarg, J.F., 1988. Carbonate Sequence Stratigraphy. *In* Wilgus, C.K. (Ed.). Sea-Level Changes - An Integrated Approach. Society of Economic Paleontologists and Mineralogists Special Publication No. 42, p. 155-181.

Savoy, L.E. and Mountjoy, E.W., 1995. Cratonic-Margin and Antler-Age Foreland Basin Strata (Middle Devonian to Lower Carboniferous) of the Southern Canadian Rocky Mountains and Adjacent Plains. *In* Dorobek, S.L. and Ross, G.M. (Eds.). Stratigraphic Evolution of Foreland Basins. Society of Economic Paleontologists and Mineralogists Special Publication No. 52, p. 214-231.

Schlumberger, 1995. Open Hole Basics.

Scotese, C.R., 1984. An Introduction to this Volume: Paleozoic Paleomagnetism and the Assembly of Pangea. *In* Van der Voo, R., Scotese, C.R. and Bonhommet, N. (Eds.). Plate Reconstruction from Paleozoic Paleomagnetism. American Geophysical Union Geodynamics Series, V.12, p. 1-10.

Scotese, C.R., Bambach, R.K., Barton, C., Van der Voo, R. and Ziegler, A.M., 1979. Paleozoic base maps. Journal of Geology, 87, p. 217-277.

Selley, R.C., 1985. Ancient Sedimentary Environments and their Subsurface Diagnosis. 3rd Edition. Cornell University Press, Ithaca, New York, 317p.

Shanmugam, G., Spalding, T.D., Rofheart, D.H., 1993. Process Sedimentology and Reservoir Quality of Deep-Marine Bottom-Current Reworked Sands (Sandy Contourites): An Example from the Gulf of Mexico. American Association of Petroleum Geologists Bulletin, 77 (7), p. 1241-1259.

Shinn, E.A., 1973. Sedimentary accretion along the leeward, southeast coast of Qatar Peninsula, Persian Gulf. *In* Purser, B.D. (Ed.). The Persian Gulf, Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Springer-Verlag, New York, p. 199-209.

Sloss, L.L., 1963. Sequences in the cratonic interior of North America. Geological Society of America Bulletin, 74, p. 93-113.

Smith, D.L., 1977. Transition from Deep- to Shallow-Water Carbonates, Paine Member, Lodgepole Formation, Central Montana. *In* Cook, H.E. and Enos, P. (Eds.). Deep-Water Carbonate Environments. Society of Economic Paleontologists and Mineralogists Special Publication 25, p. 187-201.

Smith, M.T., Dickenson, W.R., and Gehrels, G.E., 1993. Contractional nature of Devonian-Mississippian Antler Tectonism along the North American continental margin. Geology, 21, p. 21-24.

Specht, R.W. and Brenner, R.L., 1979. Storm-Wave Genesis of Bioclastic Carbonates in Upper Jurassic Epicontinental Mudstones, East-Central Wyoming. Journal of Sedimentary Petrology, 49(4), p. 1307-1322.

Spreng, A.C., 1953. Mississippian cyclic sedimentation, Sunwapta Pass area, Alberta, Canada. American Association of Petroleum Geologists Bulletin, 37, p. 665-689.

Stoakes, F.A., 1992. Early Mississippian Megasequences. *In* Wendte, J., Stoakes, F.A. and Campbell, C.V. (Eds.). Devonian-Early Mississippian Carbonates of the Western Canada Sedimentary Basin: A Sequence Stratigraphic Framework. Society of Economic Paleontologists and Mineralogists Short Course No. 28, Calgary, p. 241-249.

Switzer, S.B., Holland, W.G., Christie, D.S., Graf, G.C., Hedinger, A.S., McAuley, R.J., Wierzbicki, R.A. and Packard, J.J., 1994. Devonian Woodbend-Winterburn Strata of the Western Canada Sedimentary Basin. *In* Mossop, G.D. and Shetsen, I. (Comps.). Geological Atlas of the Western Canada Sedimentary Basin. Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, Ch. 12, p. 165-202.

Thomas, A., 1984. Dynamic stratigraphy of epicontinental carbonates, Upper Muschelkalk (Middle Triassic), South-German Basin. Neues Jahrbuch fuer Geologie und Palaeontologie, Abhandlungen, 169(2), p. 127-159.

Trewin, N., 1988. Use of the scanning electron microscope in sedimentology. *In* Tucker, M. (Ed.). Techniques in Sedimentology. Blackwell Scientific Publications, London, p. 229-273.

Tucker, M.E., 1991. Sedimentary Petrology. Blackwell Scientific Publications, Oxford, 260p.

Tucker, M.E., Calvet, F., and Hunt, D., 1993. Sequence stratigraphy of carbonate ramps: system tracts, models and application to the Muschelkalk carbonate platforms of eastern Spain. Special Publication of the International Association of Sedimentology, 18, p. 397-415.

Tucker, M.E. and Wright, V.P., 1990. Carbonate Sedimentology. Blackwell Scientific Publications, Oxford, 482p.

Vail, P.R., 1987. Seismic stratigraphy interpretation using sequence stratigraphy: Part 1. Seismic stratigraphy interpretation procedure. American Association of Petroleum Geologists Studies in Geology 27(1), p. 1-10.

Van der Voo, R., 1988. Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: Comparisons of paleomagnetism with paleoclimatology and biogeographical patterns. Geological Society of America Bulletin, 100, p. 311-324.

Van Der Zwan, C.J., Boulter, M.C. and Hubbard, R.N.L.B., 1985. Climatic Change During The Lower Carboniferous In Euramerica, Based On Multivariate Statistical Analysis Of Palynological Data. Palaeogeography, Palaeoclimatology, Palaeoecology, 52, p. 1-20.

Warren, P.S., 1927. Banff area, Alberta. Geological Survey of Canada, Memoir 153, 94p.

Warren, P.S., 1937. Age of the Exshaw shale in the Canadian Rockies.. American Journal of Science, 33(198), p. 454-457.

Watney, W., 1979. Gammaray-neutron cross-plots as an aid to sedimentological analysis. *In* Gill, D. and Merrian, D.F. (Eds.). Geomathematical and petrophysical studies in sedimentology. Computer Geology, 3, p. 81-100.

Wilson, J.L., 1975. Carbonate Facies in Geologic History. Springer Verlag, New York, 471p.

Wilson, J.L. and Jordan, C., 1983. Middle Shelf Environment. *In* Scholle, P.A., Bebout, D.G., and Moore, C.H. (Eds.). Carbonate Depositional Environments. American Association of Petroleum Geologists Memoir 33, p. 297-343.

Witze, B.J. and Heckel, P.H., 1988. Paleoclimatic indicators and inferred Devonian paleolatitudes of Euramerica. *In* McMillan, N.J., Embry, A.F. and Glass, D.J. (Eds.). Devonian of the World. Canadian Society of Petroleum Geologists Memoir 14, V.1, p. 49-63.

Wright, V.P., 1986. Facies sequences on a carbonate ramp: the Carboniferous Limestone of South Wales. Sedimentology, 33, p. 221-241.

Wright, V.P., 1987. The evolution of the early Carboniferous Limestone province in southwest Britain. Geological Magazine, 124(5), p. 477-480.

Wright, V.P., 1990. Equatorial aridity and climatic oscillations during the early Carboniferous, southern Britain. Journal of the Geological Society of London, 147, p. 359-363.

Wright, V.P. and Faulkner, T.J., 1990. Sediment dynamics of Early Carboniferous ramps: a proposal. Geological Journal, 25, p. 139-144.

Yancey, T.E., 1991. Controls on carbonate and siliciclastic sediment deposition on a mixed carbonate-siliciclastic shelf (Pennsylvanian Eastern Shelf of north Texas. *In* Franseen, E.K., Watney, W.L., Kendall, C.G., and Ross, W. (Eds.). Sedimentary Modeling: Computer Simulations and Methods for Improved Parameter Definition. Kansas Geological Survey, Bulletin 233, p. 263-272.

Ziegler, P.A., 1988. Laurussia-The Old Red Continent. *In* McMillan, N.J., Embry, A.F. and Glass, D.J. (Eds.). Devonian of the World. Canadian Society of Petroleum Geologists Memoir 14, V.1, p. 14-48.

APPENDIX A

GEOPHYSICAL WELL LOGS TOPS DATABASE

APPENDIX A:

Legend
NP= not present
NDE= well not deep enough
NPL= no porosity log

* All tops are reported in metres.

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
02/06-01-021-07W400	1037.3	NP	NP	NDE	NDE	NDE
02/14-05-021-07W400	1014	NDE	NDE	NDE	NDE	NDE
00/08-06-021-07W400	1007	NDE	NDE	NDE	NDE	NDE
02/06-07-021-07W400	1019	NDE	NDE	NDE	NDE	NDE
00/09-09-021-07W400	1019.6	NDE	NDE	NDE	NDE	NDE
00/07-12-021-07W400	1043.6	NDE	NDE	NDE	NDE	NDE
00/10-12-021-07W400	1059.5	NDE	NDE	NDE	NDE	NDE
00/14-15-021-07W400	1041.7	NDE	NDE	NDE	NDE	NDE
00/15-16-021-07W400	1042.4	NP	NP	1145.1	1148.5	1159.8
00/11-18-021-07W400	997	NDE	NDE	NDE	NDE	NDE
00/12-22-021-07W400	1029	NDE	NDE	NDE	NDE	NDE
02/06-23-021-07W400	1032	NDE	NDE	NDE	NDE	NDE
00/15-29-021-07W400	994.7	NDE	NDE	NDE	NDE	NDE
00/15-31-021-07W400	994.7	NDE	NDE	NDE	NDE	NDE
00/03-34-021-07W400	1010.4	NP	NP	1133.9	NDE	NDE
00/11-34-021-07W400	998.8	NP	NP	1118.6	1121.7	1135.4
00/16-34-021-07W400	971	NP	NP	1098	1101.3	1115
00/11-35-021-07W400	970	NDE	NDE	NDE	NDE	NDE
00/06-36-021-07W400	985.4	NDE	NDE	NDE	NDE	NDE
00/07-36-021-07W400	952.6	NDE	NDE	NDE	NDE	NDE
02/06-02-021-08W400	1038	NDE	NDE	NDE	NDE	NDE
02/06-03-021-08W400	1023.3	NDE	NDE	NDE	NDE	NDE
00/12-03-021-08W400	1034.5	NP	NP	NDE	NDE	NDE
00/02-05-021-08W400	975	NDE	NDE	NDE	NDE	NDE
00/04-05-021-08W400	984.5	NDE	NDE	NDE	NDE	NDE
00/06-05-021-08W400	989	NDE	NDE	NDE	NDE	NDE
00/07-05-021-08W400	983	NDE	NDE	NDE	NDE	NDE
00/14-05-021-08W400	995.5	NP	NP	NDE	NDE	NDE
00/07-06-021-08W400	985.8	NDE	NDE	NDE	NDE	NDE
00/08-06-021-08W400	1023.5	NDE	NDE	NDE	NDE	NDE
00/09-06-021-08W400	990	NDE	NDE	NDE	NDE	NDE
00/10-06-021-08W400	995.5	NDE	NDE	NDE	NDE	NDE
00/11-06-021-08W400	994	NDE	NDE	NDE	NDE	NDE
00/15-06-021-08W400	995	NDE	NDE	NDE	NDE	NDE
00/16-06-021-08W400	992	NDE	NDE	NDE	NDE	NDE
00/01-07-021-08W400	992.8	NDE	NDE	NDE	NDE	NDE
00/02-07-021-08W400	994.3	NDE	NDE	NDE	NDE	NDE
00/03-07-021-08W400	999	NDE	NDE	NDE	NDE	NDE
00/04-07-021-08W400	996.3	NDE	NDE	NDE	NDE	NDE
00/05-07-021-08W400	993	NDE	NDE	NDE	NDE	NDE
00/06-07-021-08W400	1002.8	NDE	NDE	NDE	NDE	NDE
00/07-07-021-08W400	994.8	NDE	NDE	NDE	NDE	NDE
00/08-07-021-08W400	1008.9	NDE	NDE	NDE	NDE	NDE
00/09-07-021-08W400	991	NDE	NDE	NDE	NDE	NDE
00/11-07-021-08W400	1019.3	NDE	NDE	NDE	NDE	NDE
00/12-07-021-08W400	994	NDE	NDE	NDE	NDE	NDE
00/13-07-021-08W400	1012	NDE	NDE	NDE	NDE	NDE
00/14-07-021-08W400	999.1	NDE	NDE	NDE	NDE	NDE
00/15-07-021-08W400	1012.3	NDE	NDE	NDE	NDE	NDE
00/16-07-021-08W400	1000.8	NDE	NDE	NDE	NDE	NDE
00/03-08-021-08W400	1005	NDE	NDE	NDE	NDE	NDE
00/04-08-021-08W400	987	NDE	NDE	NDE	NDE	NDE
00/05-08-021-08W400	992.1	NDE	NDE	NDE	NDE	NDE
00/12-08-021-08W400	985	NDE	NDE	NDE	NDE	NDE
00/15-09-021-08W400	1024	NDE	NDE	NDE	NDE	NDE
00/10-10-021-08W400	1014.4	NDE	NDE	NDE	NDE	NDE
00/09-12-021-08W400	1014	NDE	NDE	NDE	NDE	NDE
00/10-13-021-08W400	961.3	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/13-14-021-08W400	1013	NDE	NDE	NDE	NDE	NDE
00/05-16-021-08W400	1022.7	NDE	NDE	NDE	NDE	NDE
00/07-16-021-08W400	1023	NDE	NDE	NDE	NDE	NDE
00/05-17-021-08W400	1028	NDE	NDE	NDE	NDE	NDE
00/01-18-021-08W400	999	NDE	NDE	NDE	NDE	NDE
00/04-18-021-08W400	1009.8	NP	NP	1129.3	1133.2	1148.5
02/04-18-021-08W400	1010	NDE	NDE	NDE	NDE	NDE
03/04-18-021-08W400	1012	NDE	NDE	NDE	NDE	NDE
00/05-18-021-08W400	1008.8	NDE	NDE	NDE	NDE	NDE
00/06-18-021-08W400	1012.9	NDE	NDE	NDE	NDE	NDE
02/06-18-021-08W400	1015	NP	NP	NDE	NDE	NDE
00/07-18-021-08W400	1022	NDE	NDE	NDE	NDE	NDE
00/08-18-021-08W400	1022.6	NDE	NDE	NDE	NDE	NDE
00/10-18-021-08W400	1014	NDE	NDE	NDE	NDE	NDE
00/11-18-021-08W400	1007.8	NDE	NDE	NDE	NDE	NDE
00/12-18-021-08W400	1006.4	NDE	NDE	NDE	NDE	NDE
00/15-18-021-08W400	1009	NDE	NDE	NDE	NDE	NDE
00/01-19-021-08W400	996.1	NDE	NDE	NDE	NDE	NDE
00/04-19-021-08W400	993	NDE	NDE	NDE	NDE	NDE
02/14-19-021-08W400	985	NDE	NDE	NDE	NDE	NDE
00/06-20-021-08W400	999.6	NDE	NDE	NDE	NDE	NDE
00/09-20-021-08W400	1013.6	NDE	NDE	NDE	NDE	NDE
00/12-23-021-08W400	1027	NDE	NDE	NDE	NDE	NDE
02/14-23-021-08W400	1032	NDE	NDE	NDE	NDE	NDE
00/03-24-021-08W400	1019.6	NDE	NDE	NDE	NDE	NDE
00/10-24-021-08W400	1007.7	NDE	NDE	NDE	NDE	NDE
02/06-26-021-08W400	1030	NDE	NDE	NDE	NDE	NDE
02/16-27-021-08W400	1004.6	NDE	NDE	NDE	NDE	NDE
00/10-28-021-08W400	1015.9	NDE	NDE	NDE	NDE	NDE
00/05-29-021-08W400	982	NDE	NDE	NDE	NDE	NDE
00/11-29-021-08W400	982	NDE	NDE	NDE	NDE	NDE
00/13-31-021-08W400	999.5	NDE	NDE	NDE	NDE	NDE
02/06-32-021-08W400	1000	NDE	NDE	NDE	NDE	NDE
00/13-32-021-08W400	994	NDE	NDE	NDE	NDE	NDE
00/10-33-021-08W400	997.6	NDE	NDE	NDE	NDE	NDE
02/16-33-021-08W400	998.5	NDE	NDE	NDE	NDE	NDE
00/06-34-021-08W400	997.5	NDE	NDE	NDE	NDE	NDE
00/06-35-021-08W400	1049	NDE	NDE	NDE	NDE	NDE
00/06-36-021-08W400	1016	NDE	NDE	NDE	NDE	NDE
00/04-01-021-09W400	983.7	NDE	NDE	NDE	NDE	NDE
00/10-01-021-09W400	988	NP	NP	NDE	NDE	NDE
00/16-01-021-09W400	1004.8	NDE	NDE	NDE	NDE	NDE
00/06-02-021-09W400	1027.2	NDE	NDE	NDE	NDE	NDE
00/06-07-021-09W400	1040	NP	NP	1150.6	1153.4	1164.6
00/16-08-021-09W400	1010	NDE	NDE	NDE	NDE	NDE
02/10-09-021-09W400	1013	NP	NP	1121	1124	NDE
00/09-12-021-09W400	995	NDE	NDE	NDE	NDE	NDE
00/12-13-021-09W400	990	NP	NP	1105.5	1109	NDE
02/06-14-021-09W400	1003	NDE	NDE	NDE	NDE	NDE
00/02-15-021-09W400	995	NDE	NDE	NDE	NDE	NDE
00/04-16-021-09W400	1000	NDE	NDE	NDE	NDE	NDE
00/03-17-021-09W400	1009	NDE	NDE	NDE	NDE	NDE
00/06-19-021-09W400	1036	NDE	NDE	NDE	NDE	NDE
00/04-20-021-09W400	1011.9	NDE	NDE	NDE	NDE	NDE
00/03-21-021-09W400	985	NP	NP	1097.5	1100	1112
00/11-22-021-09W400	1000	NP	NP	1089	1091.8	1103
00/05-23-021-09W400	980	NP	NP	1101.5	1105	NDE
00/04-25-021-09W400	986	NDE	NDE	NDE	NDE	NDE
00/02-26-021-09W400	978	NDE	NDE	NDE	NDE	NDE
00/05-27-021-09W400	959	NP	NP	1081	1083.5	1095.5
00/06-28-021-09W400	959.8	NDE	NDE	NDE	NDE	NDE
00/10-29-021-09W400	979.6	NDE	NDE	NDE	NDE	NDE
00/07-30-021-09W400	1013.8	NDE	NDE	NDE	NDE	NDE
00/02-35-021-09W400	976.7	NDE	NDE	NDE	NDE	NDE
00/02-36-021-09W400	985.5	NDE	NDE	NDE	NDE	NDE
02/16-01-021-10W400	1027.5	NP	NP	1145	1147.5	1158

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/08-11-021-10W400	1025	NDE	NDE	NDE	NDE	NDE
00/07-13-021-10W400	1043	NDE	NDE	NDE	NDE	NDE
00/10-15-021-10W400	1069.5	NDE	NDE	NDE	NDE	NDE
00/07-16-021-10W400	1042.4	NDE	NDE	NDE	NDE	NDE
00/10-20-021-10W400	1016.2	NDE	NDE	NDE	NDE	NDE
00/10-25-021-10W400	1026.3	NDE	NDE	NDE	NDE	NDE
00/06-26-021-10W400	1009.5	NDE	NDE	NDE	NDE	NDE
02/06-29-021-10W400	1005.6	NDE	NDE	NDE	NDE	NDE
00/14-30-021-10W400	994	NP	NP	1116	1119.5	1130
00/11-31-021-10W400	994.3	NDE	NDE	NDE	NDE	NDE
00/16-32-021-10W400	995	NDE	NDE	NDE	NDE	NDE
00/10-33-021-10W400	1010	NDE	NDE	NDE	NDE	NDE
00/10-21-021-11W400	1024.7	NDE	NDE	NDE	NDE	NDE
00/11-22-021-11W400	988.5	NDE	NDE	NDE	NDE	NDE
00/10-24-021-11W400	1006.8	NDE	NDE	NDE	NDE	NDE
00/10-25-021-11W400	1000	NDE	NDE	NDE	NDE	NDE
00/07-26-021-11W400	993	NP	NP	1114	1117.5	1131
00/06-27-021-11W400	1000	NP	NP	1112.5	1115.5	1125.5
00/06-30-021-11W400	985	NDE	NDE	NDE	NDE	NDE
00/11-04-021-12W400	992.7	NDE	NDE	NDE	NDE	NDE
00/14-10-021-12W400	1023	NDE	NDE	NDE	NDE	NDE
00/07-17-021-12W400	986	NP	NP	1122.6	1125.9	1132.3
00/07-27-021-12W400	990.3	NP	NP	1119.5	1121.7	1132.9
00/07-31-021-12W400	980.2	NP	NP	1118.6	1120.1	1133.9
02/10-36-021-12W400	974	NDE	NDE	NDE	NDE	NDE
00/06-13-021-13W400	1064.7	NP	NP	NDE	NDE	NDE
00/07-13-021-13W400	1011.9	NP	NP	NDE	NDE	NDE
00/14-14-021-13W400	1017.4	NP	NP	NDE	NDE	NDE
00/10-16-021-13W400	1036.3	NP	NP	1164.3	1165.9	1176.5
00/14-30-021-13W400	1045.3	NDE	NDE	NDE	NDE	NDE
00/07-16-021-14W400	1109.5	NP	NP	1240.2	1246.6	1252.1
00/12-20-021-14W400	1110	NP	NP	1243	1249	1254.5
00/08-01-021-15W400	1109.6	NDE	NDE	NDE	NDE	NDE
00/12-31-021-15W400	1092.5	NDE	NDE	NDE	NDE	NDE
00/06-01-021-16W400	1140.6	NDE	NDE	NDE	NDE	NDE
00/07-08-021-16W400	1155.2	NDE	NDE	NDE	NDE	NDE
00/06-22-021-16W400	1172	NP	NP	NDE	NDE	NDE
00/06-33-021-16W400	1145.6	NP	NP	NDE	NDE	NDE
00/11-01-022-07W400	930.9	NDE	NDE	NDE	NDE	NDE
00/07-02-022-07W400	947.9	NDE	NDE	NDE	NDE	NDE
00/04-03-022-07W400	996	NP	NP	1118	1121.4	1135.1
00/08-03-022-07W400	975	NP	NP	1080.5	1082.5	1096
00/06-06-022-07W400	1018.6	NDE	NDE	NDE	NDE	NDE
00/07-11-022-07W400	927.5	NDE	NDE	NDE	NDE	NDE
00/07-12-022-07W400	945	NDE	NDE	NDE	NDE	NDE
00/11-13-022-07W400	929	NDE	NDE	NDE	NDE	NDE
00/07-15-022-07W400	909.5	NDE	NDE	NDE	NDE	NDE
00/08-16-022-07W400	922	NP	NP	1053	1056	1070
00/06-17-022-07W400	952.8	NDE	NDE	NDE	NDE	NDE
00/06-20-022-07W400	918.1	NDE	NDE	NDE	NDE	NDE
00/06-21-022-07W400	906.2	NDE	NDE	NDE	NDE	NDE
00/06-22-022-07W400	893.5	NDE	NDE	NDE	NDE	NDE
00/07-23-022-07W400	877.2	NDE	NDE	NDE	NDE	NDE
00/10-25-022-07W400	827.5	NDE	NDE	NDE	NDE	NDE
00/11-31-022-07W400	857.7	NDE	NDE	NDE	NDE	NDE
00/10-34-022-07W400	887	NDE	NDE	NDE	NDE	NDE
00/06-35-022-07W400	836.7	NDE	NDE	NDE	NDE	NDE
00/11-01-022-08W400	1008.6	NDE	NDE	NDE	NDE	NDE
00/10-03-022-08W400	1023.5	NDE	NDE	NDE	NDE	NDE
00/09-04-022-08W400	1001.1	NDE	NDE	NDE	NDE	NDE
00/10-04-022-08W400	991.5	NP	NP	NDE	NDE	NDE
02/06-05-022-08W400	1010	NDE	NDE	NDE	NDE	NDE
00/06-06-022-08W400	999.7	NDE	NDE	NDE	NDE	NDE
00/05-07-022-08W400	995.6	NP	NP	NDE	NDE	NDE
00/06-08-022-08W400	982.1	NDE	NDE	NDE	NDE	NDE
00/07-11-022-08W400	1012.2	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-10-022-08W400	954	NDE	NDE	NDE	NDE	NDE
00/07-15-022-08W400	988.2	NDE	NDE	NDE	NDE	NDE
00/05-16-022-08W400	997.6	NDE	NDE	NDE	NDE	NDE
00/05-17-022-08W400	997.6	NP	NP	NDE	NDE	NDE
00/06-18-022-08W400	986	NDE	NDE	NDE	NDE	NDE
00/13-21-022-08W400	955	NP	NP	NDE	NDE	NDE
00/10-25-022-08W400	901.6	NDE	NDE	NDE	NDE	NDE
00/07-28-022-08W400	914.4	NDE	NDE	NDE	NDE	NDE
00/06-29-022-08W400	847	NDE	NDE	NDE	NDE	NDE
00/12-32-022-08W400	917.8	NDE	NDE	NDE	NDE	NDE
00/07-35-022-08W400	900.1	NP	NP	NDE	NDE	NDE
00/16-01-022-09W400	988	NP	NP	NDE	NDE	NDE
00/15-02-022-09W400	865.5	NDE	NDE	NDE	NDE	NDE
00/11-03-022-09W400	903	NDE	NDE	NDE	NDE	NDE
00/06-05-022-09W400	981.8	NDE	NDE	NDE	NDE	NDE
00/06-08-022-09W400	862.6	NDE	NDE	NDE	NDE	NDE
00/06-09-022-09W400	868.1	NDE	NDE	NDE	NDE	NDE
00/11-10-022-09W400	984.8	NDE	NDE	NDE	NDE	NDE
00/10-12-022-09W400	995.2	NP	NP	NDE	NDE	NDE
00/03-13-022-09W400	949.2	NDE	NDE	NDE	NDE	NDE
00/02-15-022-09W400	982.3	NDE	NDE	NDE	NDE	NDE
00/11-16-022-09W400	965	NDE	NDE	NDE	NDE	NDE
00/10-18-022-09W400	868.7	NDE	NDE	NDE	NDE	NDE
00/07-20-022-09W400	870	NDE	NDE	NDE	NDE	NDE
00/07-21-022-09W400	976.7	NDE	NDE	NDE	NDE	NDE
00/06-22-022-09W400	969	NDE	NDE	NDE	NDE	NDE
00/06-23-022-09W400	973.5	NDE	NDE	NDE	NDE	NDE
00/06-26-022-09W400	962	NDE	NDE	NDE	NDE	NDE
00/05-27-022-09W400	953	NDE	NDE	NDE	NDE	NDE
02/04-28-022-09W400	967.5	NDE	NDE	NDE	NDE	NDE
00/09-28-022-09W400	972.5	NP	NP	1099	1102	1114
00/10-29-022-09W400	960.7	NDE	NDE	NDE	NDE	NDE
00/10-30-022-09W400	953	NDE	NDE	NDE	NDE	NDE
00/15-31-022-09W400	963.7	NDE	NDE	NDE	NDE	NDE
00/05-33-022-09W400	962	NP	NP	NDE	NDE	NDE
02/04-34-022-09W400	943	NDE	NDE	NDE	NDE	NDE
00/03-35-022-09W400	948.3	NP	NP	NDE	NDE	NDE
00/12-36-022-09W400	919	NP	NP	NDE	NDE	NDE
00/06-01-022-10W400	1024	NDE	NDE	NDE	NDE	NDE
00/10-02-022-10W400	1005.2	NP	NP	NDE	NDE	NDE
00/06-10-022-10W400	970	NDE	NDE	NDE	NDE	NDE
00/08-12-022-10W400	1004.5	NP	NP	1129.5	1132.5	1146
00/09-15-022-10W400	962.5	NDE	NDE	NDE	NDE	NDE
00/12-17-022-10W400	973	NP	NP	NDE	NDE	NDE
00/03-18-022-10W400	978.5	NDE	NDE	NDE	NDE	NDE
00/01-20-022-10W400	975	NDE	NDE	NDE	NDE	NDE
00/11-21-022-10W400	977.2	NDE	NDE	NDE	NDE	NDE
00/04-23-022-10W400	965.2	NDE	NDE	NDE	NDE	NDE
00/12-26-022-10W400	961	NDE	NDE	NDE	NDE	NDE
00/06-27-022-10W400	968.3	NDE	NDE	NDE	NDE	NDE
00/06-33-022-10W400	957.7	NDE	NDE	NDE	NDE	NDE
00/06-34-022-10W400	957.1	NDE	NDE	NDE	NDE	NDE
00/11-35-022-10W400	964.7	NDE	NDE	NDE	NDE	NDE
00/06-36-022-10W400	955.5	NDE	NDE	NDE	NDE	NDE
00/06-03-022-11W400	982.4	NDE	NDE	NDE	NDE	NDE
00/16-05-022-11W400	1022	NDE	NDE	NDE	NDE	NDE
00/06-13-022-11W400	975.5	NDE	NDE	NDE	NDE	NDE
00/05-15-022-11W400	975.5	NP	NP	1111	1114.5	1125
00/09-19-022-11W400	965	NDE	NDE	NDE	NDE	NDE
00/11-21-022-11W400	968	NDE	NDE	NDE	NDE	NDE
00/04-22-022-11W400	972.3	NP	NP	NDE	NDE	NDE
02/14-26-022-11W400	967.6	NDE	NDE	NDE	NDE	NDE
00/07-34-022-11W400	967	NDE	NDE	NDE	NDE	NDE
02/08-35-022-11W400	962	NDE	NDE	NDE	NDE	NDE
00/11-02-022-12W400	973	NP	NP	NDE	NDE	NDE
00/06-03-022-12W400	974	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Silkstone Top	Silkstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/10-05-022-12W400	980.2	NP	NP	NDE	NDE	NDE
00/07-11-022-12W400	969	NDE	NDE	NDE	NDE	NDE
00/14-12-022-12W400	970	NDE	NDE	NDE	NDE	NDE
00/10-16-022-12W400	973.1	NDE	NDE	NDE	NDE	NDE
02/14-18-022-12W400	957	NP	NP	NDE	NDE	NDE
02/08-19-022-12W400	975	NDE	NDE	NDE	NDE	NDE
00/07-20-022-12W400	973.8	NDE	NDE	NDE	NDE	NDE
00/13-23-022-12W400	973.2	NP	NP	1102.8	1104.9	1117.1
00/11-27-022-12W400	988.2	NDE	NDE	NDE	NDE	NDE
00/10-29-022-12W400	979.9	NDE	NDE	NDE	NDE	NDE
02/16-31-022-12W400	971.8	NDE	NDE	NDE	NDE	NDE
00/12-35-022-12W400	938	NDE	NDE	NDE	NDE	NDE
00/03-36-022-12W400	927.2	NDE	NDE	NDE	NDE	NDE
00/01-06-022-13W400	1045.5	NP	NP	1173.5	1175	1190.2
00/04-06-022-13W400	1065.3	NP	NP	1187.2	1188.7	1199.4
00/14-07-022-13W400	1077.7	NP	NP	NDE	NDE	NDE
00/14-15-022-13W400	1014	NP	NP	1146	1151.5	1162
00/10-22-022-13W400	1007.7	NDE	NDE	NDE	NDE	NDE
00/16-23-022-13W400	966.5	NP	NP	NDE	NDE	NDE
00/15-25-022-13W400	968	NP	NP	NDE	NDE	NDE
00/05-28-022-13W400	1031.7	NP	NP	1156.4	1159.8	1170.4
02/06-32-022-13W400	1078	NDE	NDE	NDE	NDE	NDE
00/12-08-022-14W400	1072.9	NDE	NDE	NDE	NDE	NDE
00/10-10-022-14W400	1061.9	NDE	NDE	NDE	NDE	NDE
00/10-15-022-14W400	1057.7	NDE	NDE	NDE	NDE	NDE
00/06-18-022-14W400	1049.7	NDE	NDE	NDE	NDE	NDE
00/12-25-022-14W400	1025.7	NDE	NDE	NDE	NDE	NDE
00/06-05-022-15W400	1074.5	NP	NP	NDE	NDE	NDE
00/14-06-022-15W400	1075.6	NP	NP	NDE	NDE	NDE
00/10-27-022-15W400	1100.3	NDE	NDE	NDE	NDE	NDE
00/09-28-022-15W400	1107.9	NDE	NDE	NDE	NDE	NDE
00/14-04-022-16W400	1095.3	NP	NP	NDE	NDE	NDE
00/14-13-022-16W400	1128.6	NP	NP	NDE	NDE	NDE
00/06-24-022-16W400	1115	NDE	NDE	NDE	NDE	NDE
00/06-33-022-16W400	1148	NDE	NDE	NDE	NDE	NDE
00/11-04-023-07W400	833.9	NDE	NDE	NDE	NDE	NDE
00/06-05-023-07W400	846.7	NDE	NDE	NDE	NDE	NDE
00/11-08-023-07W400	814	NDE	NDE	NDE	NDE	NDE
00/06-11-023-07W400	807.7	NDE	NDE	NDE	NDE	NDE
00/01-13-023-07W400	907.7	NP	NP	1034.8	1037.8	1055.2
00/11-16-023-07W400	898.2	NDE	NDE	NDE	NDE	NDE
00/06-17-023-07W400	810.2	NP	NP	953.1	955.2	NDE
00/10-18-023-07W400	829	NDE	NDE	NDE	NDE	NDE
00/02-19-023-07W400	827.5	NP	NP	NDE	NDE	NDE
00/07-20-023-07W400	892.1	NDE	NDE	NDE	NDE	NDE
00/12-21-023-07W400	880	NDE	NDE	NDE	NDE	NDE
00/14-22-023-07W400	891.6	NP	NP	NDE	NDE	NDE
00/06-25-023-07W400	944.9	961	969	NDE	NDE	NDE
00/02-31-023-07W400	914	935	944	NDE	NDE	NDE
00/10-32-023-07W400	927	942	946.8	NDE	NDE	NDE
00/11-33-023-07W400	899	NP	NP	1035	1038	1052.5
00/06-34-023-07W400	941.8	947.9	952.8	NDE	NDE	NDE
00/16-36-023-07W400	982	991.5	995	NDE	NDE	NDE
00/12-01-023-08W400	821.5	NP	NP	NDE	NDE	NDE
00/07-04-023-08W400	839	NP	NP	NDE	NDE	NDE
00/06-06-023-08W400	927.8	NP	NP	NDE	NDE	NDE
00/06-07-023-08W400	927.7	NP	NP	NDE	NDE	NDE
00/07-12-023-08W400	832.1	NP	NP	NDE	NDE	NDE
00/06-18-023-08W400	905	NP	NP	NDE	NDE	NDE
00/06-21-023-08W400	896.7	NP	NP	1040.6	1044.2	NDE
00/06-24-023-08W400	847.3	NDE	NDE	NDE	NDE	NDE
00/07-31-023-08W400	922.3	NP	NP	1060.1	1065	NDE
00/10-01-023-09W400	924.5	NP	NP	NDE	NDE	NDE
00/05-02-023-09W400	936.3	NP	NP	NDE	NDE	NDE
02/03-06-023-09W400	946	NDE	NDE	NDE	NDE	NDE
00/08-06-023-09W400	953.1	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/10-06-023-09W400	951.6	NDE	NDE	NDE	NDE	NDE
00/06-07-023-09W400	963.7	NDE	NDE	NDE	NDE	NDE
00/07-08-023-09W400	958.3	NDE	NDE	NDE	NDE	NDE
00/09-09-023-09W400	941	NDE	NDE	NDE	NDE	NDE
00/06-10-023-09W400	945	NP	NP	NDE	NDE	NDE
00/06-12-023-09W400	921.5	NP	NP	NDE	NDE	NDE
00/07-13-023-09W400	907.7	NDE	NDE	NDE	NDE	NDE
00/06-15-023-09W400	938.8	NP	NP	NDE	NDE	NDE
00/01-17-023-09W400	951.8	NDE	NDE	NDE	NDE	NDE
00/10-18-023-09W400	960	NDE	NDE	NDE	NDE	NDE
00/07-19-023-09W400	944.9	NDE	NDE	NDE	NDE	NDE
00/10-27-023-09W400	917	NDE	NDE	NDE	NDE	NDE
00/06-28-023-09W400	973	NDE	NDE	NDE	NDE	NDE
00/11-31-023-09W400	931.2	NP	NP	1068.3	1073.2	1084.5
00/06-32-023-09W400	942.7	947.9	953.1	NDE	NDE	NDE
00/14-34-023-09W400	969	NP	NP	1096	1099	NDE
00/05-01-023-10W400	950.6	NDE	NDE	NDE	NDE	NDE
00/16-02-023-10W400	953	NDE	NDE	NDE	NDE	NDE
00/06-03-023-10W400	954	NDE	NDE	NDE	NDE	NDE
00/04-04-023-10W400	947.9	NP	NP	1083.6	1087.5	1100.3
02/06-05-023-10W400	963	NP	NP	NDE	NDE	NDE
00/01-07-023-10W400	954.5	NP	NP	NDE	NDE	NDE
00/03-08-023-10W400	952	NP	NP	NDE	NDE	NDE
00/06-10-023-10W400	985.1	NDE	NDE	NDE	NDE	NDE
00/15-11-023-10W400	954	NDE	NDE	NDE	NDE	NDE
00/06-12-023-10W400	947	NDE	NDE	NDE	NDE	NDE
00/01-13-023-10W400	953.4	NP	NP	1088.1	1090.3	NDE
00/11-14-023-10W400	941.8	NDE	NDE	NDE	NDE	NDE
00/06-15-023-10W400	952.2	NDE	NDE	NDE	NDE	NDE
00/12-16-023-10W400	945.3	NDE	NDE	NDE	NDE	NDE
00/11-17-023-10W400	946	NDE	NDE	NDE	NDE	NDE
02/14-18-023-10W400	947.6	NP	NP	NDE	NDE	NDE
00/11-19-023-10W400	941.3	NP	NP	NDE	NDE	NDE
00/06-20-023-10W400	944.8	NDE	NDE	NDE	NDE	NDE
00/10-21-023-10W400	951.3	NP	NP	NDE	NDE	NDE
00/12-22-023-10W400	962	NP	NP	NDE	NDE	NDE
00/10-23-023-10W400	965	NDE	NDE	NDE	NDE	NDE
00/10-24-023-10W400	947	NDE	NDE	NDE	NDE	NDE
00/14-26-023-10W400	955.3	NP	NP	NDE	NDE	NDE
00/13-28-023-10W400	955	NDE	NDE	NDE	NDE	NDE
00/11-29-023-10W400	944.9	NP	NP	1086.6	1089.7	NDE
00/06-31-023-10W400	947.3	NDE	NDE	NDE	NDE	NDE
00/10-33-023-10W400	947	NDE	NDE	NDE	NDE	NDE
00/07-34-023-10W400	944	NDE	NDE	NDE	NDE	NDE
00/12-35-023-10W400	947.9	NDE	NDE	NDE	NDE	NDE
02/06-01-023-11W400	964	NP	NP	NDE	NDE	NDE
00/06-02-023-11W400	946	NP	NP	NDE	NDE	NDE
00/06-03-023-11W400	959	NDE	NDE	NDE	NDE	NDE
00/07-03-023-11W400	969	NDE	NDE	NDE	NDE	NDE
00/11-04-023-11W400	961.9	NDE	NDE	NDE	NDE	NDE
00/04-10-023-11W400	965.3	NDE	NDE	NDE	NDE	NDE
00/14-10-023-11W400	966	NDE	NDE	NDE	NDE	NDE
00/06-11-023-11W400	946.7	NDE	NDE	NDE	NDE	NDE
00/13-11-023-11W400	958	NP	NP	NDE	NDE	NDE
02/16-12-023-11W400	947.5	NDE	NDE	NDE	NDE	NDE
00/11-13-023-11W400	946.5	NDE	NDE	NDE	NDE	NDE
00/10-24-023-11W400	947	NDE	NDE	NDE	NDE	NDE
00/06-27-023-11W400	969.3	NP	NP	1096.1	1097.9	1111
00/10-27-023-11W400	962	NDE	NDE	NDE	NDE	NDE
00/06-32-023-11W400	981.5	NDE	NDE	NDE	NDE	NDE
00/08-35-023-11W400	953	NDE	NDE	NDE	NDE	NDE
00/06-01-023-12W400	969.3	NDE	NDE	NDE	NDE	NDE
02/06-04-023-12W400	976.5	NDE	NDE	NDE	NDE	NDE
00/06-06-023-12W400	977.5	NDE	NDE	NDE	NDE	NDE
00/07-06-023-12W400	964	NDE	NDE	NDE	NDE	NDE
00/10-07-023-12W400	990	993.6	996.7	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Sikastone Top	Sikastone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/15-07-023-12W400	990	998	1002	NDE	NDE	NDE
00/12-11-023-12W400	972	NDE	NDE	NDE	NDE	NDE
00/09-13-023-12W400	963	NDE	NDE	NDE	NDE	NDE
02/16-13-023-12W400	963	NDE	NDE	NDE	NDE	NDE
02/16-15-023-12W400	969	NDE	NDE	NDE	NDE	NDE
00/07-19-023-12W400	1015.3	NP	NP	NDE	NDE	NDE
02/16-23-023-12W400	967	NDE	NDE	NDE	NDE	NDE
00/03-24-023-12W400	959	NDE	NDE	NDE	NDE	NDE
00/15-31-023-12W400	1001.9	NDE	NDE	NDE	NDE	NDE
02/15-31-023-12W400	1014	NDE	NDE	NDE	NDE	NDE
02/06-33-023-12W400	995	NDE	NDE	NDE	NDE	NDE
00/11-35-023-12W400	965	NDE	NDE	NDE	NDE	NDE
00/16-36-023-12W400	978.5	NDE	NDE	NDE	NDE	NDE
00/14-01-023-13W400	977	NDE	NDE	NDE	NDE	NDE
02/06-02-023-13W400	1004.5	NDE	NDE	NDE	NDE	NDE
00/10-06-023-13W400	1022.9	NDE	NDE	NDE	NDE	NDE
00/11-07-023-13W400	1018.4	NDE	NDE	NDE	NDE	NDE
00/03-09-023-13W400	1016.8	NDE	NDE	NDE	NDE	NDE
00/14-09-023-13W400	999	NDE	NDE	NDE	NDE	NDE
00/08-11-023-13W400	997	NDE	NDE	NDE	NDE	NDE
00/03-12-023-13W400	998	NP	NP	NDE	NDE	NDE
00/06-12-023-13W400	990	NDE	NDE	NDE	NDE	NDE
00/13-12-023-13W400	991.8	NDE	NDE	NDE	NDE	NDE
00/06-14-023-13W400	1011	NDE	NDE	NDE	NDE	NDE
00/06-15-023-13W400	1010	NP	NP	NDE	NDE	NDE
00/13-15-023-13W400	1006	NDE	NDE	NDE	NDE	NDE
02/06-17-023-13W400	1006	NP	NP	NDE	NDE	NDE
00/08-18-023-13W400	1032	NDE	NDE	NDE	NDE	NDE
02/16-18-023-13W400	1012	NP	NP	NDE	NDE	NDE
00/14-19-023-13W400	1015	NDE	NDE	NDE	NDE	NDE
00/10-20-023-13W400	1000	NP	NP	NDE	NDE	NDE
00/07-21-023-13W400	992.7	NDE	NDE	NDE	NDE	NDE
00/11-22-023-13W400	993.6	NDE	NDE	NDE	NDE	NDE
00/11-23-023-13W400	1025.3	NDE	NDE	NDE	NDE	NDE
00/10-25-023-13W400	1018	NDE	NDE	NDE	NDE	NDE
00/11-27-023-13W400	981.5	NDE	NDE	NDE	NDE	NDE
00/14-27-023-13W400	988	NDE	NDE	NDE	NDE	NDE
00/10-29-023-13W400	1002	NDE	NDE	NDE	NDE	NDE
00/11-29-023-13W400	1002.8	NDE	NDE	NDE	NDE	NDE
00/08-31-023-13W400	1004	NP	NP	NDE	NDE	NDE
00/14-32-023-13W400	1004	NDE	NDE	NDE	NDE	NDE
02/06-33-023-13W400	994	NDE	NDE	NDE	NDE	NDE
00/06-34-023-13W400	990	NDE	NDE	NDE	NDE	NDE
02/06-34-023-13W400	1014	NDE	NDE	NDE	NDE	NDE
00/06-35-023-13W400	1000	NDE	NDE	NDE	NDE	NDE
00/10-01-023-14W400	1020.2	NDE	NDE	NDE	NDE	NDE
00/05-02-023-14W400	1030	NDE	NDE	NDE	NDE	NDE
00/08-03-023-14W400	1036.3	NDE	NDE	NDE	NDE	NDE
00/11-04-023-14W400	1033.3	NDE	NDE	NDE	NDE	NDE
00/16-05-023-14W400	1031.7	NP	NP	1180.2	1182.6	1194.8
00/09-09-023-14W400	1027	NDE	NDE	NDE	NDE	NDE
02/08-11-023-14W400	1013.6	NDE	NDE	NDE	NDE	NDE
00/14-12-023-14W400	1023	NDE	NDE	NDE	NDE	NDE
00/06-13-023-14W400	1029.6	NDE	NDE	NDE	NDE	NDE
00/07-14-023-14W400	1013.6	NP	NP	NDE	NDE	NDE
00/06-15-023-14W400	1023.2	NDE	NDE	NDE	NDE	NDE
00/01-16-023-14W400	1030.8	NDE	NDE	NDE	NDE	NDE
00/06-18-023-14W400	1015	NDE	NDE	NDE	NDE	NDE
00/11-21-023-14W400	1068.3	NDE	NDE	NDE	NDE	NDE
00/11-23-023-14W400	1026.9	NDE	NDE	NDE	NDE	NDE
00/06-24-023-14W400	1018	NDE	NDE	NDE	NDE	NDE
00/08-25-023-14W400	1020.5	NDE	NDE	NDE	NDE	NDE
00/06-28-023-14W400	1039.4	NDE	NDE	NDE	NDE	NDE
00/04-33-023-14W400	1039.7	NDE	NDE	NDE	NDE	NDE
02/14-34-023-14W400	1033	NP	NP	1163.5	1165	1175
00/06-35-023-14W400	1018.9	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
02/16-36-023-14W400	1027	NDE	NDE	NDE	NDE	NDE
00/09-08-023-15W400	1102	NP	NP	1237.6	1240	1247
00/11-10-023-15W400	1116	NP	NP	1253	1255	1264.5
00/06-11-023-15W400	1079	NDE	NDE	NDE	NDE	NDE
00/08-13-023-15W400	1049	NDE	NDE	NDE	NDE	NDE
00/07-17-023-15W400	1083.9	NDE	NDE	NDE	NDE	NDE
00/06-19-023-15W400	1146	NDE	NDE	NDE	NDE	NDE
00/12-21-023-15W400	1131.7	NDE	NDE	NDE	NDE	NDE
00/14-23-023-15W400	1110	NDE	NDE	NDE	NDE	NDE
00/07-24-023-15W400	1046.7	NDE	NDE	NDE	NDE	NDE
00/04-25-023-15W400	1068.9	NDE	NDE	NDE	NDE	NDE
00/11-29-023-15W400	1135.1	NDE	NDE	NDE	NDE	NDE
00/10-31-023-15W400	1105.5	NDE	NDE	NDE	NDE	NDE
00/02-32-023-15W400	1133	NP	NP	1239	1241	1246
00/11-33-023-15W400	1116	NP	NP	NDE	NDE	NDE
00/10-35-023-15W400	1103.7	NP	NP	NDE	NDE	NDE
00/01-02-023-16W400	1136.9	NP	NP	1264.9	1269.5	1283.2
00/10-21-023-16W400	1175.3	NDE	NDE	NDE	NDE	NDE
00/11-29-023-16W400	1218.6	NDE	NDE	NDE	NDE	NDE
00/10-35-023-16W400	1168.3	NP	NP	NDE	NDE	NDE
00/06-01-024-07W400	976.6	NP	NP	NDE	NDE	NDE
00/06-09-024-07W400	981.7	NP	NP	NDE	NDE	NDE
00/10-16-024-07W400	976	NP	NP	NDE	NDE	NDE
00/10-34-024-07W400	937	NP	NP	NDE	NDE	NDE
00/13-35-024-07W400	960.7	NP	NP	NDE	NDE	NDE
00/10-01-024-08W400	952.8	NP	NP	NDE	NDE	NDE
00/06-03-024-08W400	927.5	NDE	NDE	NDE	NDE	NDE
00/10-09-024-08W400	933.6	944.9	949.1	1065.3	1068.6	NDE
00/04-12-024-08W400	945	NDE	NDE	NDE	NDE	NDE
00/08-13-024-08W400	944	950	953	1072	1076	1090
00/11-17-024-08W400	933	943	947	NDE	NDE	NDE
00/16-21-024-08W400	982.3	NP	NP	NDE	NDE	NDE
00/06-30-024-08W400	963.8	974.8	978.4	NDE	NDE	NDE
00/14-33-024-08W400	966.5	973	977	NDE	NDE	NDE
00/12-36-024-08W400	972	NP	NP	NDE	NDE	NDE
00/11-06-024-09W400	949.5	NDE	NDE	NDE	NDE	NDE
00/10-12-024-09W400	946.7	NDE	NDE	NDE	NDE	NDE
00/10-17-024-09W400	931	946	957	NDE	NDE	NDE
00/10-18-024-09W400	929.3	NDE	NDE	NDE	NDE	NDE
00/02-22-024-09W400	938	955.5	963	1079	1082.5	1095.5
00/12-24-024-09W400	945	964	968	NDE	NDE	NDE
00/06-26-024-09W400	951	966	970	NDE	NDE	NDE
00/07-30-024-09W400	947	955	960	1077.5	1081	1093
00/09-32-024-09W400	939	956	960	1078	1081	1093.5
00/05-33-024-09W400	958	NDE	NDE	NDE	NDE	NDE
00/06-34-024-09W400	957.1	NDE	NDE	NDE	NDE	NDE
00/11-01-024-10W400	944.7	NDE	NDE	NDE	NDE	NDE
00/06-04-024-10W400	945	NDE	NDE	NDE	NDE	NDE
00/12-05-024-10W400	960	NDE	NDE	NDE	NDE	NDE
00/06-06-024-10W400	945.8	NP	NP	1086.9	1087.8	NDE
00/10-07-024-10W400	949	NP	NP	NDE	NDE	NDE
00/11-08-024-10W400	948.8	NDE	NDE	NDE	NDE	NDE
00/06-09-024-10W400	968	NDE	NDE	NDE	NDE	NDE
00/06-10-024-10W400	953.5	NDE	NDE	NDE	NDE	NDE
00/03-11-024-10W400	939	NDE	NDE	NDE	NDE	NDE
00/06-12-024-10W400	938.2	NDE	NDE	NDE	NDE	NDE
00/06-13-024-10W400	945.2	NDE	NDE	NDE	NDE	NDE
00/06-14-024-10W400	941.2	NDE	NDE	NDE	NDE	NDE
00/07-15-024-10W400	946.4	NDE	NDE	NDE	NDE	NDE
00/11-18-024-10W400	938.8	NDE	NDE	NDE	NDE	NDE
00/07-19-024-10W400	948.5	NDE	NDE	NDE	NDE	NDE
00/01-20-024-10W400	944.6	NDE	NDE	NDE	NDE	NDE
00/06-24-024-10W400	940	NDE	NDE	NDE	NDE	NDE
00/06-27-024-10W400	961.6	NDE	NDE	NDE	NDE	NDE
00/06-31-024-10W400	976.9	NDE	NDE	NDE	NDE	NDE
00/07-32-024-10W400	982	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/09-01-024-11W400	954	NDE	NDE	NDE	NDE	NDE
00/10-02-024-11W400	949	NDE	NDE	NDE	NDE	NDE
00/11-02-024-11W400	970	NDE	NDE	NDE	NDE	NDE
00/15-06-024-11W400	984	NDE	NDE	NDE	NDE	NDE
00/11-09-024-11W400	954.9	NP	NP	NDE	NDE	NDE
00/11-11-024-11W400	951	NDE	NDE	NDE	NDE	NDE
00/05-12-024-11W400	942	NP	NP	NDE	NDE	NDE
00/06-13-024-11W400	938.5	NDE	NDE	NDE	NDE	NDE
00/11-17-024-11W400	975	NP	NP	NDE	NDE	NDE
00/13-18-024-11W400	999	NDE	NDE	NDE	NDE	NDE
00/10-19-024-11W400	982.7	NDE	NDE	NDE	NDE	NDE
00/10-27-024-11W400	968.7	NDE	NDE	NDE	NDE	NDE
00/09-28-024-11W400	979	NDE	NDE	NDE	NDE	NDE
00/11-31-024-11W400	987.6	NDE	NDE	NDE	NDE	NDE
00/10-33-024-11W400	973	NP	NP	NDE	NDE	NDE
02/06-04-024-12W400	997	NDE	NDE	NDE	NDE	NDE
00/05-09-024-12W400	1014	NDE	NDE	NDE	NDE	NDE
00/14-13-024-12W400	1008	NDE	NDE	NDE	NDE	NDE
00/08-14-024-12W400	1005	NDE	NDE	NDE	NDE	NDE
00/10-14-024-12W400	1009.5	NDE	NDE	NDE	NDE	NDE
00/04-16-024-12W400	1023	NDE	NDE	NDE	NDE	NDE
00/06-16-024-12W400	1028.5	NDE	NDE	NDE	NDE	NDE
00/08-16-024-12W400	1024	NDE	NDE	NDE	NDE	NDE
00/10-18-024-12W400	1028	NDE	NDE	NDE	NDE	NDE
00/12-18-024-12W400	1043.9	NDE	NDE	NDE	NDE	NDE
00/02-19-024-12W400	1037	NDE	NDE	NDE	NDE	NDE
00/04-19-024-12W400	1036	NDE	NDE	NDE	NDE	NDE
02/06-19-024-12W400	1037	NDE	NDE	NDE	NDE	NDE
00/08-19-024-12W400	1044	NDE	NDE	NDE	NDE	NDE
00/10-19-024-12W400	1047	NDE	NDE	NDE	NDE	NDE
00/12-19-024-12W400	1025	NP	NP	NDE	NDE	NDE
00/14-19-024-12W400	1047	NDE	NDE	NDE	NDE	NDE
00/16-19-024-12W400	1054.5	NDE	NDE	NDE	NDE	NDE
02/06-20-024-12W400	1023	NDE	NDE	NDE	NDE	NDE
00/02-21-024-12W400	1042	NDE	NDE	NDE	NDE	NDE
00/14-21-024-12W400	1063	NDE	NDE	NDE	NDE	NDE
00/06-22-024-12W400	1020	NDE	NDE	NDE	NDE	NDE
00/13-22-024-12W400	1040	NDE	NDE	NDE	NDE	NDE
00/11-23-024-12W400	1018.6	NDE	NDE	NDE	NDE	NDE
02/11-23-024-12W400	1019	NDE	NDE	NDE	NDE	NDE
00/16-23-024-12W400	1021	NDE	NDE	NDE	NDE	NDE
00/04-27-024-12W400	1031.4	NDE	NDE	NDE	NDE	NDE
00/16-28-024-12W400	1061	NDE	NDE	NDE	NDE	NDE
02/06-29-024-12W400	1039	NDE	NDE	NDE	NDE	NDE
00/12-29-024-12W400	1051.5	NDE	NDE	NDE	NDE	NDE
00/02-30-024-12W400	1044.5	NDE	NDE	NDE	NDE	NDE
00/04-30-024-12W400	1024	NDE	NDE	NDE	NDE	NDE
02/06-30-024-12W400	1028	NDE	NDE	NDE	NDE	NDE
00/08-30-024-12W400	1047	NDE	NDE	NDE	NDE	NDE
00/10-30-024-12W400	1035	NDE	NDE	NDE	NDE	NDE
00/12-30-024-12W400	1018.2	NDE	NDE	NDE	NDE	NDE
00/14-30-024-12W400	1022	NDE	NDE	NDE	NDE	NDE
00/16-30-024-12W400	1037.5	NDE	NDE	NDE	NDE	NDE
00/04-31-024-12W400	1023	NDE	NDE	NDE	NDE	NDE
02/06-31-024-12W400	1025	NDE	NDE	NDE	NDE	NDE
00/08-31-024-12W400	1030	NDE	NDE	NDE	NDE	NDE
00/01-34-024-12W400	1033	NP	NP	NDE	NDE	NDE
00/06-34-024-12W400	1042.4	NDE	NDE	NDE	NDE	NDE
00/08-34-024-12W400	1037.5	NDE	NDE	NDE	NDE	NDE
00/10-34-024-12W400	1047	NDE	NDE	NDE	NDE	NDE
00/02-35-024-12W400	1027	NDE	NDE	NDE	NDE	NDE
00/10-35-024-12W400	1036	NP	NP	NDE	NDE	NDE
00/12-35-024-12W400	1039	NDE	NDE	NDE	NDE	NDE
00/13-35-024-12W400	1046	NDE	NDE	NDE	NDE	NDE
00/14-35-024-12W400	1036	NDE	NDE	NDE	NDE	NDE
00/04-36-024-12W400	1005	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-03-024-13W400	984	NDE	NDE	NDE	NDE	NDE
00/09-05-024-13W400	1010	NDE	NDE	NDE	NDE	NDE
00/14-05-024-13W400	1023.5	1025.5	1032	NDE	NDE	NDE
00/16-05-024-13W400	1026	NDE	NDE	NDE	NDE	NDE
00/05-06-024-13W400	1013	NP	NP	NDE	NDE	NDE
00/08-06-024-13W400	1013	NDE	NDE	NDE	NDE	NDE
00/06-07-024-13W400	1053.4	NDE	NDE	NDE	NDE	NDE
00/05-11-024-13W400	1009	NDE	NDE	NDE	NDE	NDE
00/16-11-024-13W400	1008	NDE	NDE	NDE	NDE	NDE
00/02-13-024-13W400	1034.8	NDE	NDE	NDE	NDE	NDE
00/06-13-024-13W400	1017.4	NDE	NDE	NDE	NDE	NDE
00/08-13-024-13W400	1043.6	NDE	NDE	NDE	NDE	NDE
00/10-13-024-13W400	1031.4	NDE	NDE	NDE	NDE	NDE
00/14-13-024-13W400	1015	NDE	NDE	NDE	NDE	NDE
00/02-14-024-13W400	1002.5	NDE	NDE	NDE	NDE	NDE
00/06-14-024-13W400	996	NDE	NDE	NDE	NDE	NDE
00/10-14-024-13W400	1037.2	NDE	NDE	NDE	NDE	NDE
00/14-15-024-13W400	1008	NDE	NDE	NDE	NDE	NDE
00/16-15-024-13W400	1012	NDE	NDE	NDE	NDE	NDE
00/03-16-024-13W400	1008	NDE	NDE	NDE	NDE	NDE
00/11-17-024-13W400	1005.8	NDE	NDE	NDE	NDE	NDE
00/06-18-024-13W400	1036	NDE	NDE	NDE	NDE	NDE
00/16-20-024-13W400	1031	NDE	NDE	NDE	NDE	NDE
02/06-21-024-13W400	1027	NDE	NDE	NDE	NDE	NDE
00/08-21-024-13W400	1018.5	NDE	NDE	NDE	NDE	NDE
00/14-21-024-13W400	1019	NDE	NDE	NDE	NDE	NDE
00/16-21-024-13W400	1027	NDE	NDE	NDE	NDE	NDE
03/06-22-024-13W400	1011.5	NDE	NDE	NDE	NDE	NDE
00/08-22-024-13W400	1000.5	1008	NDE	NDE	NDE	NDE
00/14-22-024-13W400	1011.9	NDE	NDE	NDE	NDE	NDE
00/16-22-024-13W400	1023.2	NDE	NDE	NDE	NDE	NDE
00/02-23-024-13W400	1014.1	NDE	NDE	NDE	NDE	NDE
00/10-23-024-13W400	1014	NDE	NDE	NDE	NDE	NDE
00/12-23-024-13W400	1023	NDE	NDE	NDE	NDE	NDE
00/02-24-024-13W400	1017	NP	NP	NDE	NDE	NDE
00/04-24-024-13W400	1011.3	NDE	NDE	NDE	NDE	NDE
00/08-24-024-13W400	1023	NDE	NDE	NDE	NDE	NDE
00/10-24-024-13W400	1015	NDE	NDE	NDE	NDE	NDE
02/12-24-024-13W400	1004.5	NDE	NDE	NDE	NDE	NDE
00/14-24-024-13W400	1009	NDE	NDE	NDE	NDE	NDE
00/16-24-024-13W400	1020	NDE	NDE	NDE	NDE	NDE
00/02-25-024-13W400	1013	NDE	NDE	NDE	NDE	NDE
00/04-25-024-13W400	1014	NDE	NDE	NDE	NDE	NDE
02/06-25-024-13W400	1005	NDE	NDE	NDE	NDE	NDE
00/08-25-024-13W400	1013	NDE	NDE	NDE	NDE	NDE
00/10-25-024-13W400	1003	NDE	NDE	NDE	NDE	NDE
00/12-25-024-13W400	1027.5	NDE	NDE	NDE	NDE	NDE
00/14-25-024-13W400	1011	NDE	NDE	NDE	NDE	NDE
00/16-25-024-13W400	1005.2	NDE	NDE	NDE	NDE	NDE
02/06-26-024-13W400	1015.6	NDE	NDE	NDE	NDE	NDE
00/07-26-024-13W400	1018	NDE	NDE	NDE	NDE	NDE
00/14-26-024-13W400	1022.6	NDE	NDE	NDE	NDE	NDE
00/16-26-024-13W400	1018.6	NDE	NDE	NDE	NDE	NDE
00/08-27-024-13W400	1028.7	NDE	NDE	NDE	NDE	NDE
00/14-27-024-13W400	1022.3	NDE	NDE	NDE	NDE	NDE
00/16-27-024-13W400	1022	NDE	NDE	NDE	NDE	NDE
00/06-29-024-13W400	1033	NDE	NDE	NDE	NDE	NDE
00/06-31-024-13W400	1029	NDE	NDE	NDE	NDE	NDE
00/06-33-024-13W400	1035.1	NDE	NDE	NDE	NDE	NDE
00/08-33-024-13W400	1036	NDE	NDE	NDE	NDE	NDE
02/06-34-024-13W400	1031	NDE	NDE	NDE	NDE	NDE
00/08-34-024-13W400	1026	NDE	NDE	NDE	NDE	NDE
00/14-34-024-13W400	1027	NDE	NDE	NDE	NDE	NDE
00/16-34-024-13W400	1027	NDE	NDE	NDE	NDE	NDE
00/04-35-024-13W400	1016	NDE	NDE	NDE	NDE	NDE
00/06-35-024-13W400	1014.7	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
03/06-35-024-13W400	1014.5	NDE	NDE	NDE	NDE	NDE
00/07-35-024-13W400	1019.9	NDE	NDE	NDE	NDE	NDE
00/10-35-024-13W400	1023	NDE	NDE	NDE	NDE	NDE
00/12-35-024-13W400	1026	NDE	NDE	NDE	NDE	NDE
00/14-35-024-13W400	1021.5	NDE	NDE	NDE	NDE	NDE
00/16-35-024-13W400	1024	NDE	NDE	NDE	NDE	NDE
00/02-36-024-13W400	1004.5	NDE	NDE	NDE	NDE	NDE
00/06-36-024-13W400	1011.3	NDE	NDE	NDE	NDE	NDE
00/08-36-024-13W400	1016.8	NDE	NDE	NDE	NDE	NDE
00/12-36-024-13W400	1005.2	NDE	NDE	NDE	NDE	NDE
00/14-36-024-13W400	1023.8	NDE	NDE	NDE	NDE	NDE
00/16-36-024-13W400	1011.9	NDE	NDE	NDE	NDE	NDE
00/06-03-024-14W400	1041.5	NDE	NDE	NDE	NDE	NDE
00/12-05-024-14W400	1064	NDE	NDE	NDE	NDE	NDE
02/16-06-024-14W400	994.7	NDE	NDE	NDE	NDE	NDE
00/02-07-024-14W400	1011	NP	NP	NDE	NDE	NDE
00/06-09-024-14W400	1069.2	NP	NP	NDE	NDE	NDE
02/06-11-024-14W400	1047.3	NDE	NDE	NDE	NDE	NDE
00/06-12-024-14W400	1037.5	NP	NP	NDE	NDE	NDE
00/10-13-024-14W400	1045.6	NDE	NDE	NDE	NDE	NDE
02/16-13-024-14W400	1053	NP	NP	NDE	NDE	NDE
00/06-14-024-14W400	1054.9	NDE	NDE	NDE	NDE	NDE
00/02-15-024-14W400	1054.3	NDE	NDE	NDE	NDE	NDE
00/05-16-024-14W400	1069	NDE	NDE	NDE	NDE	NDE
00/04-17-024-14W400	1075	NDE	NDE	NDE	NDE	NDE
02/06-20-024-14W400	1068	NP	NP	NDE	NDE	NDE
02/08-21-024-14W400	1050.6	NDE	NDE	NDE	NDE	NDE
00/07-22-024-14W400	1055.8	NDE	NDE	NDE	NDE	NDE
00/05-23-024-14W400	1048.7	1058	1062	NDE	NDE	NDE
00/11-25-024-14W400	1068.7	NP	NP	NDE	NDE	NDE
02/06-27-024-14W400	1052	NDE	NDE	NDE	NDE	NDE
00/07-28-024-14W400	1057	NDE	NDE	NDE	NDE	NDE
00/10-29-024-14W400	1099.1	NDE	NDE	NDE	NDE	NDE
00/10-30-024-14W400	1079.6	NP	NP	NDE	NDE	NDE
00/10-32-024-14W400	1095	NDE	NDE	NDE	NDE	NDE
00/03-33-024-14W400	1063	NDE	NDE	NDE	NDE	NDE
00/11-34-024-14W400	1063	1071.5	1075	NDE	NDE	NDE
00/06-02-024-15W400	1106	NDE	NDE	NDE	NDE	NDE
00/06-04-024-15W400	1142.7	NDE	NDE	NDE	NDE	NDE
00/07-05-024-15W400	1120.4	NDE	NDE	NDE	NDE	NDE
00/07-06-024-15W400	1118	NDE	NDE	NDE	NDE	NDE
00/10-08-024-15W400	1124.7	NDE	NDE	NDE	NDE	NDE
00/10-09-024-15W400	1124.7	NDE	NDE	NDE	NDE	NDE
00/07-11-024-15W400	1106.4	NP	NP	1244.2	1246	1261.9
00/10-12-024-15W400	1076	NDE	NDE	NDE	NDE	NDE
00/06-14-024-15W400	1099.7	NDE	NDE	NDE	NDE	NDE
00/10-16-024-15W400	1094.2	NDE	NDE	NDE	NDE	NDE
00/11-18-024-15W400	1101.5	NP	NP	1225.3	1228.3	1239.6
00/11-19-024-15W400	1103.4	NDE	NDE	NDE	NDE	NDE
00/06-23-024-15W400	1116.5	NDE	NDE	NDE	NDE	NDE
00/13-25-024-15W400	1035	NDE	NDE	NDE	NDE	NDE
00/11-26-024-15W400	1100	NDE	NDE	NDE	NDE	NDE
00/05-27-024-15W400	1112.8	NP	NP	NDE	NDE	NDE
00/10-28-024-15W400	1086	NDE	NDE	NDE	NDE	NDE
00/10-29-024-15W400	1107	NDE	NDE	NDE	NDE	NDE
00/10-30-024-15W400	1127.2	NDE	NDE	NDE	NDE	NDE
00/10-33-024-15W400	1085	NDE	NDE	NDE	NDE	NDE
00/06-34-024-15W400	1110	NDE	NDE	NDE	NDE	NDE
00/01-01-024-16W400	1098.5	NDE	NDE	NDE	NDE	NDE
00/15-02-024-16W400	1150	NP	NP	NDE	NDE	NDE
00/09-06-024-16W400	1212.5	NDE	NDE	NDE	NDE	NDE
00/16-07-024-16W400	1191.5	NP	NP	1300	1302.1	1309.4
00/02-11-024-16W400	1153	NDE	NDE	NDE	NDE	NDE
00/06-12-024-16W400	1147.5	NDE	NDE	NDE	NDE	NDE
00/10-16-024-16W400	1155.2	NDE	NDE	NDE	NDE	NDE
00/06-21-024-16W400	1164	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-23-024-16W400	1150.9	NDE	NDE	NDE	NDE	NDE
00/06-26-024-16W400	1139	NDE	NDE	NDE	NDE	NDE
00/10-30-024-16W400	1191.5	NDE	NDE	NDE	NDE	NDE
00/10-32-024-16W400	1185	NDE	NDE	NDE	NDE	NDE
00/08-33-024-16W400	1167	NDE	NDE	NDE	NDE	NDE
00/07-34-024-16W400	1139.3	NP	NP	NDE	NDE	NDE
00/06-35-024-16W400	1148.8	NDE	NDE	NDE	NDE	NDE
00/11-36-024-16W400	1121.1	NDE	NDE	NDE	NDE	NDE
00/07-01-025-07W400	974.8	NP	NP	NDE	NDE	NDE
00/06-03-025-07W400	961	NDE	NDE	NDE	NDE	NDE
00/08-04-025-07W400	934	NDE	NDE	NDE	NDE	NDE
00/07-10-025-07W400	934	NP	NP	1027	1033	NDE
00/07-11-025-07W400	978.7	NP	NP	1061.6	1064.9	1086
00/01-12-025-07W400	970	NP	NP	NDE	NDE	NDE
00/16-13-025-07W400	1019	NDE	NDE	NDE	NDE	NDE
00/14-15-025-07W400	949	NP	NP	1042.5	1047.5	1061.5
00/10-24-025-07W400	1007.4	NP	NP	1093.9	1098.5	NDE
00/11-29-025-07W400	975	NDE	NDE	NDE	NDE	NDE
00/11-31-025-07W400	1037.8	NDE	NDE	NDE	NDE	NDE
00/16-36-025-07W400	971	NP	NP	NDE	NDE	NDE
00/12-02-025-08W400	990	NDE	NDE	NDE	NDE	NDE
00/16-06-025-08W400	991	NP	NP	1106	1108.5	NDE
00/10-07-025-08W400	997	1002	1005.8	1096.4	1099	NDE
00/08-09-025-08W400	974	NDE	NDE	NDE	NDE	NDE
00/08-11-025-08W400	1032	NDE	NDE	NDE	NDE	NDE
00/07-21-025-08W400	992.1	NDE	NDE	NDE	NDE	NDE
02/10-27-025-08W400	1025.5	NDE	NDE	NDE	NDE	NDE
00/10-30-025-08W400	1022.6	NDE	NDE	NDE	NDE	NDE
00/01-33-025-08W400	1044	NDE	NDE	NDE	NDE	NDE
00/06-03-025-09W400	963.2	NDE	NDE	NDE	NDE	NDE
00/06-04-025-09W400	965.3	NDE	NDE	NDE	NDE	NDE
00/07-05-025-09W400	949.8	NP	NP	NDE	NDE	NDE
00/10-06-025-09W400	938	NDE	NDE	NDE	NDE	NDE
00/06-08-025-09W400	952.2	NDE	NDE	NDE	NDE	NDE
00/07-09-025-09W400	964.5	NDE	NDE	NDE	NDE	NDE
00/15-12-025-09W400	982	NP	NP	1095	1097	1113
00/07-17-025-09W400	965	972.3	976.6	1081.7	1083.6	1100
00/06-18-025-09W400	982.7	NDE	NDE	NDE	NDE	NDE
00/10-19-025-09W400	995	NDE	NDE	NDE	NDE	NDE
00/10-20-025-09W400	1020	NDE	NDE	NDE	NDE	NDE
08/13-23-025-09W400	1028	NP	NP	NDE	NDE	NDE
00/10-24-025-09W400	1002.8	NDE	NDE	NDE	NDE	NDE
00/08-30-025-09W400	996	NP	NP	NDE	NDE	NDE
00/06-34-025-09W400	1019.9	NP	NP	NDE	NDE	NDE
00/11-35-025-09W400	1013	NDE	NDE	NDE	NDE	NDE
00/06-03-025-10W400	966.2	NDE	NDE	NDE	NDE	NDE
00/07-04-025-10W400	960.4	NDE	NDE	NDE	NDE	NDE
00/08-06-025-10W400	976	NDE	NDE	NDE	NDE	NDE
00/02-07-025-10W400	970.5	NDE	NDE	NDE	NDE	NDE
00/03-08-025-10W400	979	NDE	NDE	NDE	NDE	NDE
00/11-10-025-10W400	975.1	NDE	NDE	NDE	NDE	NDE
00/09-11-025-10W400	992	NDE	NDE	NDE	NDE	NDE
00/16-16-025-10W400	1000.5	1006.5	1010	1117.5	1119	1128
00/02-17-025-10W400	990	997.8	1001.8	NDE	NDE	NDE
00/07-19-025-10W400	998	NDE	NDE	NDE	NDE	NDE
00/07-20-025-10W400	1011	NDE	NDE	NDE	NDE	NDE
00/11-23-025-10W400	1021.7	NDE	NDE	NDE	NDE	NDE
00/08-24-025-10W400	985	NDE	NDE	NDE	NDE	NDE
00/12-25-025-10W400	1001	NDE	NDE	NDE	NDE	NDE
00/13-26-025-10W400	1009	NDE	NDE	NDE	NDE	NDE
00/09-27-025-10W400	1014.7	NP	NP	NDE	NDE	NDE
00/16-28-025-10W400	1036	NP	NP	NDE	NDE	NDE
00/04-29-025-10W400	1016.5	NP	NP	NDE	NDE	NDE
00/02-31-025-10W400	1009	NDE	NDE	NDE	NDE	NDE
00/11-32-025-10W400	1016	NP	NP	NDE	NDE	NDE
00/07-34-025-10W400	1028	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/06-35-025-10W400	1015	NP	NP	NDE	NDE	NDE
00/03-36-025-10W400	996	NDE	NDE	NDE	NDE	NDE
00/10-02-025-11W400	974.5	NDE	NDE	NDE	NDE	NDE
00/12-03-025-11W400	984	NDE	NDE	NDE	NDE	NDE
00/14-07-025-11W400	1017.5	1023	1028	NDE	NDE	NDE
00/08-09-025-11W400	988	990	992.5	NDE	NDE	NDE
00/16-12-025-11W400	980	996.5	1000	NDE	NDE	NDE
00/06-15-025-11W400	993	NDE	NDE	NDE	NDE	NDE
00/11-15-025-11W400	1001.5	NDE	NDE	NDE	NDE	NDE
00/14-17-025-11W400	1017.5	1026.5	NDE	NDE	NDE	NDE
00/14-18-025-11W400	1026	NDE	NDE	NDE	NDE	NDE
00/06-19-025-11W400	1028.5	1032.5	1036.5	NDE	NDE	NDE
00/13-24-025-11W400	998	NDE	NDE	NDE	NDE	NDE
00/02-26-025-11W400	1011	NDE	NDE	NDE	NDE	NDE
00/14-28-025-11W400	1033	NDE	NDE	NDE	NDE	NDE
00/04-30-025-11W400	1062.5	1065.5	NDE	NDE	NDE	NDE
00/06-30-025-11W400	1063.5	NP	NP	NDE	NDE	NDE
00/08-30-025-11W400	1044	NP	NP	NDE	NDE	NDE
00/12-30-025-11W400	1068	NDE	NDE	NDE	NDE	NDE
00/14-30-025-11W400	1072	NDE	NDE	NDE	NDE	NDE
00/06-31-025-11W400	1069	NDE	NDE	NDE	NDE	NDE
00/10-31-025-11W400	1084	NDE	NDE	NDE	NDE	NDE
00/10-32-025-11W400	1030.8	NDE	NDE	NDE	NDE	NDE
00/01-36-025-11W400	1018	NP	NP	NDE	NDE	NDE
00/02-02-025-12W400	1046	NDE	NDE	NDE	NDE	NDE
00/04-02-025-12W400	1041	NDE	NDE	NDE	NDE	NDE
00/06-02-025-12W400	1041	NDE	NDE	NDE	NDE	NDE
00/10-02-025-12W400	1053	1059	1065	NDE	NDE	NDE
00/12-02-025-12W400	1055	NDE	NDE	NDE	NDE	NDE
00/14-02-025-12W400	1050	NDE	NDE	NDE	NDE	NDE
00/01-03-025-12W400	1061	NDE	NDE	NDE	NDE	NDE
00/02-03-025-12W400	1054.6	NDE	NDE	NDE	NDE	NDE
00/04-03-025-12W400	1055	NDE	NDE	NDE	NDE	NDE
00/10-03-025-12W400	1057.7	NDE	NDE	NDE	NDE	NDE
00/12-04-025-12W400	1037	1042	1048	NDE	NDE	NDE
00/03-05-025-12W400	1039.4	NDE	NDE	NDE	NDE	NDE
00/10-05-025-12W400	1039.4	NP	NP	1147.3	1148.8	1158.2
00/11-05-025-12W400	1044	NDE	NDE	NDE	NDE	NDE
00/02-10-025-12W400	1060	NDE	NDE	NDE	NDE	NDE
00/10-10-025-12W400	1063	NDE	NDE	NDE	NDE	NDE
00/01-11-025-12W400	1042	1056	1064	NDE	NDE	NDE
00/02-11-025-12W400	1038	NDE	NDE	NDE	NDE	NDE
00/04-11-025-12W400	1054.6	NDE	NDE	NDE	NDE	NDE
00/06-11-025-12W400	1053.4	NDE	NDE	NDE	NDE	NDE
00/12-11-025-12W400	1055.2	NDE	NDE	NDE	NDE	NDE
00/14-11-025-12W400	1043	NDE	NDE	NDE	NDE	NDE
00/12-13-025-12W400	1046	NDE	NDE	NDE	NDE	NDE
00/10-14-025-12W400	1048.5	NDE	NDE	NDE	NDE	NDE
00/16-14-025-12W400	1044.9	1050.6	1055.8	NDE	NDE	NDE
02/16-14-025-12W400	1041	1050	1055	1155.3	1156.5	1169
00/02-15-025-12W400	1070.5	NDE	NDE	NDE	NDE	NDE
00/14-15-025-12W400	1041	NDE	NDE	NDE	NDE	NDE
00/14-16-025-12W400	1053	NDE	NDE	NDE	NDE	NDE
00/16-16-025-12W400	1047	1051.9	1054.3	NDE	NDE	NDE
00/11-17-025-12W400	1037	NDE	NDE	NDE	NDE	NDE
00/15-17-025-12W400	1042	NDE	NDE	NDE	NDE	NDE
00/06-18-025-12W400	1032	NP	NP	NDE	NDE	NDE
00/08-18-025-12W400	1024	NDE	NDE	NDE	NDE	NDE
00/10-18-025-12W400	1023.5	NDE	NDE	NDE	NDE	NDE
02/10-18-025-12W400	1021	1025	1030	NDE	NDE	NDE
00/16-18-025-12W400	1023	NDE	NDE	NDE	NDE	NDE
00/01-19-025-12W400	1036.5	NP	NP	NDE	NDE	NDE
00/14-19-025-12W400	1064	NDE	NDE	NDE	NDE	NDE
00/02-20-025-12W400	1059.5	NP	NP	NDE	NDE	NDE
00/06-20-025-12W400	1042	NP	NP	NDE	NDE	NDE
00/08-20-025-12W400	1049	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/10-20-025-12W400	1060	NDE	NDE	NDE	NDE	NDE
00/12-20-025-12W400	1067	NP	NP	NDE	NDE	NDE
00/14-20-025-12W400	1062	NP	NP	NDE	NDE	NDE
00/16-20-025-12W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/02-21-025-12W400	1068.5	NDE	NDE	NDE	NDE	NDE
00/06-21-025-12W400	1065	NDE	NDE	NDE	NDE	NDE
00/08-21-025-12W400	1068.6	NDE	NDE	NDE	NDE	NDE
00/10-21-025-12W400	1057.7	NDE	NDE	NDE	NDE	NDE
00/12-21-025-12W400	1064	NDE	NDE	NDE	NDE	NDE
00/14-21-025-12W400	1065	NDE	NDE	NDE	NDE	NDE
00/02-22-025-12W400	1050.3	NDE	NDE	NDE	NDE	NDE
00/04-22-025-12W400	1035.1	NDE	NDE	NDE	NDE	NDE
00/06-22-025-12W400	1036.9	NDE	NDE	NDE	NDE	NDE
00/08-22-025-12W400	1039.4	NDE	NDE	NDE	NDE	NDE
00/10-22-025-12W400	1042.4	NDE	NDE	NDE	NDE	NDE
02/16-22-025-12W400	1039	NP	NP	NDE	NDE	NDE
00/14-23-025-12W400	1037	NDE	NDE	NDE	NDE	NDE
00/02-24-025-12W400	1047.5	1056	1060	NDE	NDE	NDE
00/04-24-025-12W400	1046.5	NDE	NDE	NDE	NDE	NDE
00/10-24-025-12W400	1053	1058	1062	NDE	NDE	NDE
00/12-24-025-12W400	1042.4	1046.7	1051.6	NDE	NDE	NDE
00/02-25-025-12W400	1061	1067	NDE	NDE	NDE	NDE
00/10-25-025-12W400	1058	NP	NP	NDE	NDE	NDE
00/04-26-025-12W400	1034.2	NDE	NDE	NDE	NDE	NDE
02/04-26-025-12W400	1036	NP	NP	1141	1142	1153
00/06-26-025-12W400	1038.5	NDE	NDE	NDE	NDE	NDE
00/12-26-025-12W400	1037.2	NDE	NDE	NDE	NDE	NDE
00/16-26-025-12W400	1048.5	NDE	NDE	NDE	NDE	NDE
00/01-27-025-12W400	1045.5	NDE	NDE	NDE	NDE	NDE
00/06-27-025-12W400	1047	NDE	NDE	NDE	NDE	NDE
00/12-27-025-12W400	1047.6	NDE	NDE	NDE	NDE	NDE
00/16-27-025-12W400	1040.3	NDE	NDE	NDE	NDE	NDE
00/02-28-025-12W400	1072	NDE	NDE	NDE	NDE	NDE
00/02-29-025-12W400	1060	NDE	NDE	NDE	NDE	NDE
00/04-29-025-12W400	1073	NP	NP	NDE	NDE	NDE
00/06-29-025-12W400	1068.9	NDE	NDE	NDE	NDE	NDE
00/08-29-025-12W400	1067.5	NP	NP	NDE	NDE	NDE
00/04-30-025-12W400	1063	NP	NP	NDE	NDE	NDE
00/06-30-025-12W400	1058.5	NP	NP	NDE	NDE	NDE
00/12-30-025-12W400	1055.5	NDE	NDE	NDE	NDE	NDE
00/16-30-025-12W400	1072	NP	NP	NDE	NDE	NDE
00/09-31-025-12W400	1056.5	NP	NP	NDE	NDE	NDE
00/12-31-025-12W400	1063.5	1068	1072	NDE	NDE	NDE
00/15-31-025-12W400	1057	NP	NP	NDE	NDE	NDE
00/14-32-025-12W400	1059.8	NDE	NDE	NDE	NDE	NDE
00/15-32-025-12W400	1069.2	NDE	NDE	NDE	NDE	NDE
00/03-33-025-12W400	1059.5	NDE	NDE	NDE	NDE	NDE
00/11-33-025-12W400	1053	NDE	NDE	NDE	NDE	NDE
00/16-33-025-12W400	1063.5	NDE	NDE	NDE	NDE	NDE
00/02-34-025-12W400	1082	NDE	NDE	NDE	NDE	NDE
00/06-34-025-12W400	1062.5	NDE	NDE	NDE	NDE	NDE
00/10-34-025-12W400	1063.8	NDE	NDE	NDE	NDE	NDE
00/12-34-025-12W400	1067.5	NP	NP	NDE	NDE	NDE
00/14-34-025-12W400	1068	NDE	NDE	NDE	NDE	NDE
00/02-35-025-12W400	1048	NDE	NDE	NDE	NDE	NDE
00/08-35-025-12W400	1059.2	NDE	NDE	NDE	NDE	NDE
00/10-35-025-12W400	1059	NDE	NDE	NDE	NDE	NDE
00/16-35-025-12W400	1060.1	NDE	NDE	NDE	NDE	NDE
00/02-01-025-13W400	1017.7	NDE	NDE	NDE	NDE	NDE
00/04-01-025-13W400	1025	NDE	NDE	NDE	NDE	NDE
00/13-01-025-13W400	1027.5	NDE	NDE	NDE	NDE	NDE
00/15-01-025-13W400	1016	NDE	NDE	NDE	NDE	NDE
00/01-02-025-13W400	1025	NDE	NDE	NDE	NDE	NDE
00/02-02-025-13W400	1026	NDE	NDE	NDE	NDE	NDE
00/04-02-025-13W400	1018.5	NDE	NDE	NDE	NDE	NDE
00/05-02-025-13W400	1037	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Sikatone Top	Sikatone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/08-02-025-13W400	1028.5	NDE	NDE	NDE	NDE	NDE
00/13-02-025-13W400	1029	NDE	NDE	NDE	NDE	NDE
00/15-02-025-13W400	1035	NDE	NDE	NDE	NDE	NDE
02/15-02-025-13W400	1032	NDE	NDE	NDE	NDE	NDE
00/16-02-025-13W400	1030	NDE	NDE	NDE	NDE	NDE
00/06-03-025-13W400	1040.5	NDE	NDE	NDE	NDE	NDE
00/14-03-025-13W400	1041	NDE	NDE	NDE	NDE	NDE
00/02-04-025-13W400	1043	NDE	NDE	NDE	NDE	NDE
00/16-09-025-13W400	1028.3	NP	NP	1138.5	1139.7	1150.5
00/06-10-025-13W400	1037.2	NDE	NDE	NDE	NDE	NDE
00/02-12-025-13W400	1016	NDE	NDE	NDE	NDE	NDE
00/08-12-025-13W400	1032.5	NDE	NDE	NDE	NDE	NDE
00/12-12-025-13W400	1019	NDE	NDE	NDE	NDE	NDE
00/05-14-025-13W400	1048	NDE	NDE	NDE	NDE	NDE
00/07-16-025-13W400	1055	NDE	NDE	NDE	NDE	NDE
00/11-19-025-13W400	1052	NDE	NDE	NDE	NDE	NDE
00/06-20-025-13W400	1046	1054	NDE	NDE	NDE	NDE
00/07-21-025-13W400	1057	1061.9	NDE	NDE	NDE	NDE
00/08-21-025-13W400	1042	1049	1056.5	NDE	NDE	NDE
00/14-23-025-13W400	1046.5	1053	1060	NDE	NDE	NDE
00/02-24-025-13W400	1013	NP	NP	NDE	NDE	NDE
00/16-24-025-13W400	1012	1019	1027.5	1104	1105.5	1117
02/16-24-025-13W400	1027	1019	1027.5	NDE	NDE	NDE
00/04-25-025-13W400	1044	NDE	NDE	NDE	NDE	NDE
00/14-25-025-13W400	1059	NDE	NDE	NDE	NDE	NDE
00/16-25-025-13W400	1059	NDE	NDE	NDE	NDE	NDE
00/02-26-025-13W400	1037	1041	1046.5	NDE	NDE	NDE
00/08-27-025-13W400	1064	NP	NP	NDE	NDE	NDE
00/11-27-025-13W400	1059.8	NP	NP	1174.4	1175.6	1186.3
00/07-28-025-13W400	1049.7	NDE	NDE	NDE	NDE	NDE
00/09-29-025-13W400	1046	1054.5	1061	NDE	NDE	NDE
00/14-31-025-13W400	1066	1071.5	1075	NDE	NDE	NDE
02/14-31-025-13W400	1061	NDE	NDE	NDE	NDE	NDE
00/11-33-025-13W400	1059	1062	1069	NDE	NDE	NDE
00/08-34-025-13W400	1058	1063	NDE	NDE	NDE	NDE
00/10-35-025-13W400	1054.5	1058	1064	NDE	NDE	NDE
00/11-35-025-13W400	1059	1062	1068	NDE	NDE	NDE
02/16-35-025-13W400	1055	NDE	NDE	NDE	NDE	NDE
00/13-36-025-13W400	1060	1069	1074	NDE	NDE	NDE
00/14-36-025-13W400	1072	NDE	NDE	NDE	NDE	NDE
02/14-36-025-13W400	1063	NDE	NDE	NDE	NDE	NDE
00/07-01-025-14W400	1045.5	NP	NP	1155.5	1157	1165.9
00/08-01-025-14W400	1046	1063	1067	1154	1155.5	1164
00/10-02-025-14W400	1076.9	NDE	NDE	NDE	NDE	NDE
00/01-05-025-14W400	1112	NDE	NDE	NDE	NDE	NDE
00/09-06-025-14W400	1123	NDE	NDE	NDE	NDE	NDE
02/16-09-025-14W400	1086	NDE	NDE	NDE	NDE	NDE
00/08-10-025-14W400	1072.9	NP	NP	1196.3	1199.4	1214.6
00/05-11-025-14W400	1058	NP	NP	NDE	NDE	NDE
00/08-12-025-14W400	1080	NDE	NDE	NDE	NDE	NDE
00/07-13-025-14W400	1063.8	NDE	NDE	NDE	NDE	NDE
00/12-15-025-14W400	1098	NDE	NDE	NDE	NDE	NDE
00/06-16-025-14W400	1075	NDE	NDE	NDE	NDE	NDE
00/10-17-025-14W400	1102.8	NDE	NDE	NDE	NDE	NDE
00/10-18-025-14W400	1121.7	NP	NP	NDE	NDE	NDE
00/06-19-025-14W400	1144	NDE	NDE	NDE	NDE	NDE
00/06-20-025-14W400	1116.5	NDE	NDE	NDE	NDE	NDE
00/15-23-025-14W400	1092	NDE	NDE	NDE	NDE	NDE
00/07-25-025-14W400	1067.7	NDE	NDE	NDE	NDE	NDE
00/11-27-025-14W400	1091.8	NDE	NDE	NDE	NDE	NDE
00/09-28-025-14W400	1095	NDE	NDE	NDE	NDE	NDE
00/15-33-025-14W400	1094	NDE	NDE	NDE	NDE	NDE
00/15-34-025-14W400	1126	1131	1140	NDE	NDE	NDE
00/16-35-025-14W400	1099.5	NDE	NDE	NDE	NDE	NDE
00/10-01-025-15W400	1101	NP	NP	1235.5	1236.5	NDE
00/11-02-025-15W400	1083	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/11-03-025-15W400	1002	NDE	NDE	NDE	NDE	NDE
00/07-04-025-15W400	992	NDE	NDE	NDE	NDE	NDE
00/07-05-025-15W400	1069.8	NP	NP	1206.7	1208.2	1215.2
00/10-07-025-15W400	1009	NDE	NDE	NDE	NDE	NDE
00/06-08-025-15W400	1054	NDE	NDE	NDE	NDE	NDE
00/10-09-025-15W400	1055	NDE	NDE	NDE	NDE	NDE
00/06-10-025-15W400	1090.3	NDE	NDE	NDE	NDE	NDE
00/06-11-025-15W400	1095.5	NDE	NDE	NDE	NDE	NDE
00/10-13-025-15W400	1139.6	NDE	NDE	NDE	NDE	NDE
00/14-14-025-15W400	1098	NP	NP	1213.5	1215	1225
00/03-15-025-15W400	1095	NP	NP	NDE	NDE	NDE
00/02-16-025-15W400	1084	NDE	NDE	NDE	NDE	NDE
00/06-17-025-15W400	1077.7	NDE	NDE	NDE	NDE	NDE
00/15-18-025-15W400	1038.5	NDE	NDE	NDE	NDE	NDE
00/06-19-025-15W400	1108.3	NDE	NDE	NDE	NDE	NDE
00/06-20-025-15W400	1103.7	NDE	NDE	NDE	NDE	NDE
00/06-21-025-15W400	1109	NP	NP	1221.5	1223.5	1233.5
00/10-22-025-15W400	1102.5	NP	NP	NDE	NDE	NDE
00/07-23-025-15W400	1100.3	NP	NP	NDE	NDE	NDE
02/08-24-025-15W400	1138	NP	NP	1257.3	1258.8	1278
00/11-25-025-15W400	1093.3	NDE	NDE	NDE	NDE	NDE
00/11-26-025-15W400	1105.2	NDE	NDE	NDE	NDE	NDE
00/06-27-025-15W400	1108.2	NDE	NDE	NDE	NDE	NDE
00/10-28-025-15W400	1121.1	NDE	NDE	NDE	NDE	NDE
00/06-29-025-15W400	1104.3	NDE	NDE	NDE	NDE	NDE
00/10-30-025-15W400	1111.6	NDE	NDE	NDE	NDE	NDE
00/06-31-025-15W400	1107.3	NDE	NDE	NDE	NDE	NDE
00/10-32-025-15W400	1113.1	NDE	NDE	NDE	NDE	NDE
00/06-33-025-15W400	1122.3	NDE	NDE	NDE	NDE	NDE
00/10-34-025-15W400	1119.8	NDE	NDE	NDE	NDE	NDE
00/14-35-025-15W400	1120	1126	1140	1238	1240.5	1253
00/06-36-025-15W400	1112.8	NP	NP	NDE	NDE	NDE
00/11-02-025-16W400	1155	NDE	NDE	NDE	NDE	NDE
00/08-03-025-16W400	1155	NDE	NDE	NDE	NDE	NDE
00/07-08-025-16W400	1194.8	NDE	NDE	NDE	NDE	NDE
00/06-11-025-16W400	1153.5	NDE	NDE	NDE	NDE	NDE
00/06-12-025-16W400	1129	NP	NP	NDE	NDE	NDE
00/06-13-025-16W400	1130	NDE	NDE	NDE	NDE	NDE
00/06-14-025-16W400	1141.5	NDE	NDE	NDE	NDE	NDE
00/07-15-025-16W400	1154	NDE	NDE	NDE	NDE	NDE
00/07-17-025-16W400	1213.1	NDE	NDE	NDE	NDE	NDE
00/04-18-025-16W400	1243.3	NDE	NDE	NDE	NDE	NDE
00/10-21-025-16W400	1213.1	NDE	NDE	NDE	NDE	NDE
02/10-21-025-16W400	1216	NDE	NDE	NDE	NDE	NDE
00/08-22-025-16W400	1196.5	NDE	NDE	NDE	NDE	NDE
00/03-23-025-16W400	1158.5	NDE	NDE	NDE	NDE	NDE
00/08-25-025-16W400	1146.5	NDE	NDE	NDE	NDE	NDE
00/10-26-025-16W400	1038.8	NDE	NDE	NDE	NDE	NDE
00/11-28-025-16W400	1211.3	NP	NP	NDE	NDE	NDE
00/10-31-025-16W400	1235.7	NDE	NDE	NDE	NDE	NDE
00/14-34-025-16W400	1051	NDE	NDE	NDE	NDE	NDE
00/10-35-025-16W400	1136	NDE	NDE	NDE	NDE	NDE
00/10-36-025-16W400	1121.1	1123.2	1127.4	NDE	NDE	NDE
00/07-10-026-07W400	961.6	NDE	NDE	NDE	NDE	NDE
00/06-11-026-07W400	964	NP	NP	NDE	NDE	NDE
00/06-14-026-07W400	978.3	NDE	NDE	NDE	NDE	NDE
00/06-16-026-07W400	983.9	NDE	NDE	NDE	NDE	NDE
00/10-18-026-07W400	1021	NP	NP	1091	1093	1105
00/15-21-026-07W400	952.5	NDE	NDE	NDE	NDE	NDE
00/06-22-026-07W400	969	NDE	NDE	NDE	NDE	NDE
00/07-24-026-07W400	972	NDE	NDE	NDE	NDE	NDE
00/10-24-026-07W400	970.2	NDE	NDE	NDE	NDE	NDE
00/14-25-026-07W400	955	NDE	NDE	NDE	NDE	NDE
00/07-26-026-07W400	963.2	NDE	NDE	NDE	NDE	NDE
00/02-27-026-07W400	977	NDE	NDE	NDE	NDE	NDE
00/10-30-026-07W400	1017.4	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Sikatone Top	Sikatone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/11-31-026-07W400	1013.5	NP	NP	NDE	NDE	NDE
00/06-33-026-07W400	969.3	NP	NP	1040.9	1041.8	NDE
00/11-36-026-07W400	943.7	NP	NP	NDE	NDE	NDE
00/10-03-026-08W400	1045.7	NDE	NDE	NDE	NDE	NDE
00/02-04-026-08W400	1032	NP	NP	1134.2	1136	1149.1
00/07-10-026-08W400	1069.2	NDE	NDE	NDE	NDE	NDE
00/10-11-026-08W400	1057.4	NP	NP	NDE	NDE	NDE
00/05-12-026-08W400	1022.8	NDE	NDE	NDE	NDE	NDE
00/07-14-026-08W400	1060.7	NDE	NDE	NDE	NDE	NDE
00/08-19-026-08W400	1057	NP	NP	1136	1137	1151.5
00/16-20-026-08W400	1065	NP	NP	NDE	NDE	NDE
00/06-23-026-08W400	1072.9	NDE	NDE	NDE	NDE	NDE
00/11-28-026-08W400	1089.7	NP	NP	1167.4	NDE	NDE
00/10-29-026-08W400	1051.6	NDE	NDE	NDE	NDE	NDE
00/04-04-026-09W400	1015.5	NDE	NDE	NDE	NDE	NDE
00/07-07-026-09W400	1005	NDE	NDE	NDE	NDE	NDE
00/11-08-026-09W400	994	NDE	NDE	NDE	NDE	NDE
00/01-09-026-09W400	1031	NDE	NDE	NDE	NDE	NDE
00/07-11-026-09W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/10-15-026-09W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/11-16-026-09W400	1032.7	NDE	NDE	NDE	NDE	NDE
00/11-17-026-09W400	1007.1	NDE	NDE	NDE	NDE	NDE
00/07-18-026-09W400	1016	NDE	NDE	NDE	NDE	NDE
00/12-19-026-09W400	1021	NDE	NDE	NDE	NDE	NDE
00/10-22-026-09W400	1047	NDE	NDE	NDE	NDE	NDE
00/11-23-026-09W400	1053.5	NDE	NDE	NDE	NDE	NDE
00/11-26-026-09W400	1053.5	NDE	NDE	NDE	NDE	NDE
00/02-27-026-09W400	1057	NP	NP	1138.1	1139.3	NDE
00/11-28-026-09W400	1021.1	NP	NP	NDE	NDE	NDE
00/07-29-026-09W400	1011	NDE	NDE	NDE	NDE	NDE
00/06-32-026-09W400	1026.3	NDE	NDE	NDE	NDE	NDE
00/02-34-026-09W400	1037	NP	NP	1135	1137	1147
00/03-35-026-09W400	1049	NDE	NDE	NDE	NDE	NDE
00/06-35-026-09W400	1054	NP	NP	1149.5	1151	NDE
00/07-36-026-09W400	1059	NDE	NDE	NDE	NDE	NDE
00/06-01-026-10W400	1016.7	NDE	NDE	NDE	NDE	NDE
00/14-02-026-10W400	1041	NP	NP	NDE	NDE	NDE
00/10-04-026-10W400	1046.1	NDE	NDE	NDE	NDE	NDE
00/02-05-026-10W400	1027	NP	NP	NDE	NDE	NDE
00/01-06-026-10W400	1018	NP	NP	NDE	NDE	NDE
02/06-06-026-10W400	1033.7	NDE	NDE	NDE	NDE	NDE
00/11-07-026-10W400	1027.5	NDE	NDE	NDE	NDE	NDE
00/16-07-026-10W400	1051	NP	NP	NDE	NDE	NDE
00/10-08-026-10W400	1033	NDE	NDE	NDE	NDE	NDE
00/12-09-026-10W400	1050	NDE	NDE	NDE	NDE	NDE
00/09-10-026-10W400	1044	NDE	NDE	NDE	NDE	NDE
00/09-11-026-10W400	1045	NDE	NDE	NDE	NDE	NDE
00/16-11-026-10W400	1046.5	NDE	NDE	NDE	NDE	NDE
00/07-12-026-10W400	1027.2	NDE	NDE	NDE	NDE	NDE
00/12-12-026-10W400	1042	NDE	NDE	NDE	NDE	NDE
00/04-13-026-10W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/06-15-026-10W400	1054.5	NDE	NDE	NDE	NDE	NDE
00/13-16-026-10W400	1050	NP	NP	NDE	NDE	NDE
00/01-17-026-10W400	1041	NP	NP	NDE	NDE	NDE
00/06-18-026-10W400	1036	NP	NP	NDE	NDE	NDE
00/04-20-026-10W400	1050	NDE	NDE	NDE	NDE	NDE
00/05-22-026-10W400	1059	NDE	NDE	NDE	NDE	NDE
00/06-23-026-10W400	1058.5	NDE	NDE	NDE	NDE	NDE
00/11-25-026-10W400	1065.6	NP	NP	NDE	NDE	NDE
00/02-26-026-10W400	1066	NDE	NDE	NDE	NDE	NDE
00/04-27-026-10W400	1061	NDE	NDE	NDE	NDE	NDE
00/11-28-026-10W400	1069.2	NDE	NDE	NDE	NDE	NDE
00/02-29-026-10W400	1038.5	NP	NP	NDE	NDE	NDE
00/06-30-026-10W400	1039.1	NP	NP	NDE	NDE	NDE
00/09-31-026-10W400	1050	NP	NP	1129.5	1131	1144
00/11-31-026-10W400	1049	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Silkstone Top	Silkstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/02-32-026-10W400	1047.5	NDE	NDE	NDE	NDE	NDE
00/07-33-026-10W400	1060	NDE	NDE	NDE	NDE	NDE
00/06-34-026-10W400	1065.5	NP	NP	1157.5	1158.4	1172
00/05-35-026-10W400	1061	NP	NP	NDE	NDE	NDE
00/16-36-026-10W400	1060	NDE	NDE	NDE	NDE	NDE
00/08-01-026-11W400	1017	NP	NP	NDE	NDE	NDE
00/10-02-026-11W400	1031	NP	NP	NDE	NDE	NDE
00/06-03-026-11W400	1035.1	NDE	NDE	NDE	NDE	NDE
00/02-04-026-11W400	1028	NP	NP	NDE	NDE	NDE
00/10-04-026-11W400	1038.5	NDE	NDE	NDE	NDE	NDE
00/01-08-026-11W400	1048	NDE	NDE	NDE	NDE	NDE
00/09-08-026-11W400	1043	NDE	NDE	NDE	NDE	NDE
00/10-09-026-11W400	1060.7	NDE	NDE	NDE	NDE	NDE
00/14-10-026-11W400	1041.5	NDE	NDE	NDE	NDE	NDE
00/11-11-026-11W400	1028	NP	NP	NDE	NDE	NDE
00/10-12-026-11W400	1041.5	NDE	NDE	NDE	NDE	NDE
00/11-13-026-11W400	1020	NDE	NDE	NDE	NDE	NDE
00/07-14-026-11W400	1034	NDE	NDE	NDE	NDE	NDE
00/03-15-026-11W400	1049	NP	NP	NDE	NDE	NDE
00/14-15-026-11W400	1064	NP	NP	NDE	NDE	NDE
00/02-16-026-11W400	1055.5	NP	NP	NDE	NDE	NDE
00/11-16-026-11W400	1061.5	NP	NP	NDE	NDE	NDE
00/09-17-026-11W400	1053	NP	NP	NDE	NDE	NDE
00/14-18-026-11W400	1080.5	NP	NP	NDE	NDE	NDE
00/10-19-026-11W400	1071.1	NDE	NDE	NDE	NDE	NDE
00/12-19-026-11W400	1062	NDE	NDE	NDE	NDE	NDE
00/01-20-026-11W400	1066	NDE	NDE	NDE	NDE	NDE
00/13-20-026-11W400	1068	NP	NP	NDE	NDE	NDE
00/16-20-026-11W400	1094	NP	NP	NDE	NDE	NDE
00/06-22-026-11W400	1064.1	NDE	NDE	NDE	NDE	NDE
00/11-24-026-11W400	1040.9	NP	NP	NDE	NDE	NDE
00/06-25-026-11W400	1039.4	NDE	NDE	NDE	NDE	NDE
00/10-26-026-11W400	1062.8	NDE	NDE	NDE	NDE	NDE
00/16-27-026-11W400	1064.5	NP	NP	NDE	NDE	NDE
00/10-28-026-11W400	1062	NP	NP	NDE	NDE	NDE
00/11-28-026-11W400	1075.3	NP	NP	NDE	NDE	NDE
00/11-29-026-11W400	1072.6	NDE	NDE	NDE	NDE	NDE
00/12-29-026-11W400	1072	NDE	NDE	NDE	NDE	NDE
00/09-30-026-11W400	1067	NDE	NDE	NDE	NDE	NDE
00/06-31-026-11W400	1067	NP	NP	NDE	NDE	NDE
03/06-31-026-11W400	1070	NDE	NDE	NDE	NDE	NDE
00/06-32-026-11W400	1102.2	NDE	NDE	NDE	NDE	NDE
00/14-32-026-11W400	1095	NDE	NDE	NDE	NDE	NDE
00/01-33-026-11W400	1077	NP	NP	NDE	NDE	NDE
00/03-34-026-11W400	1086	NP	NP	NDE	NDE	NDE
00/01-35-026-11W400	1053	NDE	NDE	NDE	NDE	NDE
00/10-36-026-11W400	1040.3	NP	NP	NDE	NDE	NDE
00/06-01-026-12W400	1063	NDE	NDE	NDE	NDE	NDE
00/02-02-026-12W400	1065.9	NDE	NDE	NDE	NDE	NDE
00/06-02-026-12W400	1072	NDE	NDE	NDE	NDE	NDE
00/08-02-026-12W400	1057	NDE	NDE	NDE	NDE	NDE
00/11-02-026-12W400	1067	NDE	NDE	NDE	NDE	NDE
00/12-02-026-12W400	1072	NDE	NDE	NDE	NDE	NDE
00/14-02-026-12W400	1078	NDE	NDE	NDE	NDE	NDE
00/02-03-026-12W400	1071	NDE	NDE	NDE	NDE	NDE
00/04-03-026-12W400	1065	NDE	NDE	NDE	NDE	NDE
00/08-03-026-12W400	1070	NDE	NDE	NDE	NDE	NDE
00/15-03-026-12W400	1070.5	NDE	NDE	NDE	NDE	NDE
00/02-04-026-12W400	1052.2	NP	NP	NDE	NDE	NDE
00/05-04-026-12W400	1049.7	NP	NP	NDE	NDE	NDE
00/12-04-026-12W400	1064.4	NDE	NDE	NDE	NDE	NDE
00/15-04-026-12W400	1065	NDE	NDE	NDE	NDE	NDE
00/03-05-026-12W400	1060.1	NDE	NDE	NDE	NDE	NDE
00/07-05-026-12W400	1057	NP	NP	NDE	NDE	NDE
00/11-05-026-12W400	1066.8	NDE	NDE	NDE	NDE	NDE
00/01-06-026-12W400	1039.7	1043.6	1047.3	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/04-07-026-12W400	1079	NDE	NDE	NDE	NDE	NDE
00/14-07-026-12W400	1063	NP	NP	NDE	NDE	NDE
00/08-08-026-12W400	1084.2	NDE	NDE	NDE	NDE	NDE
00/03-09-026-12W400	1047	NP	NP	NDE	NDE	NDE
00/04-09-026-12W400	1056	NDE	NDE	NDE	NDE	NDE
00/06-09-026-12W400	1060	NDE	NDE	NDE	NDE	NDE
02/06-09-026-12W400	1059	NDE	NDE	NDE	NDE	NDE
00/09-09-026-12W400	1052	NDE	NDE	NDE	NDE	NDE
02/09-09-026-12W400	1057	NDE	NDE	NDE	NDE	NDE
03/09-09-026-12W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/12-09-026-12W400	1072	NDE	NDE	NDE	NDE	NDE
00/13-09-026-12W400	1082	NDE	NDE	NDE	NDE	NDE
00/01-10-026-12W400	1084.8	NDE	NDE	NDE	NDE	NDE
00/05-10-026-12W400	1071	NP	NP	NDE	NDE	NDE
00/09-10-026-12W400	1074	NDE	NDE	NDE	NDE	NDE
00/13-10-026-12W400	1066	NDE	NDE	NDE	NDE	NDE
00/01-11-026-12W400	1069	NDE	NDE	NDE	NDE	NDE
00/06-11-026-12W400	1088.4	NDE	NDE	NDE	NDE	NDE
00/06-12-026-12W400	1073	NP	NP	NDE	NDE	NDE
00/06-13-026-12W400	1065	NP	NP	NDE	NDE	NDE
00/11-14-026-12W400	1083.3	NP	NP	NDE	NDE	NDE
00/06-15-026-12W400	1079	NDE	NDE	NDE	NDE	NDE
00/02-16-026-12W400	1064	NDE	NDE	NDE	NDE	NDE
00/04-16-026-12W400	1077	1080.5	1083	NDE	NDE	NDE
00/05-16-026-12W400	1075	NP	NP	NDE	NDE	NDE
02/05-16-026-12W400	1068	NDE	NDE	NDE	NDE	NDE
00/06-16-026-12W400	1079.6	NDE	NDE	NDE	NDE	NDE
00/11-16-026-12W400	1072.3	NP	NP	NDE	NDE	NDE
00/12-16-026-12W400	1055	NDE	NDE	NDE	NDE	NDE
00/14-16-026-12W400	1052	NDE	NDE	NDE	NDE	NDE
00/16-16-026-12W400	1074.7	NDE	NDE	NDE	NDE	NDE
00/07-17-026-12W400	1058	NDE	NDE	NDE	NDE	NDE
00/09-17-026-12W400	1050.5	NDE	NDE	NDE	NDE	NDE
00/16-19-026-12W400	1085	NDE	NDE	NDE	NDE	NDE
00/03-20-026-12W400	1079	NDE	NDE	NDE	NDE	NDE
00/06-21-026-12W400	1072	NDE	NDE	NDE	NDE	NDE
00/06-22-026-12W400	1082	NDE	NDE	NDE	NDE	NDE
00/08-23-026-12W400	1063.5	1067.5	1070	NDE	NDE	NDE
00/09-23-026-12W400	1067.3	NP	NP	1150.3	1151.2	1162.8
00/16-23-026-12W400	1062	NDE	NDE	NDE	NDE	NDE
00/11-24-026-12W400	1057.7	NP	NP	1145.4	1146	1158.2
00/14-24-026-12W400	1046	NP	NP	NDE	NDE	NDE
00/05-25-026-12W400	1070	NDE	NDE	NDE	NDE	NDE
00/06-25-026-12W400	1066.8	NP	NP	1149.1	1150.3	1162.2
00/10-25-026-12W400	1068	NP	NP	NDE	NDE	NDE
00/06-27-026-12W400	1061	NP	NP	NDE	NDE	NDE
00/02-28-026-12W400	1072.3	NDE	NDE	NDE	NDE	NDE
00/10-29-026-12W400	1082	NDE	NDE	NDE	NDE	NDE
00/02-30-026-12W400	1066.5	NDE	NDE	NDE	NDE	NDE
00/02-31-026-12W400	1084.5	NP	NP	1164.6	1166.2	NDE
00/06-33-026-12W400	1069.8	NDE	NDE	NDE	NDE	NDE
00/06-35-026-12W400	1082.6	NP	NP	NDE	NDE	NDE
00/08-36-026-12W400	1078.5	NDE	NDE	NDE	NDE	NDE
03/03-01-026-13W400	1055	1064	1068.5	NDE	NDE	NDE
04/03-01-026-13W400	1053	NDE	NDE	NDE	NDE	NDE
00/04-01-026-13W400	1065	NDE	NDE	NDE	NDE	NDE
00/05-01-026-13W400	1060	NDE	NDE	NDE	NDE	NDE
02/05-01-026-13W400	1054.5	NDE	NDE	NDE	NDE	NDE
02/06-01-026-13W400	1050	NDE	NDE	NDE	NDE	NDE
00/12-01-026-13W400	1054	NDE	NDE	NDE	NDE	NDE
00/08-02-026-13W400	1050	NDE	NDE	NDE	NDE	NDE
00/16-02-026-13W400	1062	NDE	NDE	NDE	NDE	NDE
00/11-04-026-13W400	1079	NDE	NDE	NDE	NDE	NDE
00/02-06-026-13W400	1063	1065.5	1070.5	NDE	NDE	NDE
00/08-07-026-13W400	1075	1079	1084	NDE	NDE	NDE
00/11-07-026-13W400	1075.9	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/08-08-026-13W400	1074	1077	1081	NDE	NDE	NDE
00/06-10-026-13W400	1080	NDE	NDE	NDE	NDE	NDE
00/04-12-026-13W400	1064.4	NPL	NPL	NDE	NDE	NDE
00/06-12-026-13W400	1070	NP	NP	NDE	NDE	NDE
00/10-12-026-13W400	1073	NDE	NDE	NDE	NDE	NDE
00/07-13-026-13W400	1069.2	NDE	NDE	NDE	NDE	NDE
00/11-13-026-13W400	1084	NDE	NDE	NDE	NDE	NDE
00/14-14-026-13W400	1091	NDE	NDE	NDE	NDE	NDE
00/06-15-026-13W400	1082	NDE	NDE	NDE	NDE	NDE
00/07-15-026-13W400	1077.2	NDE	NDE	NDE	NDE	NDE
00/06-16-026-13W400	1079.6	NDE	NDE	NDE	NDE	NDE
00/07-17-026-13W400	1087.2	NDE	NDE	NDE	NDE	NDE
00/08-17-026-13W400	1079	NDE	NDE	NDE	NDE	NDE
00/11-18-026-13W400	1103.4	NDE	NDE	NDE	NDE	NDE
00/14-19-026-13W400	1124	NP	NP	NDE	NDE	NDE
00/07-20-026-13W400	1093.6	NDE	NDE	NDE	NDE	NDE
00/07-22-026-13W400	1077	NDE	NDE	NDE	NDE	NDE
00/06-23-026-13W400	1077.8	NPL	NPL	NDE	NDE	NDE
00/07-24-026-13W400	1070	NP	NP	NDE	NDE	NDE
00/11-25-026-13W400	1088.5	NP	NP	NDE	NDE	NDE
00/14-25-026-13W400	1102	NDE	NDE	NDE	NDE	NDE
00/06-27-026-13W400	1084	NDE	NDE	NDE	NDE	NDE
00/14-27-026-13W400	1098	NDE	NDE	NDE	NDE	NDE
00/07-30-026-13W400	1130.5	NDE	NDE	NDE	NDE	NDE
00/01-31-026-13W400	1132.5	NP	NP	NDE	NDE	NDE
00/08-31-026-13W400	1140	NP	NP	NDE	NDE	NDE
00/16-31-026-13W400	1146	NP	NP	NDE	NDE	NDE
00/06-32-026-13W400	1150	1151	1153	NDE	NDE	NDE
00/07-32-026-13W400	1153	NDE	NDE	NDE	NDE	NDE
00/08-32-026-13W400	1122	1123.5	1126	NDE	NDE	NDE
00/14-32-026-13W400	1148	1149	1155.3	NDE	NDE	NDE
00/16-32-026-13W400	1155	NP	NP	NDE	NDE	NDE
00/14-33-026-13W400	1122	NP	NP	NDE	NDE	NDE
00/16-33-026-13W400	1127	NDE	NDE	NDE	NDE	NDE
00/07-34-026-13W400	1101	NDE	NDE	NDE	NDE	NDE
00/11-34-026-13W400	1109	NDE	NDE	NDE	NDE	NDE
00/08-36-026-13W400	1094	NP	NP	NDE	NDE	NDE
00/10-01-026-14W400	1100.9	NDE	NDE	NDE	NDE	NDE
00/04-03-026-14W400	1092	NDE	NDE	NDE	NDE	NDE
00/04-04-026-14W400	1118	NDE	NDE	NDE	NDE	NDE
00/06-06-026-14W400	1106	1117	1126	NDE	NDE	NDE
00/10-07-026-14W400	1111	NDE	NDE	NDE	NDE	NDE
00/01-08-026-14W400	1108.5	1115	1120.5	NDE	NDE	NDE
00/10-08-026-14W400	1123.8	NDE	NDE	NDE	NDE	NDE
00/03-09-026-14W400	1134.5	NDE	NDE	NDE	NDE	NDE
00/08-10-026-14W400	1101.5	NDE	NDE	NDE	NDE	NDE
00/11-11-026-14W400	1112.8	1119.8	1123.2	1224.7	1225.6	1238.1
00/10-13-026-14W400	1091.2	NDE	NDE	NDE	NDE	NDE
00/06-14-026-14W400	1099.7	1108.3	1112.2	1208.2	1209.4	1221.9
00/11-15-026-14W400	1126.2	NDE	NDE	NDE	NDE	NDE
00/10-16-026-14W400	1104.6	NDE	NDE	NDE	NDE	NDE
00/06-18-026-14W400	1111	NDE	NDE	NDE	NDE	NDE
00/05-19-026-14W400	1112	NDE	NDE	NDE	NDE	NDE
00/13-20-026-14W400	1108	NDE	NDE	NDE	NDE	NDE
00/07-21-026-14W400	1100.9	NDE	NDE	NDE	NDE	NDE
00/10-22-026-14W400	1124	NP	NP	1237	1238	1250.5
00/14-23-026-14W400	1094.2	NP	NP	1202.4	1204	1219.2
00/14-25-026-14W400	1122	NDE	NDE	NDE	NDE	NDE
00/03-26-026-14W400	1102	NDE	NDE	NDE	NDE	NDE
00/02-27-026-14W400	1103	NDE	NDE	NDE	NDE	NDE
00/07-28-026-14W400	1153.7	NDE	NDE	NDE	NDE	NDE
00/06-29-026-14W400	1117	1124	1129.5	NDE	NDE	NDE
00/11-31-026-14W400	1123.5	NDE	NDE	NDE	NDE	NDE
00/01-34-026-14W400	1123	NDE	NDE	NDE	NDE	NDE
00/14-35-026-14W400	1103.5	NDE	NDE	NDE	NDE	NDE
00/11-36-026-14W400	1136.6	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-01-026-15W400	1124.7	NDE	NDE	NDE	NDE	NDE
00/01-02-026-15W400	1120	NDE	NDE	NDE	NDE	NDE
00/06-03-026-15W400	1141.2	NDE	NDE	NDE	NDE	NDE
00/10-04-026-15W400	1161.3	NDE	NDE	NDE	NDE	NDE
00/10-06-026-15W400	1141.2	NDE	NDE	NDE	NDE	NDE
00/10-08-026-15W400	1197.9	1205.2	1213.4	NDE	NDE	NDE
00/09-09-026-15W400	1151.5	NDE	NDE	NDE	NDE	NDE
00/11-11-026-15W400	1127.2	NP	NP	1244.5	1245.8	1257.3
00/10-12-026-15W400	1119.5	NDE	NDE	NDE	NDE	NDE
00/10-13-026-15W400	1114	NDE	NDE	NDE	NDE	NDE
00/10-14-026-15W400	1132.6	1140.9	1147	NDE	NDE	NDE
00/05-15-026-15W400	1118	NP	NP	1242	1243	1255
00/03-16-026-15W400	1146	NP	NP	1258.8	1261.3	1275.9
00/05-17-026-15W400	1175	NDE	NDE	NDE	NDE	NDE
00/06-21-026-15W400	1160	1162	1167	NDE	NDE	NDE
00/08-22-026-15W400	1138.5	1147	1152	1255	1256	1269
00/15-24-026-15W400	1124	NDE	NDE	NDE	NDE	NDE
00/10-25-026-15W400	1127	NDE	NDE	NDE	NDE	NDE
00/10-29-026-15W400	1202.7	NDE	NDE	NDE	NDE	NDE
00/02-30-026-15W400	1198	1205	1209	NDE	NDE	NDE
00/07-31-026-15W400	1197.9	NDE	NDE	NDE	NDE	NDE
00/14-32-026-15W400	1192	NDE	NDE	NDE	NDE	NDE
00/02-33-026-15W400	1173	NDE	NDE	NDE	NDE	NDE
00/16-36-026-15W400	1129	NP	NP	1248	1249	1262
00/06-01-026-16W400	1124.1	NDE	NDE	NDE	NDE	NDE
00/10-02-026-16W400	1124.7	NDE	NDE	NDE	NDE	NDE
00/06-03-026-16W400	1126.8	NDE	NDE	NDE	NDE	NDE
00/10-05-026-16W400	1149	NDE	NDE	NDE	NDE	NDE
00/11-06-026-16W400	1223.2	1234.4	1238.7	NDE	NDE	NDE
00/16-07-026-16W400	1053.3	NDE	NDE	NDE	NDE	NDE
00/10-08-026-16W400	1161.3	NDE	NDE	NDE	NDE	NDE
00/10-09-026-16W400	1131.7	NDE	NDE	NDE	NDE	NDE
00/06-10-026-16W400	1132.9	NDE	NDE	NDE	NDE	NDE
00/06-11-026-16W400	1133.2	1142.4	1147.9	NDE	NDE	NDE
00/06-12-026-16W400	1144.2	NDE	NDE	NDE	NDE	NDE
00/06-13-026-16W400	1177.7	NDE	NDE	NDE	NDE	NDE
00/11-14-026-16W400	1172.5	NDE	NDE	NDE	NDE	NDE
00/10-15-026-16W400	1158.5	NDE	NDE	NDE	NDE	NDE
00/06-16-026-16W400	1146	NDE	NDE	NDE	NDE	NDE
00/06-17-026-16W400	1149.4	NDE	NDE	NDE	NDE	NDE
00/08-18-026-16W400	1132	NDE	NDE	NDE	NDE	NDE
00/16-19-026-16W400	1164.5	NDE	NDE	NDE	NDE	NDE
00/10-20-026-16W400	1168.9	NDE	NDE	NDE	NDE	NDE
00/06-21-026-16W400	1168.5	NDE	NDE	NDE	NDE	NDE
00/10-24-026-16W400	1195.4	1205.2	1211.6	NDE	NDE	NDE
00/06-26-026-16W400	1210.4	1216.2	1222.2	NDE	NDE	NDE
00/06-27-026-16W400	1198	NDE	NDE	NDE	NDE	NDE
00/07-27-026-16W400	1213.7	1222.2	1229	NDE	NDE	NDE
00/06-28-026-16W400	1205.3	1210	1215	NDE	NDE	NDE
02/10-29-026-16W400	1209	1219	1224	NDE	NDE	NDE
02/08-30-026-16W400	1174.5	NDE	NDE	NDE	NDE	NDE
00/08-32-026-16W400	1231	NDE	NDE	NDE	NDE	NDE
00/06-33-026-16W400	1212.5	NDE	NDE	NDE	NDE	NDE
00/06-34-026-16W400	1210	1219	1225.5	NDE	NDE	NDE
00/11-36-026-16W400	1204.5	1218	1223	NDE	NDE	NDE
00/07-01-027-07W400	957.1	NDE	NDE	NDE	NDE	NDE
00/07-05-027-07W400	985.1	NDE	NDE	NDE	NDE	NDE
00/16-13-027-07W400	954	NDE	NDE	NDE	NDE	NDE
00/06-27-027-07W400	1001	NP	NP	NDE	NDE	NDE
00/16-28-027-07W400	1002.5	NP	NP	NDE	NDE	NDE
00/11-29-027-07W400	1020.2	NP	NP	NDE	NDE	NDE
00/07-03-027-08W400	1052.5	NDE	NDE	NDE	NDE	NDE
00/14-05-027-08W400	1031.7	NP	NP	1108.6	1111	NDE
00/03-15-027-08W400	1020.5	NP	NP	1083.3	1084.2	1095.8
00/08-19-027-08W400	1022.5	NDE	NDE	NDE	NDE	NDE
00/08-28-027-08W400	1041.5	1055.5	1060.5	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-31-027-08W400	1006.4	NDE	NDE	NDE	NDE	NDE
00/07-33-027-08W400	1042.4	NDE	NDE	NDE	NDE	NDE
00/10-34-027-08W400	1018.5	NDE	NDE	NDE	NDE	NDE
00/06-01-027-09W400	1059.5	NDE	NDE	NDE	NDE	NDE
00/06-03-027-09W400	1040	NP	NP	NDE	NDE	NDE
00/11-09-027-09W400	1039.4	NDE	NDE	NDE	NDE	NDE
00/11-11-027-09W400	1045	NP	NP	1108.5	1109	1119
00/08-12-027-09W400	1050	NDE	NDE	NDE	NDE	NDE
00/10-15-027-09W400	1023.8	NDE	NDE	NDE	NDE	NDE
00/10-17-027-09W400	1035.5	NDE	NDE	NDE	NDE	NDE
00/07-19-027-09W400	1054.6	NP	NP	NDE	NDE	NDE
00/11-20-027-09W400	1049.1	NDE	NDE	NDE	NDE	NDE
00/13-21-027-09W400	1050.3	NP	NP	1110	1111.9	1124.7
00/12-24-027-09W400	1051	NDE	NDE	NDE	NDE	NDE
00/06-27-027-09W400	1045	NDE	NDE	NDE	NDE	NDE
00/08-32-027-09W400	1051.5	NDE	NDE	NDE	NDE	NDE
00/08-33-027-09W400	1057	NDE	NDE	NDE	NDE	NDE
00/10-36-027-09W400	1048.5	NDE	NDE	NDE	NDE	NDE
00/06-02-027-10W400	1068.9	NDE	NDE	NDE	NDE	NDE
00/07-03-027-10W400	1058	NP	NP	1155	1156	NDE
00/06-04-027-10W400	1048.2	NDE	NDE	NDE	NDE	NDE
00/06-05-027-10W400	1038.5	NDE	NDE	NDE	NDE	NDE
00/07-06-027-10W400	1040.3	NDE	NDE	NDE	NDE	NDE
00/04-07-027-10W400	1074	NDE	NDE	NDE	NDE	NDE
00/06-09-027-10W400	1038.1	NDE	NDE	NDE	NDE	NDE
00/10-10-027-10W400	1090.6	NDE	NDE	NDE	NDE	NDE
00/14-11-027-10W400	1067	NDE	NDE	NDE	NDE	NDE
00/11-12-027-10W400	1114.3	NDE	NDE	NDE	NDE	NDE
00/06-13-027-10W400	1089	NDE	NDE	NDE	NDE	NDE
00/10-14-027-10W400	1073.5	NDE	NDE	NDE	NDE	NDE
00/06-15-027-10W400	1061.5	NDE	NDE	NDE	NDE	NDE
00/16-17-027-10W400	1045.5	NDE	NDE	NDE	NDE	NDE
00/11-18-027-10W400	1075.3	NDE	NDE	NDE	NDE	NDE
00/08-19-027-10W400	1041	NP	NP	1128	1129.5	1143
00/14-20-027-10W400	1050	NP	NP	NDE	NDE	NDE
00/08-21-027-10W400	1050.5	NP	NP	NDE	NDE	NDE
00/10-22-027-10W400	1059.5	NDE	NDE	NDE	NDE	NDE
00/07-23-027-10W400	1091	NDE	NDE	NDE	NDE	NDE
00/06-24-027-10W400	1079	NDE	NDE	NDE	NDE	NDE
00/10-25-027-10W400	1044	NP	NP	1133	1134	1148
00/11-29-027-10W400	1069.2	NDE	NDE	NDE	NDE	NDE
00/10-30-027-10W400	1050.3	NDE	NDE	NDE	NDE	NDE
00/12-31-027-10W400	1072	NDE	NDE	NDE	NDE	NDE
00/14-32-027-10W400	1069	NDE	NDE	NDE	NDE	NDE
00/12-34-027-10W400	1058	NDE	NDE	NDE	NDE	NDE
00/06-35-027-10W400	1079.9	NDE	NDE	NDE	NDE	NDE
00/01-01-027-11W400	1056.5	NDE	NDE	NDE	NDE	NDE
00/10-02-027-11W400	1090.6	NDE	NDE	NDE	NDE	NDE
00/14-03-027-11W400	1067	NDE	NDE	NDE	NDE	NDE
00/04-04-027-11W400	1091.5	NP	NP	1158.5	1160	1174.3
00/07-05-027-11W400	1097	NDE	NDE	NDE	NDE	NDE
00/06-06-027-11W400	1083.5	NP	NP	1148.3	1149.5	1163.3
00/16-07-027-11W400	1088.3	NP	NP	1153	1154	1168
00/08-09-027-11W400	1067	NP	NP	1164	1165.8	1178
00/02-11-027-11W400	1079	NDE	NDE	NDE	NDE	NDE
00/06-12-027-11W400	1058.3	NDE	NDE	NDE	NDE	NDE
00/11-13-027-11W400	1073.2	NDE	NDE	NDE	NDE	NDE
00/11-14-027-11W400	1082.6	NDE	NDE	NDE	NDE	NDE
00/16-15-027-11W400	1074	NDE	NDE	NDE	NDE	NDE
00/01-16-027-11W400	1070	NDE	NDE	NDE	NDE	NDE
00/10-18-027-11W400	1100.9	NDE	NDE	NDE	NDE	NDE
02/10-19-027-11W400	1091.5	NDE	NDE	NDE	NDE	NDE
00/11-20-027-11W400	1119.5	NDE	NDE	NDE	NDE	NDE
02/10-21-027-11W400	1095	NDE	NDE	NDE	NDE	NDE
00/01-22-027-11W400	1067.5	NDE	NDE	NDE	NDE	NDE
00/06-23-027-11W400	1077.8	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Sikastone Top	Sikastone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/13-25-027-11W400	1082	NDE	NDE	NDE	NDE	NDE
00/06-27-027-11W400	1118	NDE	NDE	NDE	NDE	NDE
00/16-28-027-11W400	1064	NP	NP	1148	1149	1161.5
00/15-29-027-11W400	1068.9	NP	NP	1140.2	1144.2	1151.8
00/06-30-027-11W400	1086.3	NDE	NDE	NDE	NDE	NDE
00/15-31-027-11W400	1085	NP	NP	NDE	NDE	NDE
00/14-32-027-11W400	1093.5	NDE	NDE	NDE	NDE	NDE
00/06-34-027-11W400	1097	NP	NP	NDE	NDE	NDE
00/11-36-027-11W400	1056.1	NP	NP	NDE	NDE	NDE
00/10-01-027-12W400	1073.5	NDE	NDE	NDE	NDE	NDE
00/13-03-027-12W400	1080	NDE	NDE	NDE	NDE	NDE
00/16-05-027-12W400	1082	NDE	NDE	NDE	NDE	NDE
00/02-06-027-12W400	1085.5	NDE	NDE	NDE	NDE	NDE
00/10-07-027-12W400	1108.5	NDE	NDE	NDE	NDE	NDE
00/07-08-027-12W400	1085	NDE	NDE	NDE	NDE	NDE
00/06-09-027-12W400	1084	NDE	NDE	NDE	NDE	NDE
00/06-11-027-12W400	1082.3	NDE	NDE	NDE	NDE	NDE
00/06-13-027-12W400	1093.6	NP	NP	NDE	NDE	NDE
00/08-14-027-12W400	1087.5	NDE	NDE	NDE	NDE	NDE
00/10-17-027-12W400	1085.1	NDE	NDE	NDE	NDE	NDE
00/10-18-027-12W400	1132	NDE	NDE	NDE	NDE	NDE
00/10-20-027-12W400	1138.1	NDE	NDE	NDE	NDE	NDE
00/15-21-027-12W400	1079.5	NP	NP	1149	1150	1163
00/06-22-027-12W400	1088.1	NDE	NDE	NDE	NDE	NDE
00/06-24-027-12W400	1083	NDE	NDE	NDE	NDE	NDE
00/09-25-027-12W400	1084	NDE	NDE	NDE	NDE	NDE
00/14-27-027-12W400	1095.5	NP	NP	NDE	NDE	NDE
00/08-28-027-12W400	1103.5	NDE	NDE	NDE	NDE	NDE
00/10-29-027-12W400	1128.4	NP	NP	NDE	NDE	NDE
00/10-30-027-12W400	1148.5	NDE	NDE	NDE	NDE	NDE
00/06-31-027-12W400	1153.1	NDE	NDE	NDE	NDE	NDE
00/06-32-027-12W400	1141	NDE	NDE	NDE	NDE	NDE
00/15-33-027-12W400	1084	NP	NP	1146.5	1148	1161
00/10-34-027-12W400	1097.9	NP	NP	NDE	NDE	NDE
00/16-35-027-12W400	1081	NP	NP	NDE	NDE	NDE
00/10-36-027-12W400	1093.6	NDE	NDE	NDE	NDE	NDE
00/08-02-027-13W400	1121	NDE	NDE	NDE	NDE	NDE
00/08-03-027-13W400	1131.5	NDE	NDE	NDE	NDE	NDE
00/02-04-027-13W400	1148	NDE	NDE	NDE	NDE	NDE
00/06-06-027-13W400	1144	NDE	NDE	NDE	NDE	NDE
00/07-09-027-13W400	1151.2	NP	NP	NDE	NDE	NDE
00/06-10-027-13W400	1140.5	NP	NP	NDE	NDE	NDE
00/10-11-027-13W400	1114	NDE	NDE	NDE	NDE	NDE
00/06-12-027-13W400	1116.8	NDE	NDE	NDE	NDE	NDE
00/01-13-027-13W400	1116.5	NDE	NDE	NDE	NDE	NDE
00/06-14-027-13W400	1141.5	NDE	NDE	NDE	NDE	NDE
00/06-18-027-13W400	1142	NDE	NDE	NDE	NDE	NDE
00/14-20-027-13W400	1155	NDE	NDE	NDE	NDE	NDE
00/06-22-027-13W400	1163.7	NDE	NDE	NDE	NDE	NDE
00/10-23-027-13W400	1154.3	NDE	NDE	NDE	NDE	NDE
00/06-24-027-13W400	1160.7	NDE	NDE	NDE	NDE	NDE
00/06-25-027-13W400	1156.4	NDE	NDE	NDE	NDE	NDE
00/11-26-027-13W400	1169.2	NDE	NDE	NDE	NDE	NDE
00/11-29-027-13W400	1126	NDE	NDE	NDE	NDE	NDE
00/07-30-027-13W400	1127	NP	NP	NDE	NDE	NDE
00/06-32-027-13W400	1133.5	NDE	NDE	NDE	NDE	NDE
00/07-33-027-13W400	1157.5	NDE	NDE	NDE	NDE	NDE
00/07-35-027-13W400	1165.6	NDE	NDE	NDE	NDE	NDE
00/06-36-027-13W400	1153	NDE	NDE	NDE	NDE	NDE
00/16-02-027-14W400	1118.6	NDE	NDE	NDE	NDE	NDE
02/16-05-027-14W400	1117.5	NDE	NDE	NDE	NDE	NDE
00/07-06-027-14W400	1127.5	NDE	NDE	NDE	NDE	NDE
00/14-08-027-14W400	1124	1134	1140	NDE	NDE	NDE
00/14-09-027-14W400	1138	NDE	NDE	NDE	NDE	NDE
00/16-10-027-14W400	1142.5	NDE	NDE	NDE	NDE	NDE
00/06-13-027-14W400	1121.7	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Evshaw Fm	Big Valley Fm	Stettler Fm
00/01-14-027-14W400	1155.5	NDE	NDE	NDE	NDE	NDE
00/02-15-027-14W400	1151	1160.5	1164	1276	1278	1295
00/01-17-027-14W400	1128.5	NDE	NDE	NDE	NDE	NDE
00/10-18-027-14W400	1146.7	NDE	NDE	NDE	NDE	NDE
00/16-19-027-14W400	1153	NDE	NDE	NDE	NDE	NDE
00/10-20-027-14W400	1152.8	NP	NP	1239	1240.5	1253.9
00/11-21-027-14W400	1136.3	NDE	NDE	NDE	NDE	NDE
00/14-22-027-14W400	1116.8	NP	NP	NDE	NDE	NDE
00/11-23-027-14W400	1142.5	NDE	NDE	NDE	NDE	NDE
00/06-24-027-14W400	1142.5	NDE	NDE	NDE	NDE	NDE
00/08-25-027-14W400	1149	NDE	NDE	NDE	NDE	NDE
00/11-28-027-14W400	1145.1	NDE	NDE	NDE	NDE	NDE
00/15-32-027-14W400	1166.5	NDE	NDE	NDE	NDE	NDE
00/10-33-027-14W400	1153.1	NP	NP	1241.5	1244.2	1261
00/12-34-027-14W400	1131.5	NDE	NDE	NDE	NDE	NDE
00/11-35-027-14W400	1124.7	NP	NP	1228.6	1232	1246.3
00/06-36-027-14W400	1162	NP	NP	1252.8	1255.3	1269
00/06-01-027-15W400	1151.5	NDE	NDE	NDE	NDE	NDE
00/14-03-027-15W400	1183	NP	NP	NDE	NDE	NDE
00/06-04-027-15W400	1195	NDE	NDE	NDE	NDE	NDE
00/06-08-027-15W400	1204.6	NDE	NDE	NDE	NDE	NDE
00/15-09-027-15W400	1193	NDE	NDE	NDE	NDE	NDE
00/07-10-027-15W400	1175	NDE	NDE	NDE	NDE	NDE
00/06-11-027-15W400	1156.5	1168	1172.5	NDE	NDE	NDE
00/07-12-027-15W400	1162.5	NDE	NDE	NDE	NDE	NDE
00/06-13-027-15W400	1170	NDE	NDE	NDE	NDE	NDE
02/11-14-027-15W400	1171.5	NP	NP	NDE	NDE	NDE
00/06-15-027-15W400	1186.6	NDE	NDE	NDE	NDE	NDE
00/05-16-027-15W400	1186	NDE	NDE	NDE	NDE	NDE
00/07-17-027-15W400	1188.1	NDE	NDE	NDE	NDE	NDE
00/06-18-027-15W400	1201.8	NP	NP	NDE	NDE	NDE
00/06-19-027-15W400	1218.6	NP	NP	NDE	NDE	NDE
00/06-20-027-15W400	1203	NP	NP	NDE	NDE	NDE
00/06-21-027-15W400	1221.9	NDE	NDE	NDE	NDE	NDE
00/07-23-027-15W400	1176	NDE	NDE	NDE	NDE	NDE
00/06-24-027-15W400	1154.6	NDE	NDE	NDE	NDE	NDE
00/06-26-027-15W400	1193.6	NDE	NDE	NDE	NDE	NDE
00/06-27-027-15W400	1231.4	NDE	NDE	NDE	NDE	NDE
00/07-28-027-15W400	1204.6	NDE	NDE	NDE	NDE	NDE
02/07-29-027-15W400	1231	NP	NP	NDE	NDE	NDE
00/11-31-027-15W400	1227	NDE	NDE	NDE	NDE	NDE
00/06-34-027-15W400	1239	NDE	NDE	NDE	NDE	NDE
00/08-35-027-15W400	1195	NP	NP	NDE	NDE	NDE
00/08-36-027-15W400	1185	NDE	NDE	NDE	NDE	NDE
00/06-01-027-16W400	1214.5	1222	1226	NDE	NDE	NDE
00/06-02-027-16W400	1220.4	NDE	NDE	NDE	NDE	NDE
00/06-03-027-16W400	1236	NP	NP	NDE	NDE	NDE
00/06-04-027-16W400	1224.4	NDE	NDE	NDE	NDE	NDE
00/07-05-027-16W400	1233	NDE	NDE	NDE	NDE	NDE
00/06-06-027-16W400	1202.5	NP	NP	NDE	NDE	NDE
00/10-11-027-16W400	1231	NDE	NDE	NDE	NDE	NDE
00/03-12-027-16W400	1217.5	NDE	NDE	NDE	NDE	NDE
00/11-13-027-16W400	1237.5	NDE	NDE	NDE	NDE	NDE
00/07-14-027-16W400	1227.7	NDE	NDE	NDE	NDE	NDE
00/14-16-027-16W400	1272.5	NDE	NDE	NDE	NDE	NDE
00/08-17-027-16W400	1274	NDE	NDE	NDE	NDE	NDE
00/06-19-027-16W400	1322	NDE	NDE	NDE	NDE	NDE
00/07-20-027-16W400	1276.8	NDE	NDE	NDE	NDE	NDE
00/06-21-027-16W400	1290	NDE	NDE	NDE	NDE	NDE
00/10-24-027-16W400	1228.3	NDE	NDE	NDE	NDE	NDE
00/06-25-027-16W400	1254.3	NDE	NDE	NDE	NDE	NDE
00/07-26-027-16W400	1249.3	NDE	NDE	NDE	NDE	NDE
00/07-28-027-16W400	1271.6	NDE	NDE	NDE	NDE	NDE
00/06-30-027-16W400	1313.7	NP	NP	1436.7	1437.4	1450.8
00/11-31-027-16W400	1316.7	NDE	NDE	NDE	NDE	NDE
00/07-32-027-16W400	1300	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/11-33-027-16W400	1307.5	NDE	NDE	NDE	NDE	NDE
00/06-34-027-16W400	1266.1	NDE	NDE	NDE	NDE	NDE
00/01-35-027-16W400	1266	NDE	NDE	NDE	NDE	NDE
00/03-36-027-16W400	1256.2	NP	NP	NDE	NDE	NDE
00/10-02-028-07W400	944.3	NDE	NDE	NDE	NDE	NDE
00/03-05-028-07W400	1007.5	NP	NP	NDE	NDE	NDE
00/12-11-028-07W400	971	NP	NP	NDE	NDE	NDE
00/06-12-028-07W400	935	NP	NP	NDE	NDE	NDE
00/10-19-028-07W400	976.9	NP	NP	NDE	NDE	NDE
00/07-22-028-07W400	960	NP	NP	1041.5	1042.5	1053
00/16-23-028-07W400	934	NP	NP	NDE	NDE	NDE
00/10-27-028-07W400	955.2	NP	NP	NDE	NDE	NDE
00/10-30-028-07W400	962.6	NP	NP	NDE	NDE	NDE
00/07-32-028-07W400	982	NDE	NDE	NDE	NDE	NDE
00/11-36-028-07W400	927	NP	NP	NDE	NDE	NDE
00/15-03-028-08W400	1012	NP	NP	NDE	NDE	NDE
00/06-10-028-08W400	1017	NP	NP	NDE	NDE	NDE
00/06-12-028-08W400	996.7	NP	NP	NDE	NDE	NDE
00/07-17-028-08W400	1035	NP	NP	NDE	NDE	NDE
00/06-20-028-08W400	1036	NP	NP	NDE	NDE	NDE
00/15-22-028-08W400	1001.3	NDE	NDE	NDE	NDE	NDE
00/07-23-028-08W400	1003.5	NP	NP	NDE	NDE	NDE
00/11-25-028-08W400	990	NP	NP	NDE	NDE	NDE
00/06-28-028-08W400	981.5	NP	NP	NDE	NDE	NDE
00/08-30-028-08W400	1548	NP	NP	NDE	NDE	NDE
00/14-34-028-08W400	975	NDE	NDE	NDE	NDE	NDE
00/11-35-028-08W400	978.1	NP	NP	NDE	NDE	NDE
00/09-09-028-09W400	1046	NDE	NDE	NDE	NDE	NDE
00/10-13-028-09W400	1030.8	NP	NP	NDE	NDE	NDE
00/10-17-028-09W400	1069.2	NP	NP	NDE	NDE	NDE
00/05-19-028-09W400	1071.4	NP	NP	1127.2	1129.9	1144.8
00/11-20-028-09W400	1037	NDE	NDE	NDE	NDE	NDE
00/05-23-028-09W400	1032	NP	NP	NDE	NDE	NDE
00/06-30-028-09W400	1076.5	NP	NP	NDE	NDE	NDE
00/14-33-028-09W400	1058.5	NP	NP	NDE	NDE	NDE
00/09-36-028-09W400	1005.5	NDE	NDE	NDE	NDE	NDE
00/11-03-028-10W400	1060.7	NDE	NDE	NDE	NDE	NDE
00/05-05-028-10W400	1045.5	NP	NP	NDE	NDE	NDE
00/08-06-028-10W400	1100	NDE	NDE	NDE	NDE	NDE
00/11-07-028-10W400	1068.9	NP	NP	NDE	NDE	NDE
02/10-08-028-10W400	1052.5	NDE	NDE	NDE	NDE	NDE
00/11-09-028-10W400	1047	NDE	NDE	NDE	NDE	NDE
00/06-10-028-10W400	1052.2	NDE	NDE	NDE	NDE	NDE
00/14-12-028-10W400	1063.5	NDE	NDE	NDE	NDE	NDE
00/07-13-028-10W400	1055.8	NP	NP	NDE	NDE	NDE
00/10-16-028-10W400	1049.1	NP	NP	NDE	NDE	NDE
00/02-19-028-10W400	1056	NP	NP	NDE	NDE	NDE
00/10-20-028-10W400	1061.9	NDE	NDE	NDE	NDE	NDE
00/07-21-028-10W400	1037	NDE	NDE	NDE	NDE	NDE
00/11-23-028-10W400	1042.7	NP	NP	NDE	NDE	NDE
00/06-26-028-10W400	1036.9	NP	NP	NDE	NDE	NDE
00/06-27-028-10W400	1048	NDE	NDE	NDE	NDE	NDE
00/08-28-028-10W400	1055	NDE	NDE	NDE	NDE	NDE
00/10-30-028-10W400	1046	NP	NP	NDE	NDE	NDE
00/12-31-028-10W400	1058	NDE	NDE	NDE	NDE	NDE
00/06-32-028-10W400	1034	NDE	NDE	NDE	NDE	NDE
00/06-35-028-10W400	1038.1	NP	NP	NDE	NDE	NDE
00/04-01-028-11W400	1059.5	NP	NP	1171.3	1172.3	1177.1
00/07-02-028-11W400	1088.1	NDE	NDE	NDE	NDE	NDE
00/07-04-028-11W400	1085	NP	NP	NDE	NDE	NDE
00/06-05-028-11W400	1100	NDE	NDE	NDE	NDE	NDE
00/16-06-028-11W400	1105	NP	NP	NDE	NDE	NDE
00/14-07-028-11W400	1069.5	NP	NP	NDE	NDE	NDE
00/16-08-028-11W400	1081	NP	NP	NDE	NDE	NDE
00/06-09-028-11W400	1089	NP	NP	NDE	NDE	NDE
00/10-10-028-11W400	1080	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/06-11-028-11W400	1092	NDE	NDE	NDE	NDE	NDE
00/09-12-028-11W400	1065	NDE	NDE	NDE	NDE	NDE
00/07-15-028-11W400	1080.8	NDE	NDE	NDE	NDE	NDE
00/09-17-028-11W400	1065	NP	NP	NDE	NDE	NDE
00/11-18-028-11W400	1075.9	NDE	NDE	NDE	NDE	NDE
00/01-19-028-11W400	1089	NDE	NDE	NDE	NDE	NDE
00/06-20-028-11W400	1091	NDE	NDE	NDE	NDE	NDE
00/11-25-028-11W400	1087	NDE	NDE	NDE	NDE	NDE
00/11-26-028-11W400	1066.2	NDE	NDE	NDE	NDE	NDE
00/15-28-028-11W400	1071	NP	NP	NDE	NDE	NDE
00/11-29-028-11W400	1071	NP	NP	NDE	NDE	NDE
00/12-30-028-11W400	1060	NP	NP	NDE	NDE	NDE
00/07-31-028-11W400	1059	NDE	NDE	NDE	NDE	NDE
00/11-32-028-11W400	1069.8	NDE	NDE	NDE	NDE	NDE
00/10-33-028-11W400	1079	NDE	NDE	NDE	NDE	NDE
00/10-34-028-11W400	1036.9	NDE	NDE	NDE	NDE	NDE
00/14-35-028-11W400	1072	NP	NP	1107.5	1109	NDE
00/06-36-028-11W400	1046.4	NP	NP	NDE	NDE	NDE
00/14-01-028-12W400	1075	NP	NP	NDE	NDE	NDE
00/08-02-028-12W400	1067	NP	NP	NDE	NDE	NDE
00/16-03-028-12W400	1108	NDE	NDE	NDE	NDE	NDE
00/16-04-028-12W400	1126	NDE	NDE	NDE	NDE	NDE
00/16-05-028-12W400	1126	NDE	NDE	NDE	NDE	NDE
00/11-06-028-12W400	1135.3	NDE	NDE	NDE	NDE	NDE
00/13-07-028-12W400	1172	NP	NP	NDE	NDE	NDE
00/14-08-028-12W400	1145.7	NDE	NDE	NDE	NDE	NDE
00/16-09-028-12W400	1120.5	NP	NP	NDE	NDE	NDE
00/08-10-028-12W400	1100.5	NP	NP	NDE	NDE	NDE
00/06-11-028-12W400	1106	NDE	NDE	NDE	NDE	NDE
00/06-13-028-12W400	1091	NDE	NDE	NDE	NDE	NDE
02/06-14-028-12W400	1105	NDE	NDE	NDE	NDE	NDE
00/07-15-028-12W400	1094.8	NP	NP	NDE	NDE	NDE
00/06-16-028-12W400	1103.3	NP	NP	NDE	NDE	NDE
00/07-17-028-12W400	1126.8	NP	NP	NDE	NDE	NDE
00/06-18-028-12W400	1177	NDE	NDE	NDE	NDE	NDE
00/06-21-028-12W400	1095.8	NDE	NDE	NDE	NDE	NDE
00/06-23-028-12W400	1098	NDE	NDE	NDE	NDE	NDE
00/12-24-028-12W400	1089	NP	NP	1128.5	1129.8	1144
00/07-26-028-12W400	1079	NP	NP	NDE	NDE	NDE
00/06-27-028-12W400	1106.5	NDE	NDE	NDE	NDE	NDE
00/08-28-028-12W400	1120	NDE	NDE	NDE	NDE	NDE
00/10-29-028-12W400	1170.1	NP	NP	1209.4	1210.7	1222.9
00/11-30-028-12W400	1141	NP	NP	NDE	NDE	NDE
00/06-32-028-12W400	1146	NDE	NDE	NDE	NDE	NDE
00/13-33-028-12W400	1131	NP	NP	NDE	NDE	NDE
00/10-36-028-12W400	1059.8	NP	NP	1136	1139.3	1149.1
02/11-01-028-13W400	1183	NP	NP	NDE	NDE	NDE
00/15-02-028-13W400	1169	NP	NP	NDE	NDE	NDE
00/01-04-028-13W400	1148	NP	NP	NDE	NDE	NDE
00/12-05-028-13W400	1122.5	NP	NP	NDE	NDE	NDE
00/16-08-028-13W400	1131	NDE	NDE	NDE	NDE	NDE
00/06-09-028-13W400	1125	NDE	NDE	NDE	NDE	NDE
00/06-10-028-13W400	1175.6	NP	NP	NDE	NDE	NDE
00/10-11-028-13W400	1182.4	NP	NP	NDE	NDE	NDE
00/06-12-028-13W400	1181.5	NP	NP	NDE	NDE	NDE
00/12-13-028-13W400	1179	NP	NP	NDE	NDE	NDE
00/10-14-028-13W400	1154	NDE	NDE	NDE	NDE	NDE
00/06-16-028-13W400	1124	NDE	NDE	NDE	NDE	NDE
00/14-18-028-13W400	1123.2	NP	NP	NDE	NDE	NDE
00/15-19-028-13W400	1167	NP	NP	NDE	NDE	NDE
00/11-20-028-13W400	1144	NP	NP	NDE	NDE	NDE
00/08-22-028-13W400	1185	NDE	NDE	NDE	NDE	NDE
00/06-24-028-13W400	1179	NP	NP	NDE	NDE	NDE
00/06-27-028-13W400	1140	NP	NP	NDE	NDE	NDE
00/15-30-028-13W400	1114	NP	NP	NDE	NDE	NDE
00/10-32-028-13W400	1141.8	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/03-34-028-13W400	1171	NDE	NDE	NDE	NDE	NDE
00/14-36-028-13W400	1150	NDE	NDE	NDE	NDE	NDE
00/11-02-028-14W400	1143	NDE	NDE	NDE	NDE	NDE
00/10-03-028-14W400	1136	NP	NP	NDE	NDE	NDE
00/04-05-028-14W400	1167.5	NP	NP	NDE	NDE	NDE
00/06-07-028-14W400	1205.2	NP	NP	NDE	NDE	NDE
00/14-08-028-14W400	1192	NP	NP	1306	1307	1319
00/07-09-028-14W400	1161	NP	NP	1251.5	1254.3	NDE
00/11-09-028-14W400	1182	NP	NP	1282.6	1283.8	1297.8
00/06-10-028-14W400	1152	NP	NP	NDE	NDE	NDE
00/06-11-028-14W400	1144.2	NP	NP	1218.5	1219.8	NDE
00/13-11-028-14W400	1130.8	NDE	NDE	NDE	NDE	NDE
00/04-12-028-14W400	1133.5	NP	NP	NDE	NDE	NDE
00/10-14-028-14W400	1134.5	NDE	NDE	NDE	NDE	NDE
00/07-15-028-14W400	1135	NP	NP	NDE	NDE	NDE
00/16-16-028-14W400	1173.5	NDE	NDE	NDE	NDE	NDE
00/11-18-028-14W400	1194.5	NP	NP	1284.5	1286	1297
00/11-19-028-14W400	1207.9	NDE	NDE	NDE	NDE	NDE
00/09-20-028-14W400	1188	NDE	NDE	NDE	NDE	NDE
00/13-21-028-14W400	1175	NDE	NDE	NDE	NDE	NDE
00/06-23-028-14W400	1143	NDE	NDE	NDE	NDE	NDE
00/06-27-028-14W400	1127.8	NP	NP	NDE	NDE	NDE
00/11-32-028-14W400	1187	NP	NP	1281.5	1283.5	1295.5
00/11-33-028-14W400	1159.5	NP	NP	NDE	NDE	NDE
00/12-36-028-14W400	1100.4	NP	NP	NDE	NDE	NDE
00/14-01-028-15W400	1205	NDE	NDE	NDE	NDE	NDE
00/16-02-028-15W400	1211	NDE	NDE	NDE	NDE	NDE
00/06-06-028-15W400	1249.1	NDE	NDE	NDE	NDE	NDE
00/16-07-028-15W400	1246	NP	NP	NDE	NDE	NDE
00/10-09-028-15W400	1236.9	NP	NP	NDE	NDE	NDE
02/10-11-028-15W400	1214.5	NP	NP	NDE	NDE	NDE
00/06-12-028-15W400	1203	NP	NP	NDE	NDE	NDE
00/08-13-028-15W400	1196	NP	NP	1282	1283	1294.5
00/10-14-028-15W400	1200	NP	NP	NDE	NDE	NDE
00/11-17-028-15W400	1247.5	NDE	NDE	NDE	NDE	NDE
00/11-18-028-15W400	1276.5	NP	NP	NDE	NDE	NDE
00/07-19-028-15W400	1267.4	NDE	NDE	NDE	NDE	NDE
00/09-21-028-15W400	1248	NDE	NDE	NDE	NDE	NDE
00/11-23-028-15W400	1224	NDE	NDE	NDE	NDE	NDE
00/15-24-028-15W400	1201	NDE	NDE	NDE	NDE	NDE
00/10-25-028-15W400	1190	1201	1206	NDE	NDE	NDE
00/10-29-028-15W400	1238	NP	NP	NDE	NDE	NDE
00/02-30-028-15W400	1264.5	NP	NP	NDE	NDE	NDE
00/16-31-028-15W400	1252.5	NP	NP	NDE	NDE	NDE
00/08-32-028-15W400	1262.5	NP	NP	NDE	NDE	NDE
00/14-34-028-15W400	1246	NDE	NDE	NDE	NDE	NDE
00/06-35-028-15W400	1227	NP	NP	NDE	NDE	NDE
00/10-01-028-16W400	1260.3	NDE	NDE	NDE	NDE	NDE
00/10-02-028-16W400	1265	NP	NP	NDE	NDE	NDE
00/04-04-028-16W400	1296.5	NP	NP	NDE	NDE	NDE
00/02-05-028-16W400	1287.5	NP	NP	NDE	NDE	NDE
00/06-06-028-16W400	1305.5	NDE	NDE	NDE	NDE	NDE
00/10-09-028-16W400	1301	NDE	NDE	NDE	NDE	NDE
00/05-10-028-16W400	1304	NP	NP	NDE	NDE	NDE
00/11-12-028-16W400	1259.8	NDE	NDE	NDE	NDE	NDE
00/06-16-028-16W400	1284.4	NDE	NDE	NDE	NDE	NDE
00/07-20-028-16W400	1328	NDE	NDE	NDE	NDE	NDE
00/13-22-028-16W400	1301	NDE	NDE	NDE	NDE	NDE
00/10-23-028-16W400	1296.9	NDE	NDE	NDE	NDE	NDE
00/06-24-028-16W400	1281.5	NP	NP	NDE	NDE	NDE
00/14-25-028-16W400	1295	NP	NP	NDE	NDE	NDE
00/16-26-028-16W400	1307	NP	NP	NDE	NDE	NDE
00/11-27-028-16W400	1294.5	NDE	NDE	NDE	NDE	NDE
00/11-30-028-16W400	1372.2	NDE	NDE	NDE	NDE	NDE
00/10-32-028-16W400	1364	NP	NP	NDE	NDE	NDE
00/10-33-028-16W400	1309	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/14-35-028-16W400	1312.5	NP	NP	NDE	NDE	NDE
00/10-04-029-07W400	963	NDE	NDE	NDE	NDE	NDE
00/06-05-029-07W400	963.2	NP	NP	NDE	NDE	NDE
00/16-10-029-07W400	954	NP	NP	NDE	NDE	NDE
00/08-11-029-07W400	959.5	NP	NP	1031.7	1036.9	1052.2
00/10-13-029-07W400	946.4	NP	NP	1008.9	1010.4	1022
00/10-17-029-07W400	969	NDE	NDE	NDE	NDE	NDE
00/10-22-029-07W400	949.3	NDE	NDE	NDE	NDE	NDE
00/10-29-029-07W400	990.6	NP	NP	1036.3	1038.1	1051.6
00/06-33-029-07W400	949.5	NP	NP	NDE	NDE	NDE
00/05-02-029-08W400	982	NP	NP	NDE	NDE	NDE
00/06-03-029-08W400	979.9	NP	NP	NDE	NDE	NDE
00/07-04-029-08W400	969.3	NP	NP	NDE	NDE	NDE
00/10-05-029-08W400	974.8	NDE	NDE	NDE	NDE	NDE
00/07-07-029-08W400	963.2	NP	NP	NDE	NDE	NDE
00/06-08-029-08W400	969.9	NP	NP	NDE	NDE	NDE
00/06-10-029-08W400	964.1	NP	NP	1033.3	1036.3	1043
00/10-11-029-08W400	961.3	NP	NP	NDE	NDE	NDE
00/10-15-029-08W400	962.3	NP	NP	NDE	NDE	NDE
00/07-16-029-08W400	964.7	NDE	NDE	NDE	NDE	NDE
00/11-18-029-08W400	973.8	NDE	NDE	NDE	NDE	NDE
00/10-24-029-08W400	975.4	NDE	NDE	NDE	NDE	NDE
00/06-27-029-08W400	961.9	NP	NP	NDE	NDE	NDE
00/07-29-029-08W400	979	NDE	NDE	NDE	NDE	NDE
00/07-33-029-08W400	954.9	NDE	NDE	NDE	NDE	NDE
00/11-34-029-08W400	969.3	NDE	NDE	NDE	NDE	NDE
00/07-02-029-09W400	1014	NDE	NDE	NDE	NDE	NDE
00/01-05-029-09W400	1060.7	NP	NP	1114	1118.6	1132.3
00/11-06-029-09W400	1054	NDE	NDE	NDE	NDE	NDE
00/14-08-029-09W400	1034.5	NP	NP	NDE	NDE	NDE
00/10-10-029-09W400	1023.8	NDE	NDE	NDE	NDE	NDE
00/06-11-029-09W400	1013.8	NP	NP	1077.5	1079.6	1091.2
00/10-16-029-09W400	1034.5	NP	NP	NDE	NDE	NDE
00/07-18-029-09W400	1023	NDE	NDE	NDE	NDE	NDE
00/07-19-029-09W400	1028	NP	NP	NDE	NDE	NDE
00/10-21-029-09W400	1033.9	NDE	NDE	NDE	NDE	NDE
00/11-23-029-09W400	1012.5	NP	NP	NDE	NDE	NDE
00/07-25-029-09W400	985.7	NP	NP	NDE	NDE	NDE
00/07-26-029-09W400	1003.7	NDE	NDE	NDE	NDE	NDE
00/06-27-029-09W400	1035.7	NP	NP	NDE	NDE	NDE
00/06-30-029-09W400	1004.5	NP	NP	NDE	NDE	NDE
00/11-06-029-10W400	1043	NP	NP	NDE	NDE	NDE
00/02-07-029-10W400	1053	NDE	NDE	NDE	NDE	NDE
00/06-10-029-10W400	1060	NDE	NDE	NDE	NDE	NDE
00/11-11-029-10W400	1048.5	NDE	NDE	NDE	NDE	NDE
00/06-13-029-10W400	1042	NP	NP	NDE	NDE	NDE
00/06-15-029-10W400	1071.4	NP	NP	1108.2	1109.5	NDE
00/11-16-029-10W400	1085.1	NDE	NDE	NDE	NDE	NDE
00/10-18-029-10W400	1057.4	NDE	NDE	NDE	NDE	NDE
00/06-19-029-10W400	1027	NDE	NDE	NDE	NDE	NDE
00/14-20-029-10W400	1024.7	NP	NP	NDE	NDE	NDE
00/16-24-029-10W400	1039	NP	NP	NDE	NDE	NDE
00/11-26-029-10W400	1019.5	NDE	NDE	NDE	NDE	NDE
00/11-30-029-10W400	1035.7	NDE	NDE	NDE	NDE	NDE
00/06-31-029-10W400	1018	NDE	NDE	NDE	NDE	NDE
00/06-01-029-11W400	1041.5	NDE	NDE	NDE	NDE	NDE
00/01-02-029-11W400	1044.9	NP	NP	1094.5	1096.1	1109.5
00/07-04-029-11W400	1072.8	NDE	NDE	NDE	NDE	NDE
00/07-05-029-11W400	1089.5	NDE	NDE	NDE	NDE	NDE
00/07-06-029-11W400	1068	NP	NP	NDE	NDE	NDE
00/11-08-029-11W400	1086.3	NP	NP	NDE	NDE	NDE
00/07-09-029-11W400	1091.8	NDE	NDE	NDE	NDE	NDE
00/07-10-029-11W400	1063.8	NDE	NDE	NDE	NDE	NDE
00/04-11-029-11W400	1050.3	NDE	NDE	NDE	NDE	NDE
00/01-12-029-11W400	1036.5	NDE	NDE	NDE	NDE	NDE
00/14-13-029-11W400	1045	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-14-029-11W400	1065.6	NDE	NDE	NDE	NDE	NDE
00/06-15-029-11W400	1100.3	NP	NP	NDE	NDE	NDE
00/07-16-029-11W400	1108.6	NDE	NDE	NDE	NDE	NDE
00/11-18-029-11W400	1092.4	NDE	NDE	NDE	NDE	NDE
00/06-19-029-11W400	1100.9	NDE	NDE	NDE	NDE	NDE
00/06-20-029-11W400	1110.4	NP	NP	NDE	NDE	NDE
00/06-22-029-11W400	1074.5	NP	NP	NDE	NDE	NDE
00/11-23-029-11W400	1031.4	NP	NP	NDE	NDE	NDE
00/14-24-029-11W400	1051	NDE	NDE	NDE	NDE	NDE
00/10-27-029-11W400	1048.5	NDE	NDE	NDE	NDE	NDE
00/06-29-029-11W400	1110.4	NP	NP	NDE	NDE	NDE
00/10-32-029-11W400	1123.5	NDE	NDE	NDE	NDE	NDE
00/11-33-029-11W400	1071.1	NDE	NDE	NDE	NDE	NDE
00/11-35-029-11W400	1031.4	NP	NP	NDE	NDE	NDE
00/08-36-029-11W400	1049.5	NP	NP	NDE	NDE	NDE
00/16-01-029-12W400	1087	NDE	NDE	NDE	NDE	NDE
00/06-02-029-12W400	1084.4	NDE	NDE	NDE	NDE	NDE
00/06-05-029-12W400	1155	NP	NP	NDE	NDE	NDE
00/07-09-029-12W400	1140	NDE	NDE	NDE	NDE	NDE
00/16-10-029-12W400	1097	NDE	NDE	NDE	NDE	NDE
00/07-12-029-12W400	1072.8	NDE	NDE	NDE	NDE	NDE
00/10-13-029-12W400	1091.2	NDE	NDE	NDE	NDE	NDE
00/06-14-029-12W400	1087	NDE	NDE	NDE	NDE	NDE
00/07-15-029-12W400	1113	NP	NP	NDE	NDE	NDE
00/11-18-029-12W400	1133	NP	NP	NDE	NDE	NDE
00/06-19-029-12W400	1144.8	NP	NP	NDE	NDE	NDE
00/10-21-029-12W400	1114	NDE	NDE	NDE	NDE	NDE
00/11-22-029-12W400	1115	NP	NP	NDE	NDE	NDE
00/10-23-029-12W400	1109.5	NDE	NDE	NDE	NDE	NDE
00/14-25-029-12W400	1110.2	NDE	NDE	NDE	NDE	NDE
00/16-26-029-12W400	1101.8	NP	NP	NDE	NDE	NDE
00/06-27-029-12W400	1108	NDE	NDE	NDE	NDE	NDE
00/06-29-029-12W400	1132.6	NDE	NDE	NDE	NDE	NDE
00/11-30-029-12W400	1151.5	NDE	NDE	NDE	NDE	NDE
00/16-32-029-12W400	1095	NDE	NDE	NDE	NDE	NDE
00/07-33-029-12W400	1087.5	NP	NP	1152.8	1155.2	1166.2
00/10-34-029-12W400	1088.4	NDE	NDE	NDE	NDE	NDE
00/10-35-029-12W400	1081.7	NDE	NDE	NDE	NDE	NDE
00/04-36-029-12W400	1103	NP	NP	NDE	NDE	NDE
00/07-01-029-13W400	1161.2	NP	NP	NDE	NDE	NDE
00/06-04-029-13W400	1188.1	NDE	NDE	NDE	NDE	NDE
00/02-05-029-13W400	1227	NP	NP	NDE	NDE	NDE
00/09-09-029-13W400	1137	NP	NP	NDE	NDE	NDE
00/10-10-029-13W400	1161.3	NDE	NDE	NDE	NDE	NDE
00/15-11-029-13W400	1156	NP	NP	NDE	NDE	NDE
00/06-13-029-13W400	1172	NP	NP	1221	1223	1234
00/07-14-029-13W400	1145.4	NP	NP	NDE	NDE	NDE
00/10-15-029-13W400	1145.1	NDE	NDE	NDE	NDE	NDE
00/09-16-029-13W400	1151	NP	NP	NDE	NDE	NDE
00/13-18-029-13W400	1150	NDE	NDE	NDE	NDE	NDE
00/07-21-029-13W400	1230	NDE	NDE	NDE	NDE	NDE
00/16-25-029-13W400	1168.5	NDE	NDE	NDE	NDE	NDE
00/16-28-029-13W400	1201	NDE	NDE	NDE	NDE	NDE
00/11-31-029-13W400	1166.8	NDE	NDE	NDE	NDE	NDE
00/16-32-029-13W400	1200	NP	NP	1284	1285	1298
00/10-33-029-13W400	1213.7	NP	NP	NDE	NDE	NDE
00/08-36-029-13W400	1150.3	NDE	NDE	NDE	NDE	NDE
00/04-03-029-14W400	1131	NDE	NDE	NDE	NDE	NDE
00/06-07-029-14W400	1200.9	NDE	NDE	NDE	NDE	NDE
00/16-09-029-14W400	1095	NP	NP	1191	1192.6	1206
00/07-11-029-14W400	1103.4	NP	NP	1193	1195.1	1215.8
00/10-11-029-14W400	1102	NDE	NDE	NDE	NDE	NDE
00/03-15-029-14W400	1098.5	NP	NP	1191.2	1192.4	1207.6
00/01-16-029-14W400	1095	NP	NP	1194.5	1195.5	1208.5
00/06-22-029-14W400	1103.5	NP	NP	1204.5	1206	1218.8
00/06-25-029-14W400	1132.7	NDE	NDE	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-27-029-14W400	[illegible]	NDE	NDE	NDE	NDE	NDE
00/06-28-029-14W400	1105.2	NP	NP	NDE	NDE	NDE
00/16-30-029-14W400	1146.8	NDE	NDE	NDE	NDE	NDE
00/06-32-029-14W400	1119	NP	NP	NDE	NDE	NDE
00/14-33-029-14W400	1106	NP	NP	NDE	NDE	NDE
00/16-35-029-14W400	1127	NP	NP	1223	1224	1238.5
00/06-01-029-15W400	1199	NP	NP	1302	1303	NDE
00/13-02-029-15W400	1234	NDE	NDE	NDE	NDE	NDE
00/06-03-029-15W400	1257.5	NDE	NDE	NDE	NDE	NDE
00/06-04-029-15W400	1261.9	NP	NP	NDE	NDE	NDE
00/11-05-029-15W400	1289	NDE	NDE	NDE	NDE	NDE
00/06-06-029-15W400	1282	NDE	NDE	NDE	NDE	NDE
00/08-07-029-15W400	1285	NDE	NDE	NDE	NDE	NDE
00/07-08-029-15W400	1295.4	NDE	NDE	NDE	NDE	NDE
00/08-09-029-15W400	1288	NP	NP	1389	1390	NDE
00/08-10-029-15W400	1261	NDE	NDE	NDE	NDE	NDE
00/06-11-029-15W400	1247.5	NDE	NDE	NDE	NDE	NDE
00/07-13-029-15W400	1237.8	NDE	NDE	NDE	NDE	NDE
00/12-14-029-15W400	1278	NP	NP	NDE	NDE	NDE
00/06-15-029-15W400	1295.5	NP	NP	NDE	NDE	NDE
00/07-16-029-15W400	1316.7	NP	NP	NDE	NDE	NDE
00/10-18-029-15W400	1292.4	NDE	NDE	NDE	NDE	NDE
00/04-19-029-15W400	1276	NDE	NDE	NDE	NDE	NDE
00/08-21-029-15W400	1310	NDE	NDE	NDE	NDE	NDE
00/14-23-029-15W400	1265	NP	NP	NDE	NDE	NDE
00/16-25-029-15W400	1185	NP	NP	NDE	NDE	NDE
00/06-26-029-15W400	1267	NP	NP	NDE	NDE	NDE
00/06-27-029-15W400	1297.5	NP	NP	1399.3	1400.5	NDE
00/14-29-029-15W400	1325	NDE	NDE	NDE	NDE	NDE
00/11-30-029-15W400	1306.4	NDE	NDE	NDE	NDE	NDE
00/12-32-029-15W400	1325	NP	NP	NDE	NDE	NDE
00/14-34-029-15W400	1252.7	NP	NP	1347.2	1350.3	1368.6
00/06-01-029-16W400	1310	NDE	NDE	NDE	NDE	NDE
00/06-02-029-16W400	1305	NP	NP	NDE	NDE	NDE
00/02-03-029-16W400	1322.5	NDE	NDE	NDE	NDE	NDE
00/11-06-029-16W400	1417.3	NDE	NDE	NDE	NDE	NDE
00/06-09-029-16W400	1329.5	NDE	NDE	NDE	NDE	NDE
00/08-10-029-16W400	1346	NDE	NDE	NDE	NDE	NDE
00/07-12-029-16W400	1301.5	NDE	NDE	NDE	NDE	NDE
00/07-14-029-16W400	1320.7	NDE	NDE	NDE	NDE	NDE
00/07-15-029-16W400	1326	1329.5	1340.5	NDE	NDE	NDE
00/14-16-029-16W400	1398	NDE	NDE	NDE	NDE	NDE
00/10-18-029-16W400	1376.8	NDE	NDE	NDE	NDE	NDE
00/03-19-029-16W400	1385	NDE	NDE	NDE	NDE	NDE
00/05-21-029-16W400	1400	NP	NP	1499	1500	1513.5
00/10-22-029-16W400	1321.5	NDE	NDE	NDE	NDE	NDE
00/11-23-029-16W400	1275	NDE	NDE	NDE	NDE	NDE
00/10-25-029-16W400	1278	NP	NP	NDE	NDE	NDE
00/07-26-029-16W400	1295	NDE	NDE	NDE	NDE	NDE
00/06-27-029-16W400	1313	NDE	NDE	NDE	NDE	NDE
00/10-28-029-16W400	1369	NDE	NDE	NDE	NDE	NDE
00/11-29-029-16W400	1420.4	NDE	NDE	NDE	NDE	NDE
00/09-31-029-16W400	1430	NDE	NDE	NDE	NDE	NDE
00/14-32-029-16W400	1380	1383	1387	NDE	NDE	NDE
00/14-34-029-16W400	1315	NDE	NDE	NDE	NDE	NDE
00/14-35-029-16W400	1280	NDE	NDE	NDE	NDE	NDE
00/16-36-029-16W400	1283	NDE	NDE	NDE	NDE	NDE
00/07-01-030-07W400	906.2	NDE	NDE	NDE	NDE	NDE
00/11-06-030-07W400	902.2	NP	NP	NDE	NDE	NDE
00/08-07-030-07W400	896	NP	NP	NDE	NDE	NDE
00/07-17-030-07W400	942.7	NDE	NDE	NDE	NDE	NDE
00/10-20-030-07W400	966	NDE	NDE	NDE	NDE	NDE
00/04-21-030-07W400	952.2	NP	NP	998.8	1000.7	NDE
00/06-31-030-07W400	1015	NDE	NDE	NDE	NDE	NDE
00/12-04-030-08W400	984.5	NP	NP	1033.3	1035.1	1048.5
00/10-06-030-08W400	998	NP	NP	1048	1049	1063

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/02C-17-030-08W40	961	NP	NP	1027	1028	1043.5
00/06-18-030-08W400	972.3	NDE	NDE	NDE	NDE	NDE
00/07-21-030-08W400	973.5	NDE	NDE	NDE	NDE	NDE
00/10-23-030-08W400	975.4	NDE	NDE	NDE	NDE	NDE
00/10-24-030-08W400	969	NDE	NDE	NDE	NDE	NDE
00/10-32-030-08W400	991	NDE	NDE	NDE	NDE	NDE
00/06-34-030-08W400	989.7	NP	NP	994.6	995.8	1010.7
00/16-02-030-09W400	988.5	NP	NP	1042	1043	1058
00/05-03-030-09W400	991.2	NP	NP	1044.5	1045.5	1058.9
00/10-05-030-09W400	1005.2	NDE	NDE	NDE	NDE	NDE
00/03-12-030-09W400	956.5	NP	NP	1025	1027	1041
00/14-12-030-09W400	975.4	NP	NP	1011.9	1013.5	1027.8
00/10-14-030-09W400	985.4	NDE	NDE	NDE	NDE	NDE
00/07-15-030-09W400	1017.1	NP	NP	NDE	NDE	NDE
00/06-16-030-09W400	1050	NDE	NDE	NDE	NDE	NDE
00/11-17-030-09W400	1053.4	NDE	NDE	NDE	NDE	NDE
00/11-19-030-09W400	1018.6	NDE	NDE	NDE	NDE	NDE
00/07-24-030-09W400	983	NDE	NDE	NDE	NDE	NDE
00/06-26-030-09W400	1044.5	NDE	NDE	NDE	NDE	NDE
00/11-29-030-09W400	1024	NDE	NDE	NDE	NDE	NDE
00/08-30-030-09W400	1025	NP	NP	1031.3	1032	1042
00/06-32-030-09W400	1027	NP	NP	1033.8	1035	1050
00/10-33-030-09W400	1035.4	NP	NP	NDE	NDE	NDE
00/11-35-030-09W400	1051.6	NDE	NDE	NDE	NDE	NDE
00/07-03-030-10W400	1024.7	NP	NP	1072.3	1074.1	1087.2
00/10-04-030-10W400	1011.3	NDE	NDE	NDE	NDE	NDE
00/06-05-030-10W400	1032.5	NDE	NDE	NDE	NDE	NDE
00/11-06-030-10W400	1027.2	NP	NP	NDE	NDE	NDE
00/11-07-030-10W400	1025.5	NDE	NDE	NDE	NDE	NDE
00/15-08-030-10W400	1015.5	NDE	NDE	NDE	NDE	NDE
00/11-11-030-10W400	1010.4	NP	NP	1058	1059	1073.6
00/16-12-030-10W400	990.6	NP	NP	1046.7	1047.4	1061.9
00/10-14-030-10W400	1012.5	NDE	NDE	NDE	NDE	NDE
00/11-16-030-10W400	1015	NDE	NDE	NDE	NDE	NDE
00/11-17-030-10W400	1017	NDE	NDE	NDE	NDE	NDE
00/06-18-030-10W400	1025	NP	NP	1081.4	1082.3	1096.7
00/06-19-030-10W400	1032.1	NDE	NDE	NDE	NDE	NDE
00/10-20-030-10W400	1033.6	NDE	NDE	NDE	NDE	NDE
00/06-21-030-10W400	1033	NDE	NDE	NDE	NDE	NDE
00/08-23-030-10W400	1012.5	NDE	NDE	NDE	NDE	NDE
00/14-24-030-10W400	1031	NDE	NDE	NDE	NDE	NDE
00/06-26-030-10W400	1063.4	NDE	NDE	NDE	NDE	NDE
00/06-27-030-10W400	1031.6	NDE	NDE	NDE	NDE	NDE
00/06-30-030-10W400	1048	NDE	NDE	NDE	NDE	NDE
00/06-31-030-10W400	1038.5	NDE	NDE	NDE	NDE	NDE
00/10-35-030-10W400	1036.3	NP	NP	1065.6	1066.5	1075
00/10-36-030-10W400	1011	NP	NP	1035	1036	1049.5
00/12-01-030-11W400	1029	NDE	NDE	NDE	NDE	NDE
00/10-02-030-11W400	1023.5	NDE	NDE	NDE	NDE	NDE
00/10-03-030-11W400	1034.5	NDE	NDE	NDE	NDE	NDE
00/06-07-030-11W400	1135	NDE	NDE	NDE	NDE	NDE
00/07-09-030-11W400	1058.6	NDE	NDE	NDE	NDE	NDE
00/07-10-030-11W400	1029.6	NP	NP	NDE	NDE	NDE
00/10-11-030-11W400	1022.3	NDE	NDE	NDE	NDE	NDE
00/10-12-030-11W400	1026.3	NP	NP	NDE	NDE	NDE
00/10-13-030-11W400	1023.4	NDE	NDE	NDE	NDE	NDE
00/06-14-030-11W400	1045.8	NDE	NDE	NDE	NDE	NDE
00/08-15-030-11W400	1056	NDE	NDE	NDE	NDE	NDE
00/06-16-030-11W400	1052	NDE	NDE	NDE	NDE	NDE
00/07-17-030-11W400	1072.9	NDE	NDE	NDE	NDE	NDE
00/07-18-030-11W400	1121.7	NDE	NDE	NDE	NDE	NDE
00/06-19-030-11W400	1093	NDE	NDE	NDE	NDE	NDE
00/10-20-030-11W400	1072.9	NDE	NDE	NDE	NDE	NDE
00/07-21-030-11W400	1075.9	NDE	NDE	NDE	NDE	NDE
00/14-23-030-11W400	1056.5	NP	NP	NDE	NDE	NDE
00/10-24-030-11W400	1044.5	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Sikastone Top	Sikastone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/07-25-030-11W400	1026.3	NDE	NDE	NDE	NDE	NDE
00/07-26-030-11W400	1058.6	NP	NP	NDE	NDE	NDE
00/16-29-030-11W400	1079.5	NP	NP	NDE	NDE	NDE
00/08-32-030-11W400	1105	NDE	NDE	NDE	NDE	NDE
00/14-33-030-11W400	1089.5	NDE	NDE	NDE	NDE	NDE
00/14-34-030-11W400	1080.5	NP	NP	NDE	NDE	NDE
00/04-35-030-11W400	1058	NDE	NDE	NDE	NDE	NDE
00/11-36-030-11W400	1045.5	NP	NP	NDE	NDE	NDE
00/03-02-030-12W400	1109	NDE	NDE	NDE	NDE	NDE
00/10-04-030-12W400	1101	NDE	NDE	NDE	NDE	NDE
00/10-05-030-12W400	1104.9	NDE	NDE	NDE	NDE	NDE
00/10-07-030-12W400	1118.6	NP	NP	NDE	NDE	NDE
00/08-08-030-12W400	1103	NDE	NDE	NDE	NDE	NDE
00/08-09-030-12W400	1091	NDE	NDE	NDE	NDE	NDE
00/07-10-030-12W400	1118.9	NP	NP	NDE	NDE	NDE
00/07-11-030-12W400	1116.3	NDE	NDE	NDE	NDE	NDE
00/06-15-030-12W400	1104	NDE	NDE	NDE	NDE	NDE
00/07-16-030-12W400	1086.3	NP	NP	NDE	NDE	NDE
00/08-18-030-12W400	1104	NP	NP	NDE	NDE	NDE
00/07-19-030-12W400	1107	NP	NP	NDE	NDE	NDE
00/02-20-030-12W400	1079	NDE	NDE	NDE	NDE	NDE
00/04-22-030-12W400	1088	NDE	NDE	NDE	NDE	NDE
00/15-23-030-12W400	1122.5	NDE	NDE	NDE	NDE	NDE
00/06-28-030-12W400	1094.3	NDE	NDE	NDE	NDE	NDE
00/04-29-030-12W400	1110	NDE	NDE	NDE	NDE	NDE
00/04-32-030-12W400	1118	NDE	NDE	NDE	NDE	NDE
00/08-33-030-12W400	1137.5	NDE	NDE	NDE	NDE	NDE
00/06-34-030-12W400	1109	NDE	NDE	NDE	NDE	NDE
00/01-36-030-12W400	1104	NDE	NDE	NDE	NDE	NDE
00/14-01-030-13W400	1121	NP	NP	NDE	NDE	NDE
00/06-02-030-13W400	1152.1	NP	NP	NDE	NDE	NDE
00/06-06-030-13W400	1144	NP	NP	1248	1249	1263.5
00/06-07-030-13W400	1174	NDE	NDE	NDE	NDE	NDE
00/08-10-030-13W400	1145	NDE	NDE	NDE	NDE	NDE
00/06-11-030-13W400	1148	NDE	NDE	NDE	NDE	NDE
00/11-12-030-13W400	1137.3	NP	NP	NDE	NDE	NDE
00/10-13-030-13W400	1121.8	NDE	NDE	NDE	NDE	NDE
00/08-14-030-13W400	1152	NDE	NDE	NDE	NDE	NDE
00/06-15-030-13W400	1172	NDE	NDE	NDE	NDE	NDE
00/06-16-030-13W400	1201.2	NDE	NDE	NDE	NDE	NDE
00/14-19-030-13W400	1149	1155.2	1157.8	NDE	NDE	NDE
00/11-20-030-13W400	1174.4	NP	NP	1240.2	1242.4	1258.5
00/10-21-030-13W400	1188.7	NPL	NPL	NDE	NDE	NDE
00/06-22-030-13W400	1159.5	NP	NP	NDE	NDE	NDE
00/10-25-030-13W400	1116.5	NDE	NDE	NDE	NDE	NDE
00/10-26-030-13W400	1130.2	NP	NP	NDE	NDE	NDE
00/06-27-030-13W400	1136.5	NP	NP	NDE	NDE	NDE
00/06-28-030-13W400	1174.1	NDE	NDE	NDE	NDE	NDE
00/06-29-030-13W400	1167.4	NP	NP	NDE	NDE	NDE
00/07-30-030-13W400	1158.2	NDE	NDE	NDE	NDE	NDE
00/11-31-030-13W400	1158.2	NDE	NDE	NDE	NDE	NDE
00/11-32-030-13W400	1155.2	NDE	NDE	NDE	NDE	NDE
00/07-33-030-13W400	1152.1	NDE	NDE	NDE	NDE	NDE
00/10-34-030-13W400	1125.3	NDE	NDE	NDE	NDE	NDE
00/06-35-030-13W400	1124.1	NDE	NDE	NDE	NDE	NDE
00/07-36-030-13W400	1147.5	NDE	NDE	NDE	NDE	NDE
00/11-03-030-14W400	1112	NDE	NDE	NDE	NDE	NDE
00/07-04-030-14W400	1101	NDE	NDE	NDE	NDE	NDE
00/06-07-030-14W400	1141.5	NP	NP	1243.6	1245.1	1257.3
00/06-10-030-14W400	1105.5	NDE	NDE	NDE	NDE	NDE
00/14-13-030-14W400	1127	NP	NP	NDE	NDE	NDE
00/10-15-030-14W400	1108	NDE	NDE	NDE	NDE	NDE
00/16-16-030-14W400	1100.5	NP	NP	NDE	NDE	NDE
00/10-19-030-14W400	1122.9	NDE	NDE	NDE	NDE	NDE
00/06-23-030-14W400	1116.8	NP	NP	NDE	NDE	NDE
00/11-25-030-14W400	1131.7	1134.5	1138.7	1214.3	1230.2	1230.2

Well Location-UWI	Banff Fm	Sikastone Top	Sikastone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/06-27-030-14W400	1113	NDE	NDE	NDE	NDE	NDE
00/10-30-030-14W400	1125.3	1131.4	1135.1	NDE	NDE	NDE
00/07-32-030-14W400	1122	NP	NP	NDE	NDE	NDE
00/06-34-030-14W400	1119.8	NP	NP	NDE	NDE	NDE
00/06-35-030-14W400	1118.6	NP	NP	NDE	NDE	NDE
00/10-36-030-14W400	1138.7	NP	NP	1217.7	1219.2	1234.4
00/10-07-030-15W400	1294	NP	NP	NDE	NDE	NDE
00/08-09-030-15W400	1228.5	NP	NP	1333	1335	NDE
00/10-15-030-15W400	1181.1	NDE	NDE	NDE	NDE	NDE
00/06-19-030-15W400	1255	NP	NP	NDE	NDE	NDE
00/16-20-030-15W400	1221	NDE	NDE	NDE	NDE	NDE
00/14-21-030-15W400	1198	NP	NP	NDE	NDE	NDE
00/07-24-030-15W400	1136	NDE	NDE	NDE	NDE	NDE
00/14-28-030-15W400	1213	NP	NP	NDE	NDE	NDE
00/06-29-030-15W400	1223.5	NDE	NDE	NDE	NDE	NDE
02/10-30-030-15W400	1209	NDE	NDE	NDE	NDE	NDE
00/06-31-030-15W400	1220	NP	NP	NDE	NDE	NDE
00/06-32-030-15W400	1222	NP	NP	NDE	NDE	NDE
00/14-32-030-15W400	1214	NP	NP	1332	1334	NFE
00/03-33-030-15W400	1215	NP	NP	NDE	NDE	NDE
00/06-34-030-15W400	1183.5	NDE	NDE	NDE	NDE	NDE
00/12-02-030-16W400	1281.7	NP	NP	1392.9	1396	1412.7
02/06-09-030-16W400	1299.5	NP	NP	NDE	NDE	NDE
00/08-09-030-16W400	1311	NP	NP	1411	1413	1425
00/16-11-030-16W400	1306	NDE	NDE	NDE	NDE	NDE
00/06-13-030-16W400	1300	NDE	NDE	NDE	NDE	NDE
00/06-14-030-16W400	1289	NP	NP	1401	1402	NDE
00/06-15-030-16W400	1287.2	NDE	NDE	NDE	NDE	NDE
00/07-16-030-16W400	1290	NP	NP	1401.5	1403	1415
00/06-17-030-16W400	1323	NP	NP	NDE	NDE	NDE
00/06-19-030-16W400	1320	NDE	NDE	NDE	NDE	NDE
00/14-21-030-16W400	1275	NP	NP	1375	1377	1390
00/11-23-030-16W400	1260	NDE	NDE	NDE	NDE	NDE
00/10-24-030-16W400	1220.3	NDE	NDE	NDE	NDE	NDE
00/16-25-030-16W400	1215	NP	NP	NDE	NDE	NDE
00/10-27-030-16W400	1237.5	NDE	NDE	NDE	NDE	NDE
00/16-28-030-16W400	1258	NP	NP	1360	1362	1375
00/07-29-030-16W400	1270.5	NP	NP	NDE	NDE	NDE
00/14-30-030-16W400	1299	NP	NP	NDE	NDE	NDE
00/16-31-030-16W400	1296	NP	NP	1392	1397.5	1409
00/11-33-030-16W400	1264	NP	NP	1352	1356	1368
00/06-34-030-16W400	1242	NP	NP	NDE	NDE	NDE
00/08-36-030-16W400	1221	NP	NP	NDE	NDE	NDE
00/04-03-031-07W400	983	NP	NP	990	991.5	1006
00/06-06-031-07W400	1013.8	NP	NP	1022.9	1024.1	NDE
00/07-07-031-07W400	1008.9	NDE	NDE	NDE	NDE	NDE
00/11-13-031-07W400	996.4	NP	NP	1000.7	1002.2	NDE
00/10-15-031-07W400	1005.5	NP	NP	1016	1018	1033.5
00/11-28-031-07W400	1054.6	NDE	NDE	NDE	NDE	NDE
00/06-30-031-07W400	1041	NP	NP	1045	1046	1062
00/07-03-031-08W400	999.4	NP	NP	NDE	NDE	NDE
00/09-16-031-08W400	1032.1	NP	NP	1040.6	1042.4	NDE
00/06-18-031-08W400	1030	NP	NP	NDE	NDE	NDE
00/01-22-031-08W400	1028.7	NP	NP	1037.5	1039.4	NDE
00/11-29-031-08W400	1047.6	NDE	NDE	NDE	NDE	NDE
00/10-32-031-08W400	1059.8	NP	NP	NDE	NDE	NDE
00/11-35-031-08W400	1025	NP	NP	NDE	NDE	NDE
00/06-01-031-09W400	1056.1	NP	NP	NDE	NDE	NDE
00/06-03-031-09W400	1021	NP	NP	1027.8	1028.6	1043.8
02/06-04-031-09W400	1021	NP	NP	1025.3	1026.5	1040.5
00/06-05-031-09W400	1020	NP	NP	1027	1029	1044
00/15-07-031-09W400	1016	NP	NP	1025.5	1027	1041
00/12-08-031-09W400	1029.3	NP	NP	1034.8	1036.6	1053.1
00/13-08-031-09W400	1020	NP	NP	1026.5	1028.3	1042
00/06-09-031-09W400	1030	NP	NP	1037	1039	1055
00/04-11-031-09W400	1054.5	NP	NP	1061	1062.5	1076

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/06-13-031-09W400	1044.9	NP	NP	1050.3	1052.2	NDE
00/06-16-031-09W400	1055.8	NP	NP	1059.8	1061.9	1076.6
00/10-18-031-09W400	1023	NP	NP	1027	1029	1052
00/04-19-031-09W400	1026.3	NP	NP	1029.6	1030.8	1051.6
00/06-24-031-09W400	1043.9	NP	NP	1051.3	1053.4	NDE
00/07-26-031-09W400	1049.7	NP	NP	1058.3	1060.4	1070.2
00/14-29-031-09W400	1092	NP	NP	NDE	NDE	NDE
00/04-30-031-09W400	1040	NP	NP	1047	1048.2	1055.5
00/07-01-031-10W400	1051.5	NP	NP	1058.8	1060	1077
00/10-02-031-10W400	1032.7	NP	NP	1036.9	1039.1	1054.6
00/10-04-031-10W400	1046.7	NP	NP	1053.4	1054.3	1068.3
00/14-04-031-10W400	1046	NP	NP	1052.5	1054	NDE
00/07-05-031-10W400	1045.5	NDE	NDE	NDE	NDE	NDE
00/07-09-031-10W400	1042.4	NP	NP	-	-	1051.6
00/06-10-031-10W400	1034.5	NP	NP	1039	1040.5	NDE
00/06-11-031-10W400	1026	NP	NP	1032.5	1034	1049
00/15-14-031-10W400	1033.6	NP	NP	-	-	1050.9
00/07-18-031-10W400	1045.5	NP	NP	1049	1052	1062
00/13-19-031-10W400	1061	NP	NP	1067	1068.8	1079
00/06-23-031-10W400	1047	NP	NP	-	-	1057
00/15-24-031-10W400	1053	NP	NP	-	-	1056
00/15-25-031-10W400	1058.5	NP	NP	-	-	1063
00/16-26-031-10W400	1060	NP	NP	-	-	1059.8
00/06-27-031-10W400	1052	NP	NP	-	-	1058
00/05-28-031-10W400	1054.5	NDE	-	-	-	1062
00/08-35-031-10W400	1060	NP	NP	1066	1067	1072
00/02-36-031-10W400	1058	NP	NP	-	-	1065.5
00/05-03-031-11W400	1085	NP	NP	1092.5	1095.3	1114.5
02/06-03-031-11W400	1085	NP	NP	1095	1098	NDE
00/16-04-031-11W400	1099	NP	NP	1103.5	1104.5	1120.8
00/08-09-031-11W400	1101	NP	NP	1107.3	1108.3	1122
02/06-10-031-11W400	1091	NP	NP	1096	1097	1112
00/10-10-031-11W400	1087	NP	NP	1091.5	1092.5	1108
00/14-10-031-11W400	1089.8	NP	NP	1094	1095.6	NDE
00/15-10-031-11W400	1085.5	NP	NP	1090	1091	1105
00/14-11-031-11W400	1075.5	NP	NP	1080.6	1081.5	1095.5
00/10-12-031-11W400	1069	NDE	NDE	NDE	NDE	NDE
00/06-13-031-11W400	1058.6	NP	NP	1063.8	1065.4	1079
00/10-13-031-11W400	1055.5	NP	NP	1058.5	1060	NDE
00/01-15-031-11W400	1080.5	NP	NP	1085	1086	NDE
00/10-16-031-11W400	1094.5	NP	NP	1099.1	1100.3	1115.6
00/12-16-031-11W400	1084	NP	NP	1094	1095	NDE
00/10-18-031-11W400	1075.9	NP	NP	3578	3582	3632
00/10-19-031-11W400	1098.5	NP	NP	NDE	NDE	NDE
00/07-22-031-11W400	1093.5	NP	NP	1098.2	1099	1112.5
00/02-24-031-11W400	1059	NP	NP	1064	1065	1073
00/02-31-031-11W400	1067.5	NP	NP	1091.5	1097	1115
00/11-33-031-11W400	1120.4	NP	NP	1122.9	1124.4	1140
00/07-35-031-11W400	1112.5	NP	NP	NDE	NDE	NDE
00/04-03-031-12W400	1114	NP	NP	NDE	NDE	NDE
00/03-04-031-12W400	1107	NP	NP	1128	1129	1144.5
00/04-05-031-12W400	1119	NDE	NDE	NDE	NDE	NDE
00/07-10-031-12W400	1108	NDE	NDE	NDE	NDE	NDE
00/10-13-031-12W400	1109	NDE	NDE	NDE	NDE	NDE
00/16-14-031-12W400	1100	NP	NP	NDE	NDE	NDE
00/05-15-031-12W400	1074	NP	NP	NDE	NDE	NDE
00/11-19-031-12W400	1149	NDE	NDE	NDE	NDE	NDE
00/07-20-031-12W400	1135	NP	NP	NDE	NDE	NDE
00/14-21-031-12W400	1133	NDE	NDE	NDE	NDE	NDE
00/03-28-031-12W400	1126.5	NDE	NDE	NDE	NDE	NDE
00/13-29-031-12W400	1160	NP	NP	NDE	NDE	NDE
00/06-30-031-12W400	1157	NP	NP	NDE	NDE	NDE
00/06-31-031-12W400	1126	NP	NP	NDE	NDE	NDE
00/12-32-031-12W400	1135	NP	NP	NDE	NDE	NDE
00/06-01-031-13W400	1122	NP	NP	NDE	NDE	NDE
00/10-02-031-13W400	1121.6	NP	NP	NDE	NDE	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/10-03-031-13W400	1140	NP	NP	NDE	NDE	NDE
00/10-04-031-13W400	1156.4	NP	NP	NDE	NDE	NDE
00/06-05-031-13W400	1157.3	NP	NP	NDE	NDE	NDE
00/06-06-031-13W400	1153.1	NP	NP	NDE	NDE	NDE
00/04-08-031-13W400	1156	NP	NP	NDE	NDE	NDE
00/10-09-031-13W400	1152	NP	NP	NDE	NDE	NDE
00/07-10-031-13W400	1141.8	NP	NP	NDE	NDE	NDE
00/11-12-031-13W400	1150.3	NP	NP	NDE	NDE	NDE
00/10-13-031-13W400	1135	NP	NP	NDE	NDE	NDE
00/11-14-031-13W400	1130.2	NP	NP	NDE	NDE	NDE
00/09-15-031-13W400	1134	NP	NP	NDE	NDE	NDE
00/07-16-031-13W400	1145.8	NP	NP	NDE	NDE	NDE
00/13-17-031-13W400	1155	NP	NP	NDE	NDE	NDE
00/07-19-031-13W400	1150.3	NP	NP	NDE	NDE	NDE
00/06-20-031-13W400	1158.2	NDE	NDE	NDE	NDE	NDE
00/06-21-031-13W400	1151	NDE	NDE	NDE	NDE	NDE
00/07-22-031-13W400	1144.5	NP	NP	NDE	NDE	NDE
00/11-23-031-13W400	1145.4	NDE	NDE	NDE	NDE	NDE
00/10-24-031-13W400	1150.9	NP	NP	NDE	NDE	NDE
00/06-26-031-13W400	1125.3	NP	NP	NDE	NDE	NDE
00/02-28-031-13W400	1157.5	NP	NP	NDE	NDE	NDE
00/11-29-031-13W400	1189	NP	NP	NDE	NDE	NDE
00/11-31-031-13W400	1168.9	NP	NP	NDE	NDE	NDE
00/04-32-031-13W400	1200	NP	NP	NDE	NDE	NDE
00/16-33-031-13W400	1150	NDE	NDE	NDE	NDE	NDE
00/02-34-031-13W400	1151	NDE	NDE	NDE	NDE	NDE
02/14-36-031-13W400	1162	NDE	NDE	NDE	NDE	NDE
00/07-02-031-14W400	1162.5	NP	NP	NDE	NDE	NDE
00/06-03-031-14W400	1128.4	NP	NP	NDE	NDE	NDE
00/12-05-031-14W400	1127.8	NP	NP	NDE	NDE	NDE
00/02-06-031-14W400	1133.9	NDE	NDE	NDE	NDE	NDE
00/09-08-031-14W400	1127.8	NP	NP	NDE	NDE	NDE
00/03-09-031-14W400	1118.6	NP	NP	NDE	NDE	NDE
00/07-10-031-14W400	1135	NP	NP	NDE	NDE	NDE
00/06-11-031-14W400	1136.9	NP	NP	NDE	NDE	NDE
00/10-12-031-14W400	1124.7	NP	NP	NDE	NDE	NDE
00/10-13-031-14W400	1154	NDE	NDE	NDE	NDE	NDE
00/10-15-031-14W400	1143	1146	1151	NDE	NDE	NDE
00/13-16-031-14W400	1141.5	1152	1157	NDE	NDE	NDE
00/10-17-031-14W400	1132	1144	1149	NDE	NDE	NDE
00/11-21-031-14W400	1132.6	NP	NP	NDE	NDE	NDE
00/08-22-031-14W400	1136	NP	NP	NDE	NDE	NDE
00/07-26-031-14W400	1153.1	NP	NP	NDE	NDE	NDE
00/06-28-031-14W400	1157	1163	1172.5	NDE	NDE	NDE
00/14-30-031-14W400	1165.5	1168	1178	1238	1241	1254.6
00/07-35-031-14W400	1174.4	NP	NP	NDE	NDE	NDE
00/02-36-031-14W400	1149.7	NP	NP	1225.6	1228	NDE
00/14-01-031-15W400	1163	NP	NP	NDE	NDE	NDE
00/08-02-031-15W400	1161	NP	NP	NDE	NDE	NDE
00/10-03-031-15W400	1176.5	NP	NP	NDE	NDE	NDE
00/06-04-031-15W400	1203	NP	NP	NDE	NDE	NDE
02/06-05-031-15W400	1212	NP	NP	NDE	NDE	NDE
00/07-06-031-15W400	1200	NP	NP	NDE	NDE	NDE
00/16-07-031-15W400	1197.5	NP	NP	1295	1298.5	1312.5
00/08-09-031-15W400	1186	NP	NP	NDE	NDE	NDE
00/06-10-031-15W400	1173	NP	NP	1285.5	1287	1300
00/14-11-031-15W400	1159	NP	NP	NDE	NDE	NDE
00/03-13-031-15W400	1138.4	NP	NP	1235	1236.6	1258.8
00/01-14-031-15W400	1146	NP	NP	1254.3	1257.3	1271
00/08-14-031-15W400	1147	NP	NP	1262	1263	NDE
00/07-17-031-15W400	1188.7	NP	NP	NDE	NDE	NDE
00/04-19-031-15W400	1208	NP	NP	NDE	NDE	NDE
00/06-21-031-15W400	1189	NP	NP	1295.5	1299.8	1311.8
00/10-22-031-15W400	1186.3	NP	NP	NDE	NDE	NDE
00/16-23-031-15W400	1172	NP	NP	1270	1272	1285
00/06-30-031-15W400	1211	NP	NP	1306	1311.8	NDE

Well Location-UWI	Banff Fm	Siltstone Top	Siltstone Base	Exshaw Fm	Big Valley Fm	Stettler Fm
00/06-31-031-15W400	1195	NP	NP	1280	1286	NDE
00/16-32-031-15W400	1215	NP	NP	NDE	NDE	NDE
00/12-34-031-15W400	1156.4	NP	NP	NDE	NDE	NDE
00/04-01-031-16W400	1234.4	NP	NP	1307.6	1310.6	1328.9
00/13-01-031-16W400	1217	NP	NP	1312.5	1316.5	NDE
00/13-02-031-16W400	1235	NP	NP	NDE	NDE	NDE
00/08-03-031-16W400	1240	NP	NP	1333	1337.3	NDE
00/14-03-031-16W400	1235	NP	NP	1338	1342.5	NDE
00/16-03-031-16W400	1227	NP	NP	1333.2	1334.5	NDE
00/08-05-031-16W400	1279	NP	NP	1363	1369	1381
00/05-07-031-16W400	1314	NP	NP	NDE	NDE	NDE
00/08-08-031-16W400	1249	NP	NP	NDE	NDE	NDE
00/16-09-031-16W400	1252	NP	NP	NDE	NDE	NDE
00/03-10-031-16W400	1244	NP	NP	1339.8	1345	NDE
00/05-11-031-16W400	1227	NP	NP	1324	1329.5	NDE
00/14-12-031-16W400	1207	NP	NP	NDE	NDE	NDE
00/14-13-031-16W400	1220	NP	NP	1318	1323.4	1332
00/16-14-031-16W400	1237.6	NP	NP	NDE	NDE	NDE
00/06-15-031-16W400	1236	NP	NP	1325	1330	NDE
00/14-16-031-16W400	1229	NP	NP	1351.5	1357.5	NDE
00/16-16-031-16W400	1244	NP	NP	1333	1339	NDE
00/06-17-031-16W400	1257.5	NP	NP	NDE	NDE	NDE
00/06-18-031-16W400	1301	NP	NP	1391	1398	1409
00/08-19-031-16W400	1280	NP	NP	NDE	NDE	NDE
00/14-20-031-16W400	1265.8	NP	NP	1363.2	1369.9	1382.4
02/14-20-031-16W400	1271.8	NP	NP	1371.5	1373	NDE
00/11-22-031-16W400	1268.5	NP	NP	NDE	NDE	NDE
02/08-23-031-16W400	1257	NP	NP	1335	1340	NDE
02/14-24-031-16W400	1247	NP	NP	1330	1332	NDE
00/08-25-031-16W400	1230	NP	NP	NDE	NDE	NDE
00/10-27-031-16W400	1213	NP	NP	NDE	NDE	NDE
00/06-28-031-16W400	1235.5	NP	NP	1335.5	1342	NDE
02/06-29-031-16W400	1273	NP	NP	NDE	NDE	NDE
00/06-30-031-16W400	1260.2	NP	NP	NDE	NDE	NDE
00/16-31-031-16W400	1247.5	NP	NP	1336.3	1343.5	NDE
00/04-32-031-16W400	1240	NP	NP	NDE	NDE	NDE
00/08-33-031-16W400	1239	NP	NP	1310	1317.5	NDE
00/06-34-031-16W400	1234.5	NP	NP	1296.8	1303.5	NDE
00/06-35-031-16W400	1220	NP	NP	1297.5	1304	1317
00/06-36-031-16W400	1210.5	NP	NP	1285.5	1292	NDE

APPENDIX B

UNIT WELL LOG DATABASE

APPENDIX B:

Legend
NP= not present

* All tops are reported in metres.

Well Location-UWI	Mannville Fm	Unit 1	Shale (%)	Unit 2	Shale (%)	Unit 3	Shale (%)
00/16-34-021-07W4/0	864.5	1093	40	1069	75	1060	44
02/10-09-021-09W4/0	851.5	1115	100	1088	30	1071.5	44
00/03-21-021-09W4/0	850.4	1093	100	1065	39	1052	46
02/16-01-021-10W4/0	877	1140	100	1120	18	1098	41
00/07-26-021-11W4/0	859	1110	100	1086	4	1067	26
00/07-17-021-12W4/0	853	1122.2	100	1102.1	15	1079.5	38
00/12-20-021-14W4/0	939	1239	0	1217	77	1205	17
00/06-33-021-16W4/0	971	1282	0	1254	46	1239	47
00/08-03-022-07W4/0	857.2	1076	100	1052.5	79	1044	26
00/09-28-022-09W4/0	859	1094	100	1073	29	1060	15
00/08-12-022-10W4/0	886	1126	100	1102	8	1079	52
00/05-15-022-11W4/0	853	1107	0	1075	0	1057	33
00/14-15-022-13W4/0	876	1139	71	1121	94	1109	8
00/11-33-023-07W4/0	821	1031.5	100	1009	73	1000	22
00/06-21-023-08W4/0	816	1036.3	100	1016.2	33	1005.2	5
00/14-34-023-09W4/0	870	1093	100	1070	13	1058	42
02/14-34-023-14W4/0	906	1161	100	1140	71	1129	55
00/03-22-023-15W4/0	945	1238	83	1219	74	1207	33
00/08-13-024-08W4/0	860	1067	100	1046	45	1037	44
00/07-30-024-09W4/0	853	1073	100	1051	7	1040	9
00/12-02-024-10W4/0	850	1076	100	1052	6	1044	38
00/04-36-024-12W4/0	893	1123	80	1105	21	1089	44
00/11-18-024-15W4/0	983	1224	100	1207	59	1202.7	21
00/14-15-025-07W4/0	855	1037	100	1015	50	1006	11
00/16-06-025-08W4/0	897	1103	100	1083	25	1070	31
00/15-12-025-09W4/0	889.5	1090	100	1074	28	1060	14
00/16-16-025-10W4/0	898.5	1116	100	1103	77	1080	52
02/16-14-025-12W4/0	915	1151	100	1135	56	1119	25
00/16-24-025-13W4/0	906	1103	100	1088	20	1065	4
00/07-01-025-14W4/0	931	1151.5	100	1130.8	81	1115.5	40
00/08-01-025-14W4/0	930	1145	83	1130	13	1114	44
00/10-01-025-15W4/0	975	1233	100	1217	69	1202	13
00/07-05-025-15W4/0	966	1202.7	100	1183.8	68	1161.8	28
00/14-14-025-15W4/0	973	1210	100	1193	70	1176	53
00/06-21-025-15W4/0	990	1219	100	1201	33	1187	43
02/08-24-025-15W4/0	998	1256	33	1236	65	1220	38
00/14-35-025-15W4/0	1004.7	1235.5	33	1218	6	1198	15
00/10-18-026-07W4/0	916.3	1087	100	1075	42	1060	27
00/08-19-026-08W4/0	942	1131	100	1116.5	7	1109	40
00/06-35-026-09W4/0	948	1148	100	1140	75	1122	6
00/09-31-026-10W4/0	932	1126	66	1116.5	26	1096	20
00/06-34-026-10W4/0	960	1154	100	1143	26	1125	11
00/11-24-026-12W4/0	944	1141.7	80	1133.8	62	1123.4	9
00/06-14-026-14W4/0	978	1203.9	100	1191.7	44	1168.5	34
00/10-22-026-14W4/0	1016	1235	100	1218	15	1191.5	38
00/11-11-026-15W4/0	1021	1242.9	100	1226.5	26	1203.9	29
00/08-22-026-15W4/0	1033	1253	100	1235	8	1212	35
00/11-36-026-15W4/0	1036	1253.3	100	1231.3	20	1211.2	61
00/16-36-026-15W4/0	1029	1245	100	1222.5	18	1201	47
00/08-28-027-08W4/0	914	1074	100	1063	9	1055	25
00/11-11-027-09W4/0	932	1106.5	100	1094	16	1089	20
00/07-03-027-10W4/0	960.5	1146	0	1142	50	1122	15
00/08-19-027-10W4/0	945	1125	100	1115	30	1096	26
00/04-04-027-11W4/0	972.6	1155	100	1150	50	1134.5	32
00/06-06-027-11W4/0	960	1145	100	1137	25	1120	24
00/15-21-027-12W4/0	950	1145	100	1134.5	67	1121	7
00/15-33-027-12W4/0	970	1142.5	100	1129	63	1117	50
00/02-15-027-14W4/0	1029	1272	100	1257	67	1242	7
00/11-35-027-14W4/0	1032	1224	100	1203.9	61	1180.7	42

Well Location-UWI	Unit 4	Shale (%)	Unit 5	Shale (%)	Unit 6	Shale (%)
00/16-34-021-07W4/0	1045	53	1026	21	970.6	4
02/10-09-021-09W4/0	1051	20	NP	NP	1018	3
00/03-21-021-09W4/0	1027	16	NP	NP	985	2
02/16-01-021-10W4/0	1079	16	NP	NP	1027.5	8
00/07-26-021-11W4/0	1047	10	NP	NP	993	0
00/07-17-021-12W4/0	1053.9	9	NP	NP	986.3	0
00/12-20-021-14W4/0	NP	NP	NP	NP	1110	3
00/06-33-021-16W4/0	NP	NP	NP	NP	1146	1
00/08-03-022-07W4/0	1029	20	1009	20	975.3	6
00/09-28-022-09W4/0	1040	10	NP	NP	972.5	7
00/08-12-022-10W4/0	1052	7	NP	NP	1004	4
00/05-15-022-11W4/0	1042	13	NP	NP	975.5	0
00/14-15-022-13W4/0	1090	11	NP	NP	1014	5
00/11-33-023-07W4/0	975	12	960.5	33	898	41
00/06-21-023-08W4/0	983.2	28	972.9	17	896.7	32
00/14-34-023-09W4/0	1034	4	1021	8	969.2	17
02/14-34-023-14W4/0	1107	14	NP	NP	1033	8
00/03-22-023-15W4/0	1189	17	NP	NP	1110	8
00/08-13-024-08W4/0	1017	25	999	27	944	3
00/07-30-024-09W4/0	1014	8	996	17	947	35
00/12-02-024-10W4/0	1025	11	1007	11	939	25
00/04-36-024-12W4/0	1067	4	1051	25	1005	4
00/11-18-024-15W4/0	1184.5	33	NP	NP	1113.7	9
00/14-15-025-07W4/0	983	13	972	0	949	0
00/16-06-025-08W4/0	1043	11	1028	7	991	14
00/15-12-025-09W4/0	1044	6	1026	6	982	36
00/16-16-025-10W4/0	1053	7	1037	6	1000.5	25
02/16-14-025-12W4/0	1096	20	1080	31	1041	21
00/16-24-025-13W4/0	1048	12	1028	20	1012	56
00/07-01-025-14W4/0	1099.4	11	1085	8	1045.4	40
00/08-01-025-14W4/0	1101	15	1084	6	1046.5	40
00/10-01-025-15W4/0	1178	8	1170	38	1101	6
00/07-05-025-15W4/0	1143.6	50	1125.3	7	1070.4	30
00/14-14-025-15W4/0	1156	25	NP	NP	1098	12
00/06-21-025-15W4/0	1169	17	1158	18	1109	27
02/08-24-025-15W4/0	1204	12.5	1190	14	1138	21
00/14-35-025-15W4/0	1180	10	1168	33	1120.5	85
00/10-18-026-07W4/0	1042.5	11	1021.5	5	NP	NP
00/08-19-026-08W4/0	1095	79	1072	35	1057	13
00/06-35-026-09W4/0	NP	NP	NP	NP	NP	NP
00/09-31-026-10W4/0	1087	22	1050	7	NP	NP
00/06-34-026-10W4/0	1103	18	1085	6	1065.5	5
00/11-24-026-12W4/0	1103.9	22	1076.5	4	1057.7	6
00/06-14-026-14W4/0	1149	6	1132	0	1100	40
00/10-22-026-14W4/0	1168	30	1156.5	17	1124	12
00/11-11-026-15W4/0	1180.7	19	1169.2	32	1127	43
00/08-22-026-15W4/0	1190	7	1177	15	1138.5	77
00/11-36-026-15W4/0	1188	8	1176.5	26	1143.9	62
00/16-36-026-15W4/0	1177	25	1168	22	1129	26
00/08-28-027-08W4/0	1044	18	1019.8	36	NP	NP
00/11-11-027-09W4/0	1080	33	1059	29	1045	21
00/07-03-027-10W4/0	1103	37	1083	0	1057.8	40
00/08-19-027-10W4/0	1076	40	1044	13	1041	50
00/04-04-027-11W4/0	1111	21	1091.5	36	NP	NP
00/06-06-027-11W4/0	1102	6	1084	26	NP	NP
00/15-21-027-12W4/0	1096	16	1080	6	NP	NP
00/15-33-027-12W4/0	1106	73	1084	23	NP	NP
00/02-15-027-14W4/0	1219	39	1202	35	1151	45
00/11-35-027-14W4/0	1154.5	16	1140.5	0	1124.7	19

Well Location-UWI	Mannville Fm	Unit 1	Shale (%)	Unit 2	Shale (%)	Unit 3	Shale (%)
00/06-36-027-14W4/0	1053	1250	0	1233	59	1213	10
00/06-30-027-16W4/0	1203.4	1434.9	50	1418.5	26	1397.7	47
00/07-22-028-07W4/0	883	1035.5	100	1020.5	27	1008	24
00/06-12-028-08W4/0	921	1069.2	100	1053.9	32	1049	18
00/14-35-028-11W4/0	934	1103	100	1088	67	1076.5	0
00/12-24-028-12W4/0	957	1125.5	100	1110	68	1092	6
00/10-29-028-12W4/0	1044.5	1206.3	100	1190.5	63	1174	18
00/14-08-028-14W4/0	1079	1303	0	1284	32	1259	0
00/11-09-028-14W4/0	1065	1280	100	1260.6	34	1234.4	23
00/11-18-028-14W4/0	1090	1282	0	1261.5	15	1235.5	8
00/11-32-028-14W4/0	1086.5	1276	50	1254	5	1227	11
00/08-13-028-15W4/0	1091	1279	0	1260	11	1234	8
00/10-13-029-07W4/0	870	1002.7	100	990.6	15	984.5	30
00/06-10-029-08W4/0	897	1029	17	1018	78	1011.9	25
00/11-35-029-11W4/0	926	1077.4	100	1057.6	12	1046.3	49
00/07-33-029-12W4/0	984.5	1149.6	100	1133.2	24	1116.4	7
00/06-13-029-13W4/0	1035.5	1218	100	1203	40	1176	0
00/16-09-029-14W4/0	1008.5	1188	100	1172	6	1150	14
00/07-11-029-14W4/0	1005.8	1189.8	100	1162.5	7	1139.3	5
00/01-16-029-14W4/0	1004	1192	100	1177	13	NP	NP
00/06-22-029-14W4/0	1009	1202	100	1187	20	NP	NP
00/08-09-029-15W4/0	1194	1387	100	1370	10	1346	17
00/06-27-029-15W4/0	1196	1397.5	100	1380	20	1355	22
00/05-21-029-16W4/0	1291	1495	100	1465	17	1437	14
00/03-12-030-09W4/0	894	1019	83	1001	66	988	31
00/10-36-030-10W4/0	924	1028.5	100	1011	36	NP	NP
00/06-06-030-13W4/0	1050	1245	100	1221	25	1207	36
00/11-20-030-13W4/0	1068.3	1236	100	1211.9	33	1188.7	10
00/11-25-030-14W4/0	1031	1205.7	85	1187.4	20	1173.4	17
00/08-09-030-15W4/0	1126.5	1332	0	1316	6	1296	5
00/14-32-030-15W4/0	1115.8	1327	0	1310	24	1291	8
00/08-09-030-16W4/0	1200	1408	0	1387	14	1372	31
00/07-16-030-16W4/0	1186	1400	100	1370	13	1355	20
00/14-21-030-16W4/0	1165	1373	100	1355	33	1339	0
00/16-28-030-16W4/0	1150	1357	100	1337	30	1321	0
00/04-03-031-07W4/0	889	983	71	NP	NP	NP	NP
00/10-10-031-08W4/0	909.8	1044.5	71	1043.6	50	NP	NP
00/06-03-031-09W4/0	915	1023	71	1005	89	NP	NP
00/07-01-031-10W4/0	926.5	1052	100	1034	50	NP	NP
00/15-10-031-11W4/2	978	1085	100	NP	NP	NP	NP
00/03-04-031-12W4/0	980.5	1125	100	1107.5	37	NP	NP
00/16-07-031-15W4/0	1092	1293	100	1270	26	1260	0
00/08-14-031-15W4/0	1059.9	1258	0	1236	16	1218	0
00/08-05-031-16W4/0	1160	1361	100	1344	47	1327	18
00/03-10-031-16W4/0	1133	1337	100	1317	54	1304	NP
02/08-23-031-16W4/0	1135	1331	100	1311	38	1297	0
00/06-35-031-16W4/0	1095.5	1296	100	1276	30	1263	4

Well Location-UWI	Unit 4	Shale (%)	Unit 5	Shale (%)	Unit 6	Shale (%)
00/06-36-027-14W4/0	1192	62	1183	11	1154	5
00/06-30-027-16W4/0	1371.5	56	1349.6	56	1313.6	20
00/07-22-028-07W4/0	999.5	59	983.5	13	960	9
00/06-12-028-08W4/0	1039.3	25	1011.9	33	996.6	22
00/14-35-028-11W4/0	1072	44	NP	NP	NP	NP
00/12-24-028-12W4/0	1082.5	50	NP	NP	NP	NP
00/10-29-028-12W4/0	1170.4	33	NP	NP	NP	NP
00/14-08-028-14W4/0	1236	43	1222	14	1192	3
00/11-09-028-14W4/0	1216	57	1206.3	31	1182	32
00/11-18-028-14W4/0	1218	11	1204	0	1194	10
00/11-32-028-14W4/0	1210	29	1193	40	1187	33
00/08-13-028-15W4/0	1216	28	1196	40	NP	NP
00/10-13-029-07W4/0	974	17	960.7	9	938.1	5
00/06-10-029-08W4/0	994.9	18	971.7	39	963.8	11
00/11-35-029-11W4/0	1031	40	NP	NP	NP	NP
00/07-33-029-12W4/0	1102.1	21	NP	NP	NP	NP
00/06-13-029-13W4/0	1172	11	NP	NP	NP	NP
00/16-09-029-14W4/0	1130	0	1110	0	1095	47
00/07-11-029-14W4/0	1119.2	18	1103.3	27	NP	NP
00/01-16-029-14W4/0	NP	NP	NP	NP	NP	NP
00/06-22-029-14W4/0	NP	NP	NP	NP	NP	NP
00/08-09-029-15W4/0	1327	42	1304	22	1289	7
00/06-27-029-15W4/0	1336	5	1315	48	1298	18
00/05-21-029-16W4/0	1419	17	1400	74	NP	NP
00/03-12-030-09W4/0	973	27	956	71	NP	NP
00/10-36-030-10W4/0	NP	NP	NP	NP	NP	NP
00/06-06-030-13W4/0	1188	53	1170	17	1145	16
00/11-20-030-13W4/0	1173.5	12	NP	NP	NP	NP
00/11-25-030-14W4/0	1152.1	7	1138.7	4	NP	NP
00/08-09-030-15W4/0	1271	12	1254	53	1228	23
00/14-32-030-15W4/0	1263	14	1240	4	1214	23
00/08-09-030-16W4/0	1349	9	1337	0	1311	19
00/07-16-030-16W4/0	1339	31	1327	58	1290	14
00/14-21-030-16W4/0	1325	7	1312	23	1275	19
00/16-28-030-16W4/0	1305	19	1287	6	1258	24
00/04-03-031-07W4/0	NP	NP	NP	NP	NP	NP
00/10-10-031-08W4/0	NP	NP	NP	NP	NP	NP
00/06-03-031-09W4/0	NP	NP	NP	NP	NP	NP
00/07-01-031-10W4/0	NP	NP	NP	NP	NP	NP
00/15-10-031-11W4/2	NP	NP	NP	NP	NP	NP
00/03-04-031-12W4/0	NP	NP	NP	NP	NP	NP
00/16-07-031-15W4/0	1239	7	1223	6	1197	0
00/08-14-031-15W4/0	1193	4	1187	0	1146.6	25
00/08-05-031-16W4/0	1303	4	1297	67	1278.5	11
00/03-10-031-16W4/0	1281	4	1274	0	1244	7
02/08-23-031-16W4/0	1281	13	1272	22	1257	16
00/06-35-031-16W4/0	1248.5	7	1235	4	1220.3	7

APPENDIX C

LIST OF EXAMINED CORES

GREATER CESSFORD AREA BANFF FORMATION CORES
CORES<3M LONG NOT INCLUDED IN CHART

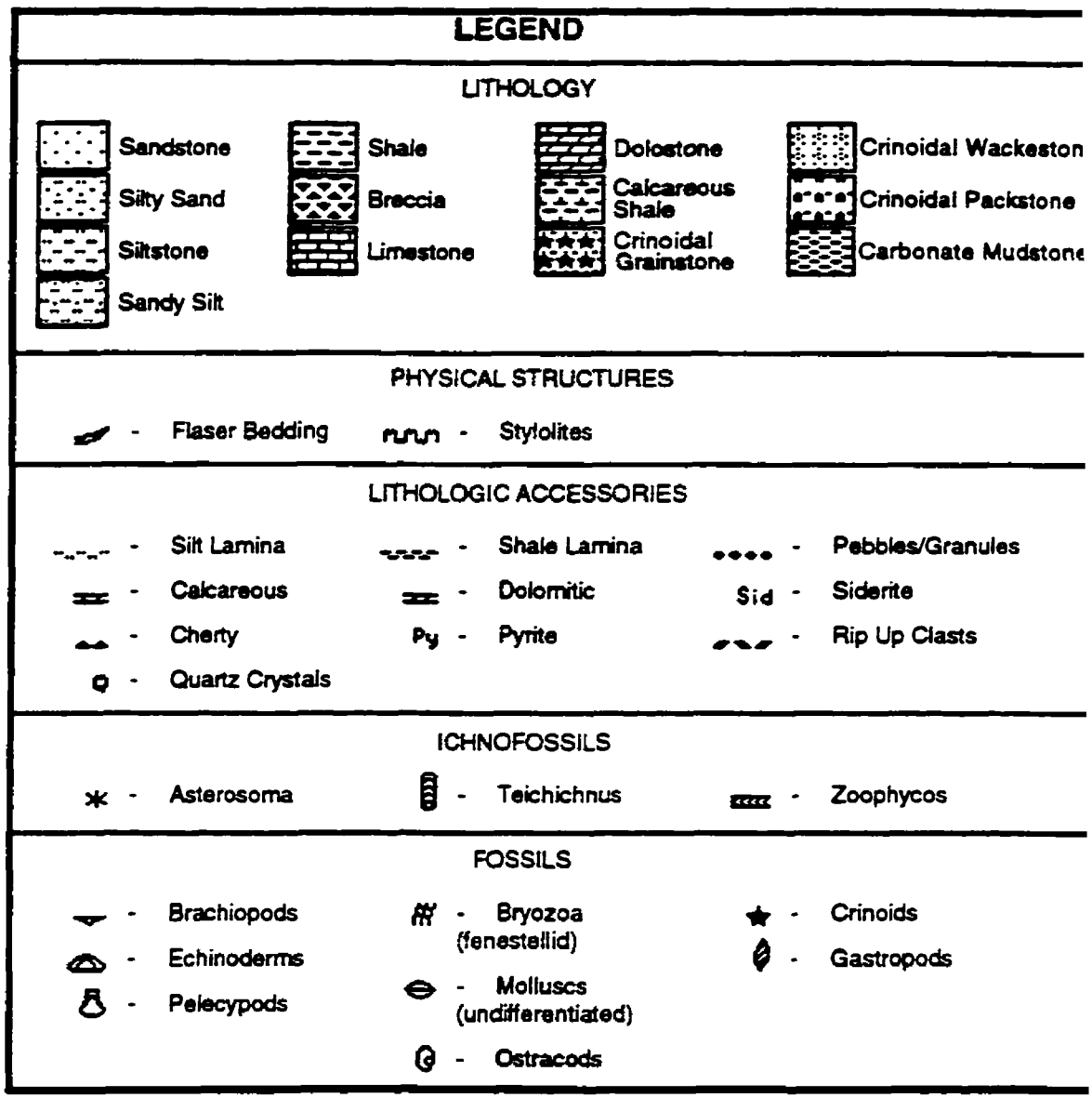
WELL LOCATION	YEAR	BNF TOP(M)	CORED INTERVAL(M)	CA	L
00/04-18-021-08W4/0	1952	1010	1011.3-1013.7	Y	Y
00/13-23-022-12W4/0	1946	973	972.0-985.4	N	Y
00/01-06-022-13W4/0	1945	1045	1127.7-1133.5	N	Y
00/11-31-023-09W4/0	1959	931	1041.5-1049.7	Y	Y
00/14-34-023-09W4/0	1987	969	972.0-987.0	Y	Y
00/16-05-023-14W4/0	1944	1032	1026.2-1061.0	N	Y
00/16-05-023-14W4/0	1944	1032	1108.8-1147.8	N	Y
00/16-06-025-08W4/0	1985	991	1076.0-1094.0	Y	Y
02/16-14-025-12W4/0	1985	1041	1045.0-1060.0	Y	Y
02/16-22-025-12W4/0	1985	1039	1040.0-1052.0	Y	Y
00/14-35-025-15W4/0	1987	1120	1116.5-1139.0	Y	Y
00/02-31-026-12W4/0	1952	1085	1142.4-1149.4	N	Y
00/06-22-026-16W4/0	1980	1165	1155.0-1193.0	Y	Y
02/10-29-026-16W4/0	1984	1208	1215.0-1227.0	Y	Y
00/14-05-027-08W4/0	1952	1032	1029.0-1038.7	N	Y
00/06-18-027-15W4/0	1960	1202	1200.2-1218.5	Y	Y
00/11-35-027-16W4/0	1960	1257	1257.0-1267.6	Y	Y
00/07-31-028-11W4/0	1979	1052	1044.0-1056.0	Y	Y
00/10-32-028-16W4/0	1963	1364	1359.6-1373.7	N	Y
02/06-15-029-10W4/0	1987	1076	1086.0-1092.0	N	Y
00/07-33-029-12W4/0	1960	1087	1085.0-1093.0	N	Y
00/06-32-029-14W4/0	1990	1119	1116.5-1131.0	Y	Y
00/14-34-029-15W4/0	1953	1253	1249.6-1261.9	N	Y
00/06-02-029-16W4/0	1986	1305	1295.0-1309.5	Y	Y
00/06-31-029-16W4/0	1988	1438	1438.0-1442.0	Y	N
00/14-32-029-16W4/0	1988	1380	1381.0-1396.0	Y	Y
00/05-03-030-09W4/0	1946	997	992.4-1008.8	N	Y
00/05-03-030-09W4/0	1946	997	1022.6-1047.9	N	Y
00/06-31-030-15W4/0	1985	1220	1228.0-1232.0	Y	Y
00/12-02-030-16W4/0	1952	1282	1281.4-1296.3	N	Y
00/06-14-030-16W4/0	1987	1289	1289.0-1311.0	Y	Y
00/14-21-030-16W4/0	1986	1275	1272.0-1281.0	Y	N
00/05-23-030-16W4/0	1985	1274	1267.0-1284.0	N	Y
00/16-28-030-16W4/0	1986	1258	1248-1267.5	Y	Y
00/06-29-030-16W4/0	1969	1303	149.7-1315.8	N	N
00/16-31-030-16W4/0	1986	1296	1285.0-1317.3	Y	Y
00/11-33-030-16W4/0	1986	1264	1251.0-1273.8	Y	N
00/16-04-031-11W4/0	1982	1099	1096.0-1103.25	N	Y
00/14-03-031-16W4/0	1986	1235	1236.6-1243.6	Y	N

00/05-11-031-16W4/0	1987	1226	1231.5-1240.7	Y	N
00/06-15-031-16W4/0	1986	1236	1235.0-1254.0	N	Y
02/14-24-031-16W4/0	1987	1247	1255.0-1264.6	Y	N
00/16-31-031-16W4/0	1986	1248	1294.0-1312.55	Y	Y
00/06-35-031-16W4/0	1987	1220	1227.6-1238.0	Y	N
WELLS LOGGED WEST OF STUDY AREA					
00/16-20-026-17W4/0	1989	1332	1337.0-1355.0	Y	Y
02/10-31-026-17W4/0	1986	1272	1277.0-1295.3	Y	Y
00/06-25-026-18W4/0	1980	1389	1391.0-1409.0	Y	Y
00/16-35-026-18W4/0	1981	1313	1327.0-1343.8	Y	Y
00/16-06-027-17W4/0	1981	1267	1269.0-1287.0	Y	Y
00/14-16-027-18W4/0	1988	1288	1304.0-1316.0	Y	Y

LEGEND
CA=CORE ANALYSIS
L=LOGGED

APPENDIX D

CORE DESCRIPTIONS

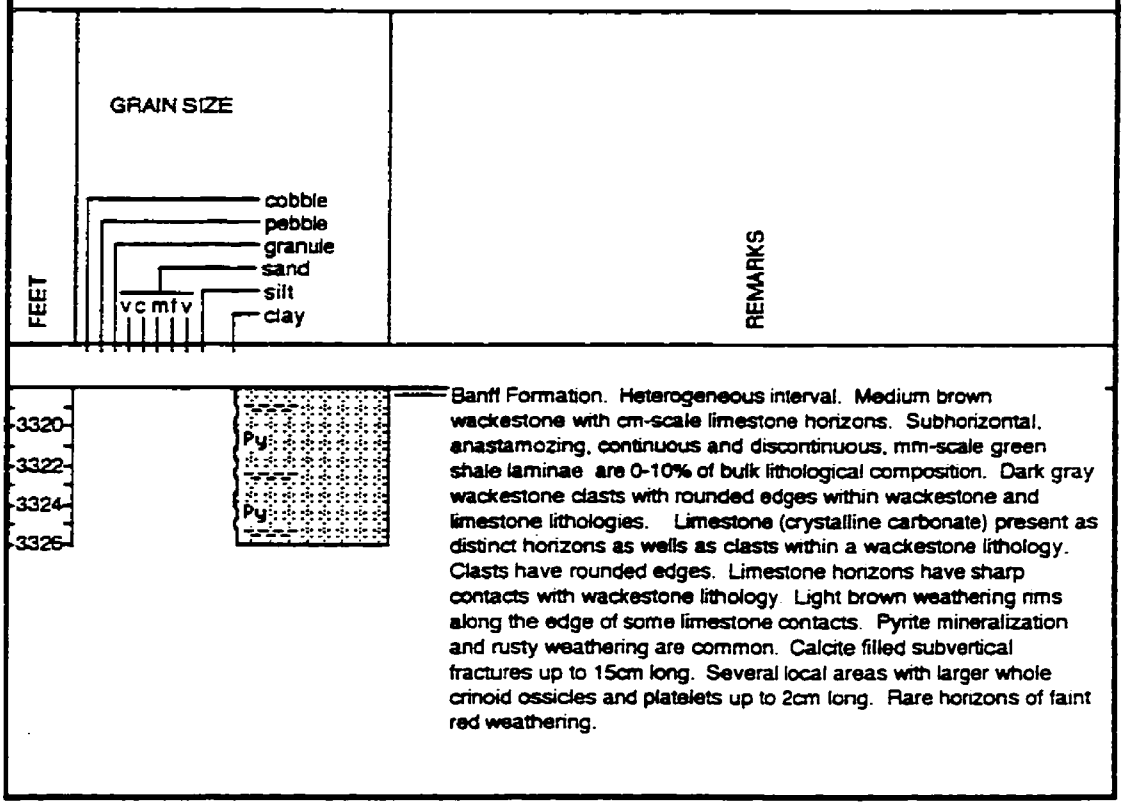


AppleCore legend for core descriptions.

Amoco Jenner
04-18-21-8w4

Ground: 765.00 ft KB: 2522.10 ft

Remarks: Not a long continuous core as indicated on the ticket. Core #68 covers 3318-3326ft. Next core above this interval covers 3279-3300ft. "Core Scrambled" written on all core boxes. Description is probably not very useful.

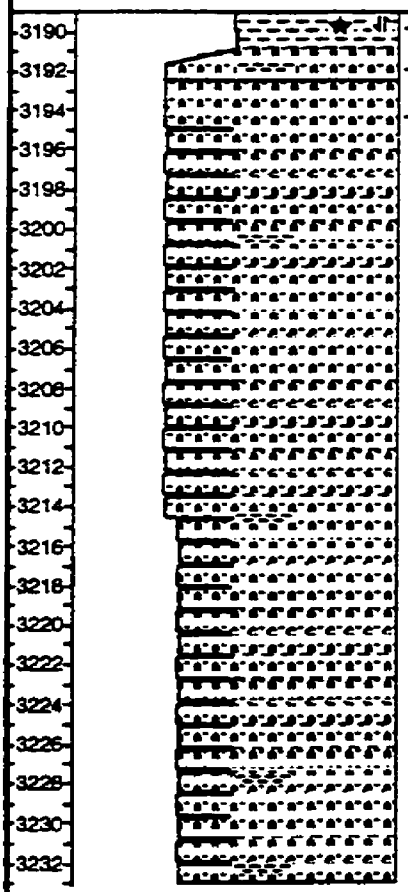


Banff Formation. Heterogeneous interval. Medium brown wackestone with cm-scale limestone horizons. Subhorizontal, anastamozing, continuous and discontinuous, mm-scale green shale laminae are 0-10% of bulk lithological composition. Dark gray wackestone clasts with rounded edges within wackestone and limestone lithologies. Limestone (crystalline carbonate) present as distinct horizons as wells as clasts within a wackestone lithology. Clasts have rounded edges. Limestone horizons have sharp contacts with wackestone lithology. Light brown weathering rims along the edge of some limestone contacts. Pyrite mineralization and rusty weathering are common. Calcite filled subvertical fractures up to 15cm long. Several local areas with larger whole crinoid ossicles and platelets up to 2cm long. Rare horizons of faint red weathering.

Gulf Cessford
13-23-22-12w4

Ground: 695.90 ft KB: 2291.12 ft

Remarks: 1 inch core. No core analysis. Well drilled in 1946. Upper Banff core including Detrital/Altered Banff/Banff contacts. Coarsening-upward cycle.



REMARKS

Altered Banff Formation. Red, orange, yellow and green weathering oxidized shales with rare scattered skeletal (dominantly crinoidal) fragments. Slickensides observed on some core end surfaces. Most of interval is broken up into pieces.

Banff Formation. Interbedded white crinoidal wackestone/packstone (85%) with red and green calcareous shales (15%). Shale horizons up to 1cm thick. Rare splotchy red weathering of the wackestone/packstone lithology. Gradational upper and lower contacts.

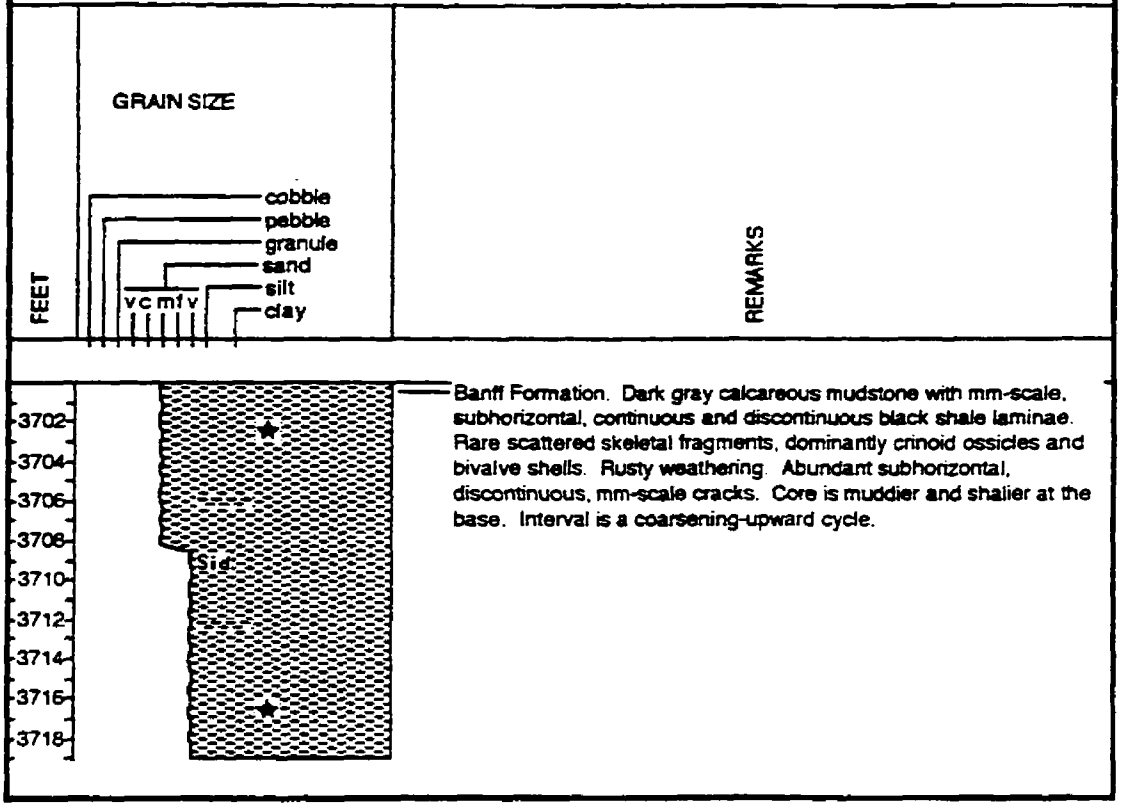
Banff Formation. Light gray crinoidal wackestone to packstone with splotchy red and green weathering. Red and green calcareous shale horizons are up to 5cm thick and contain scattered skeletal fragments. Shales between 5 and 10% of bulk lithological composition. Rare stringers of carbonaceous material and calcite filled subvertical fractures. Rusty weathering around the periphery of dark gray clasts <0.75cm wide is moderately common. Rusty weathering is also present as splotches. Bottom half of this interval has a more mottled appearance and contains black subhorizontal continuous and discontinuous mm-scale anastomozing shale laminae. These laminae are also grouped into horizons up to 1cm thick. The upper Banff in this interval is a coarsening and shallowing-upward cycle from muddier sediments in the base (dominantly wackestones) to wackestones and packstones towards the top of the interval.

Toronto Syndicate No. 1

01-06-22-13w4

Ground: 0.00 ft KB: 2382.99 ft

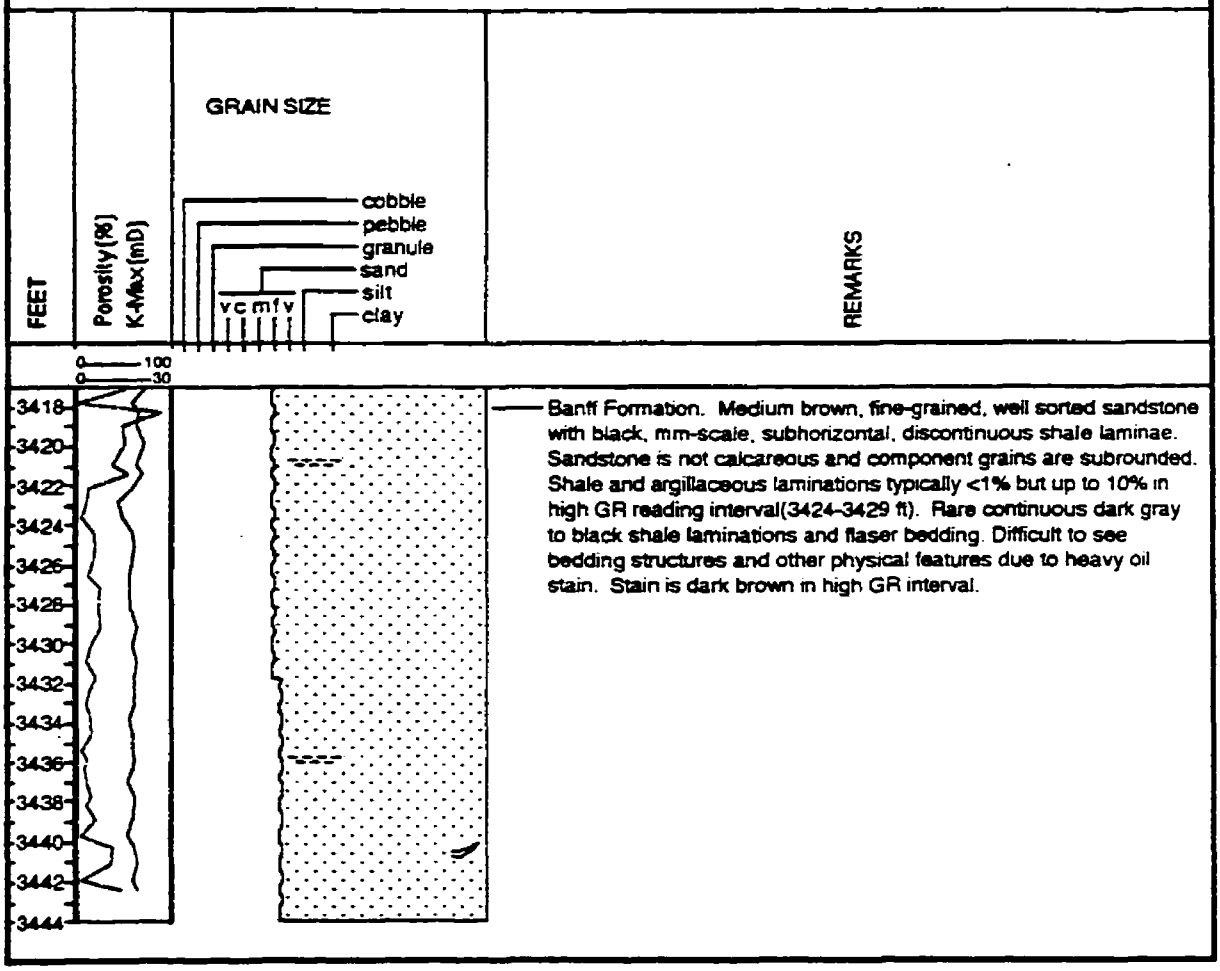
Remarks: 1 inch core. No core analysis. Old core (1945). Ground is blank on ticket.



Can Seab'd Jenner
11-31-23-09w4

Ground: 720.20 ft KB: 2376.10 ft

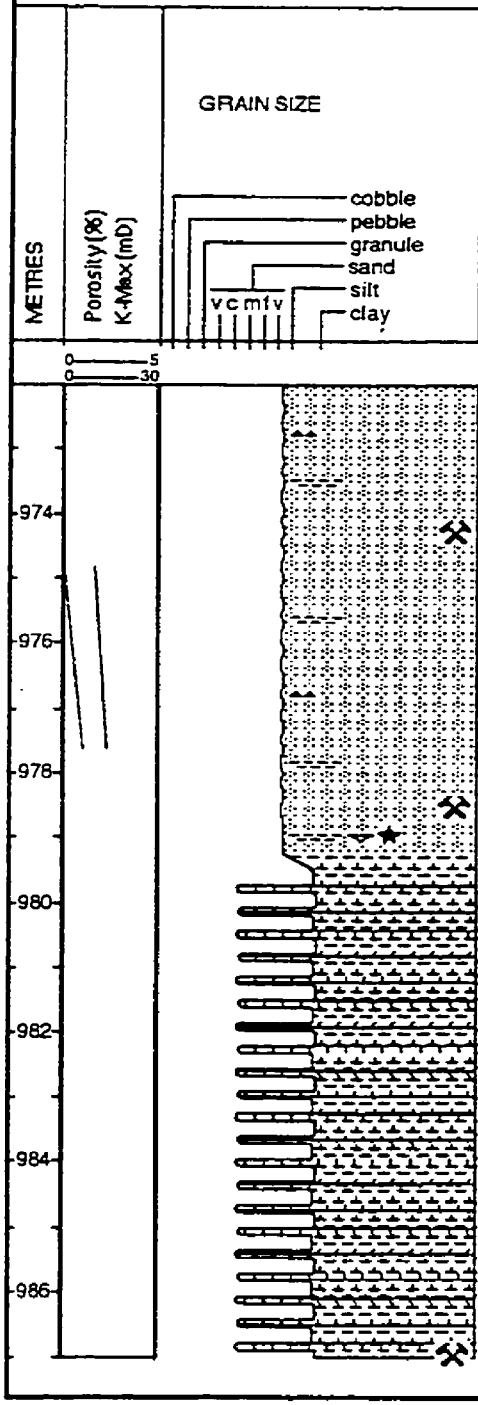
Remarks: 1 inch diameter Upper Bakken sandstone core. Hard to see features because core is heavily oil stained. Grain size coarsens-upward.



Grad & Walker Energy et al. Cessford
14-34-23-09w4

Ground: 744.30 m KB: 747.90 m

Remarks: Only new (1987) long core in the SE quadrant of the study area. This core has been heavily sampled by previous workers.



REMARKS

Banff Formation. Buff brown to gray calcareous skeletal wackestone. Large (2-10cm diameter) opaque white Tripolitic chert clasts make up 1-2% of the bulk rock composition throughout the interval. Clasts are typically angular, but some also have a "globular" appearance (smoother, rounded edges). In the lower part of this interval, several large gray, coarser-grained calcareous wackestone clasts up to 30cm long have rounded edges and a sharp contact with the buff mudstone surrounding them. Green gray, mm-scale, subhorizontal shale laminae are concentrated into bundles in parts of the interval. Subvertical and subhorizontal fractures and vugs are commonly filled with large euhedral calcite crystals. Basal 30cm of this interval contains visible shelly fragments (crinoids and brachiopods) in a brown muddy matrix which are concentrated into 1-2cm horizons. Contact with underlying interbedded limestone and shale is gradational.

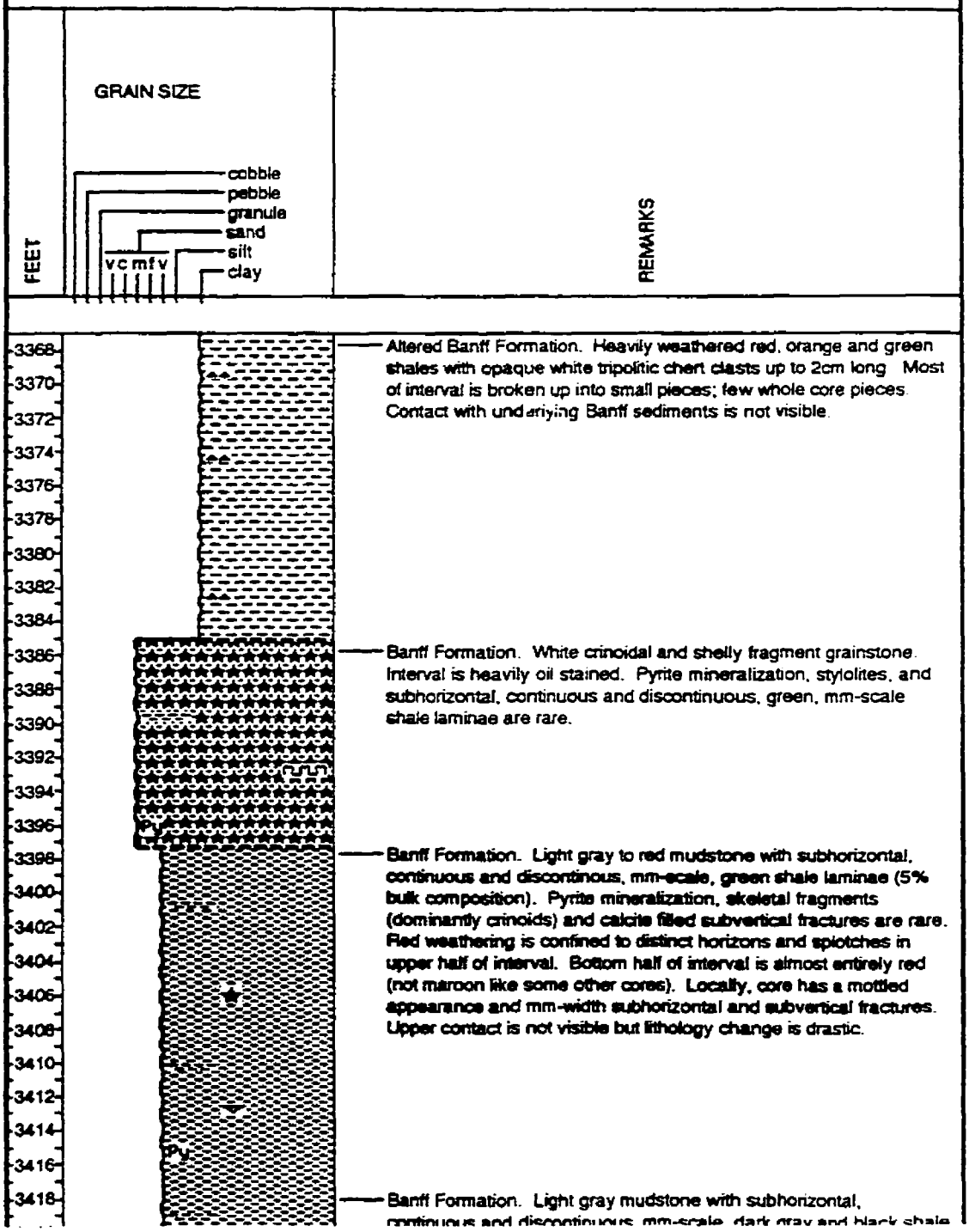
Banff Formation. Dark gray interbedded calcareous shale (70%) and calcareous crinoidal wackestone and packstone (30%). Shelly material (dominantly crinoids but some well preserved whole brachiopod, bivalve and gastropod shells) is scattered throughout the interval, but is also concentrated into several 0.5-6cm wide horizons. In these bands, crinoidal fragments make up to 40% (more typically 10-25%) of the bulk rock composition. Crinoidal fragments are also present as clasts several cm wide within a dominantly shale package. Smaller scale (<2cm) vugs are infilled with finer calcite crystals than in the overlying interval. Maroon weathering of several horizons.

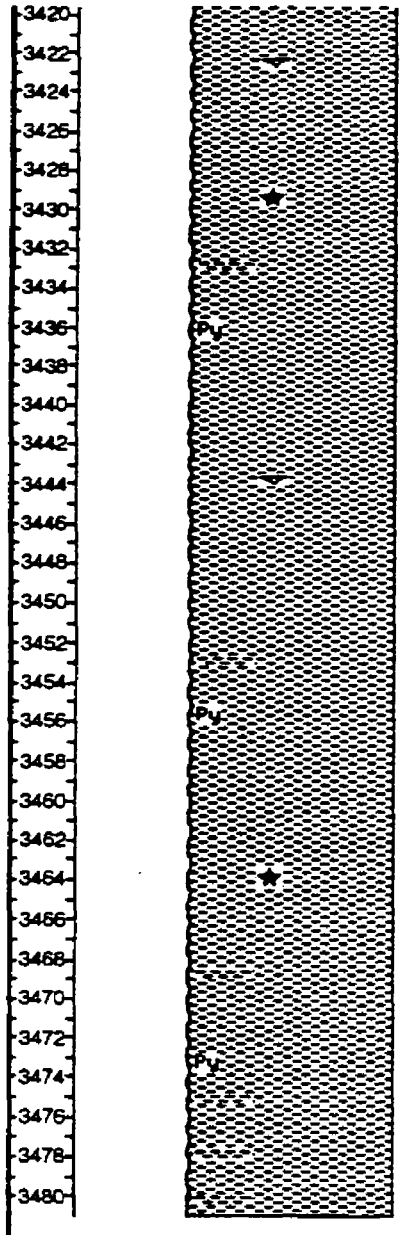
Riley-Lloyd #1

16-05-23-14w4

Ground: 2307.00 ft KB: 2315.07 ft

Remarks: 1 inch core, no core analysis. Two cores; upper Banff including altered zone and Middle and Lower Banff to the Exshaw shales. This core has some slabs, has been displayed previously.



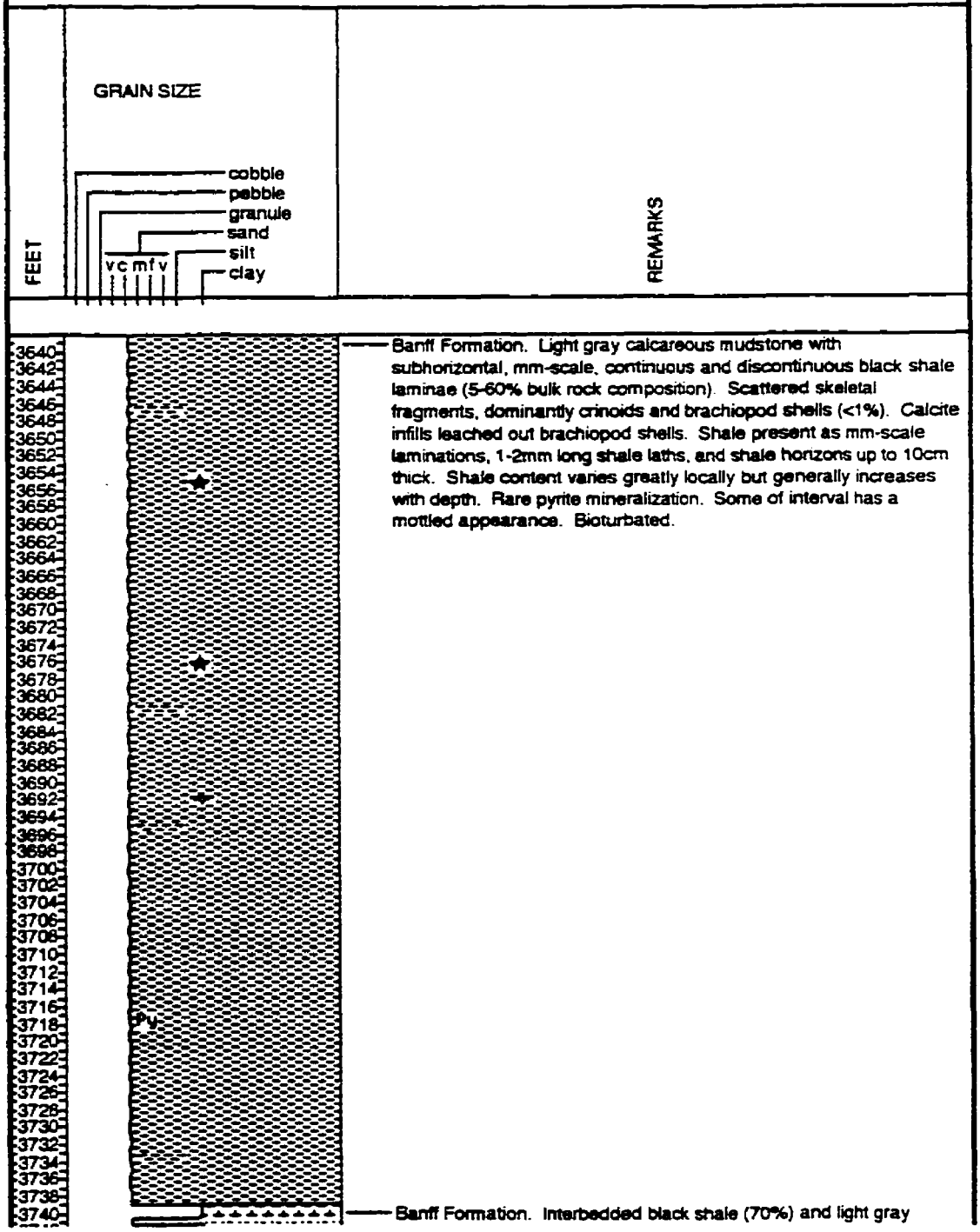


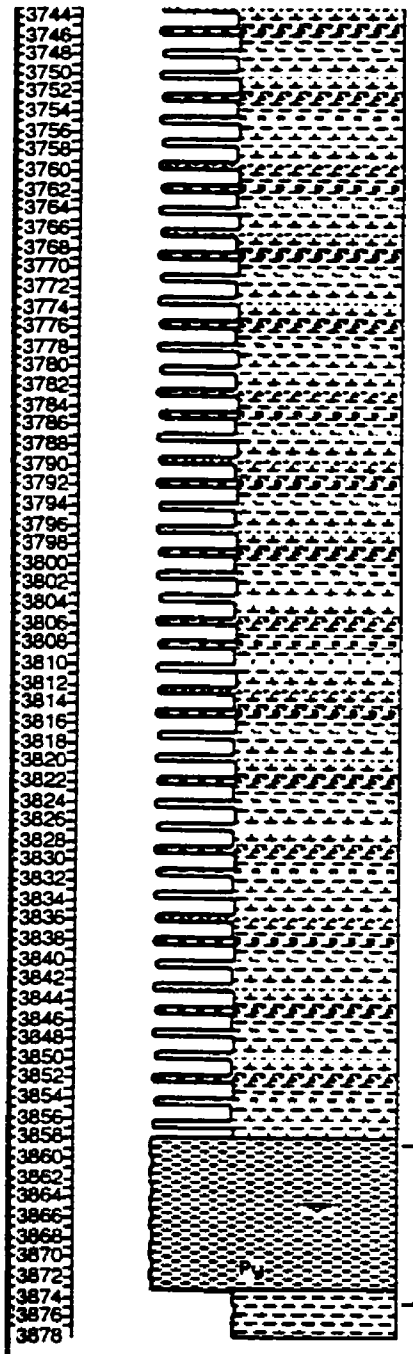
laminae. Shale content increases with depth to a maximum of 50%. Contact with overlying unit is gradational and is marked by the loss of red weathering. Parts of the interval are bleeding oil. Rusty weathering (siderite?), scattered skeletal fragments and pyrite mineralization are present throughout the unit. Several possible hardground surfaces marked by light brown muds scouring into underlying black shales. Locally, calcite infills leached out shells and muds have a mottled appearance.

Riley-Lloyd
16-05-23-14w4

Ground: 2307.00 ft KB: 2315.07 ft

Remarks: Second Banff Formation core in this well. Penetrates the lower Banff and Exshaw Formations. Note that the scale of the logged core presented below is 1:200 instead of 1:100 as for the rest of the cores logged.





interval is broken up into poker chip sized pieces. Rare red oxidation of selected packstone horizons. Interval from 3766'6"-3777' is not broken and consists of interbedded wackestone/packstone (80%) and shale (20%).

Banff Formation. Dolomitic mottled green gray mudstone. Scattered subhorizontal black 1mm thick, 1-2mm long shale laths. Scattered skeletal fragments (dominantly crinoid ossicles). Rare pyrite mineralization.

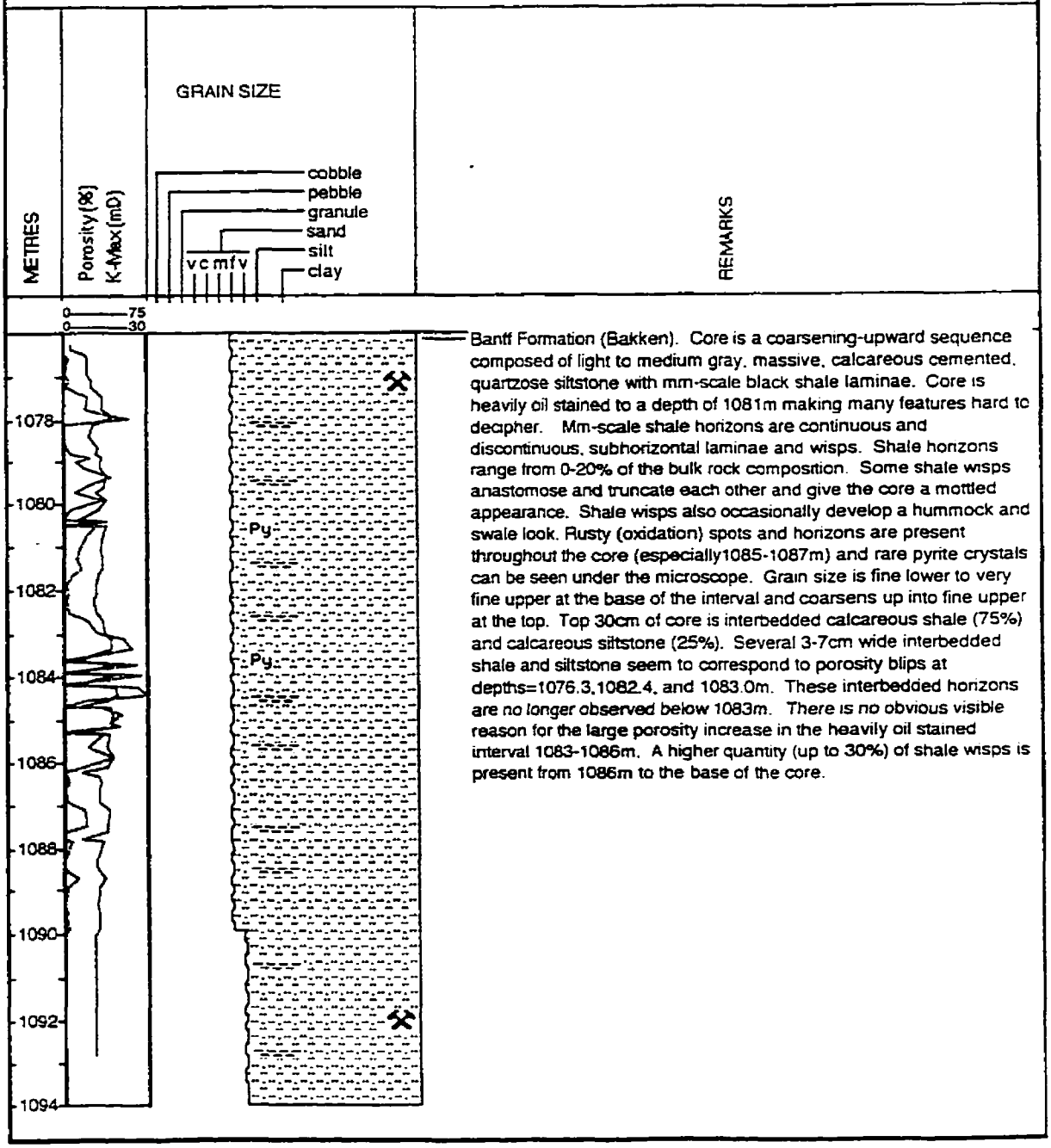
Exshaw Formation. Massive black shale broken into poker chip size pieces. Upper contact is not visible.

Suncor Kinmundy

16-06-25-08w4

Ground: 771.10 m KB: 775.20 m

Remarks: Bakken Formation siltstone core near eastern limit of study area. This core has been very well sampled by previous workers. Oil cut mud was recovered from a DST through the cored interval. Depth scale is 1:130.



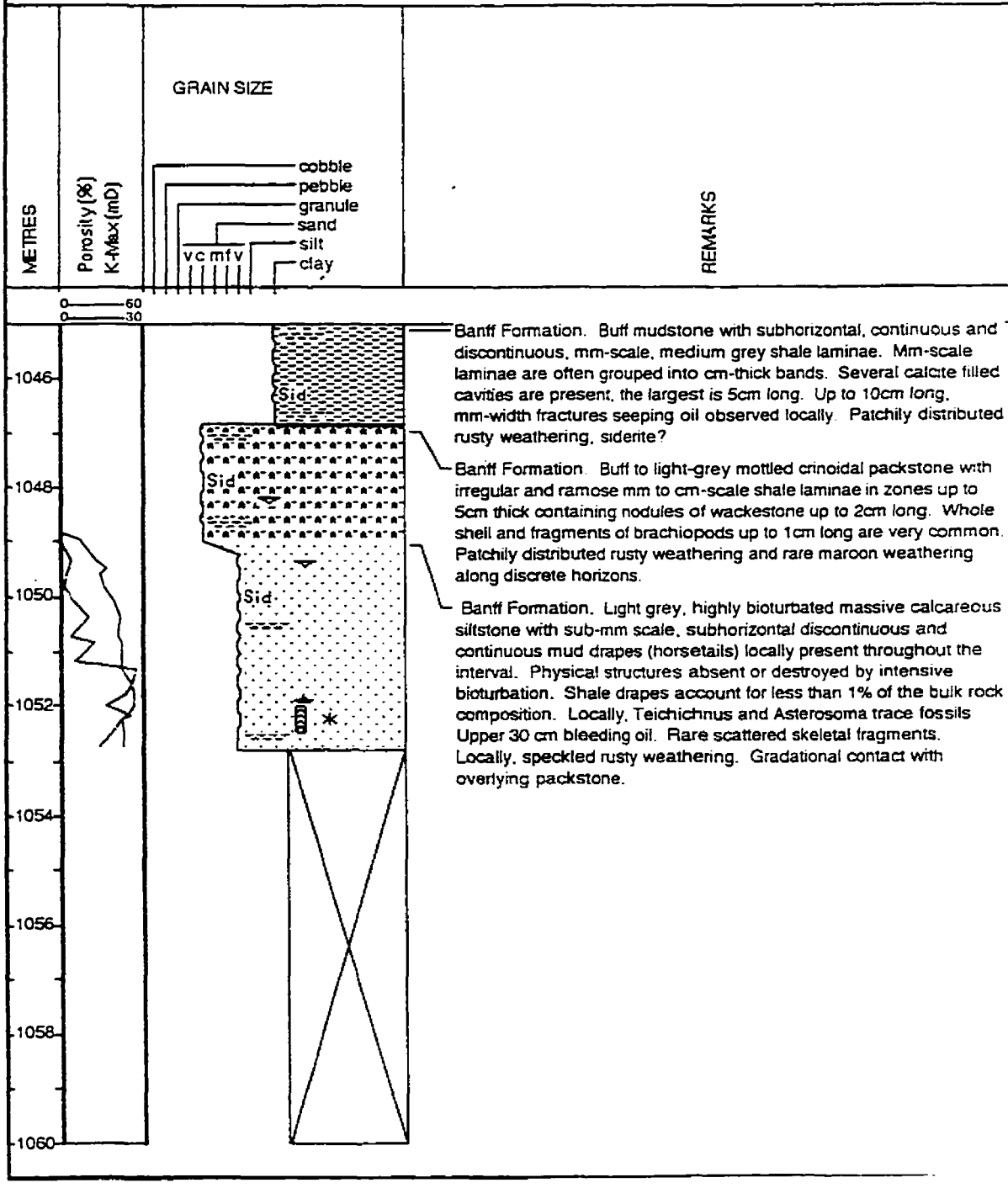
Banff Formation (Bakken). Core is a coarsening-upward sequence composed of light to medium gray, massive, calcareous cemented, quartzose siltstone with mm-scale black shale laminae. Core is heavily oil stained to a depth of 1081m making many features hard to decipher. Mm-scale shale horizons are continuous and discontinuous, subhorizontal laminae and wisps. Shale horizons range from 0-20% of the bulk rock composition. Some shale wisps anastomose and truncate each other and give the core a mottled appearance. Shale wisps also occasionally develop a hummock and swale look. Rusty (oxidation) spots and horizons are present throughout the core (especially1085-1087m) and rare pyrite crystals can be seen under the microscope. Grain size is fine lower to very fine upper at the base of the interval and coarsens up into fine upper at the top. Top 30cm of core is interbedded calcareous shale (75%) and calcareous siltstone (25%). Several 3-7cm wide interbedded shale and siltstone seem to correspond to porosity blips at depths=1076.3,1082.4, and 1083.0m. These interbedded horizons are no longer observed below 1083m. There is no obvious visible reason for the large porosity increase in the heavily oil stained interval 1083-1086m. A higher quantity (up to 30%) of shale wisps is present from 1086m to the base of the core.

Conwest et al Cessford

16-14-25-12w4

Ground: 741.10 m KB: 745.10 m

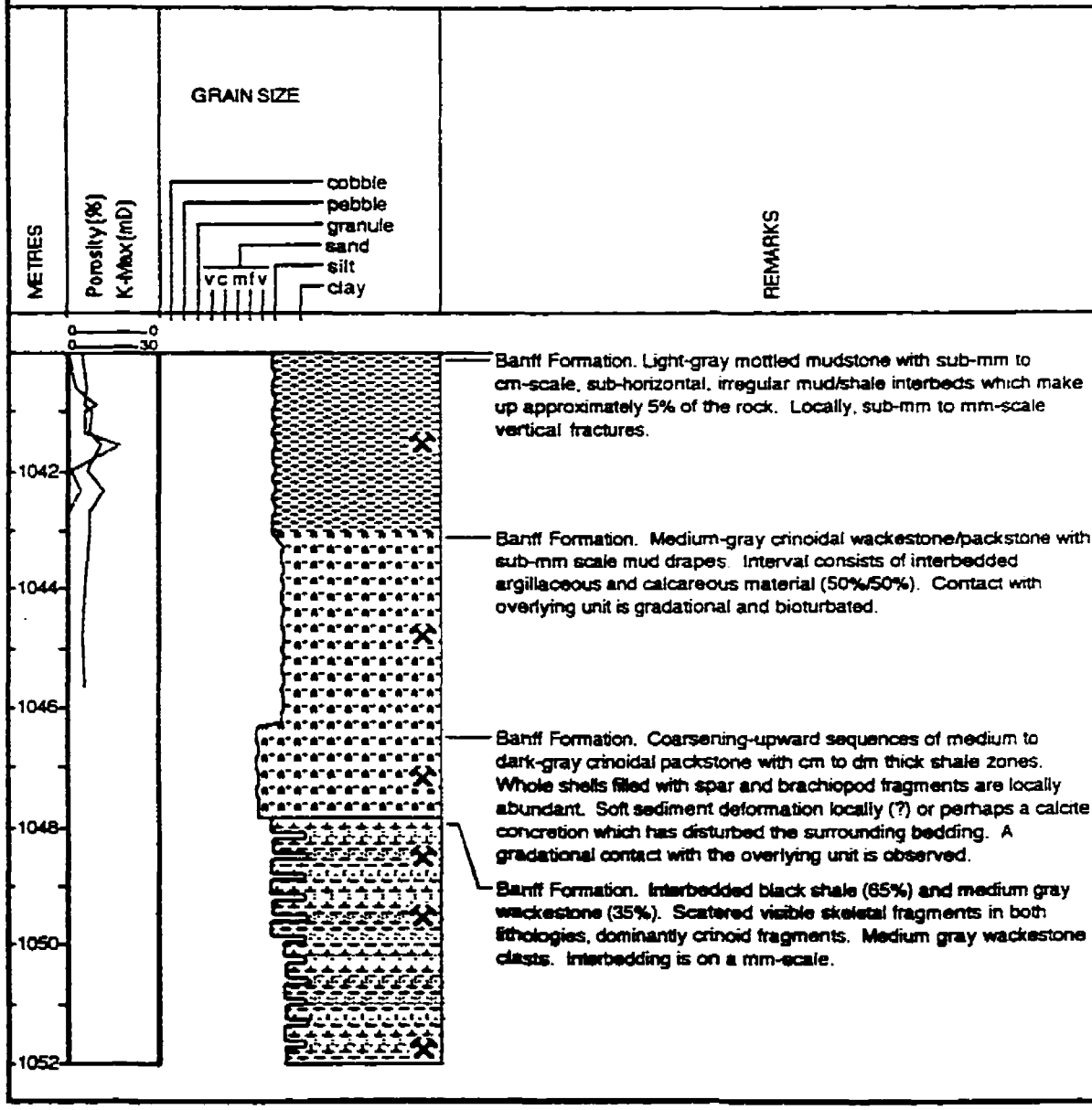
Remarks: 3 inch clean core with approximately 7.2m lost core. Core appears to have been lost from the bottom of the interval. Entire core is oil stained, about 30% of it has been cleaned off. This is an 02/ location.



Dome et al Cessford
16-22-25-12w4

Ground: 740.00 m KB: 743.80 m

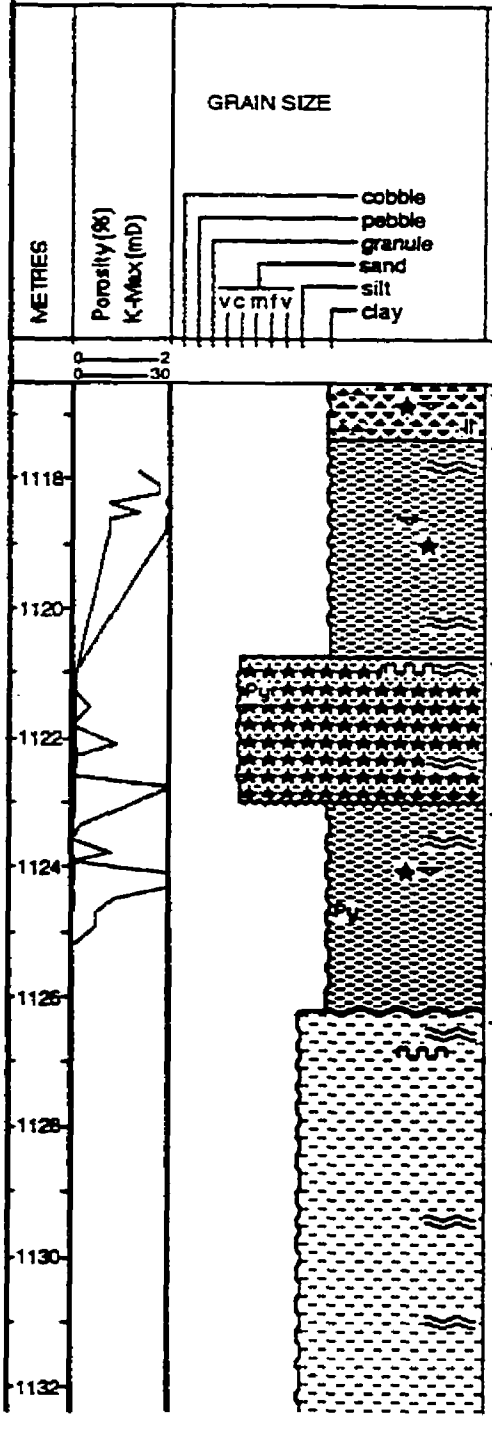
Remarks: Fully recovered 3 inch core. This is an /02 location.



Total et al. Connorsville
14-35-25-15w4

Ground: 784.90 m KB: 788.90 m

Remarks: Fully recovered 10 cm core. Banff siltstone. Except for the top two boxes, entire core has been slabbed.



REMARKS

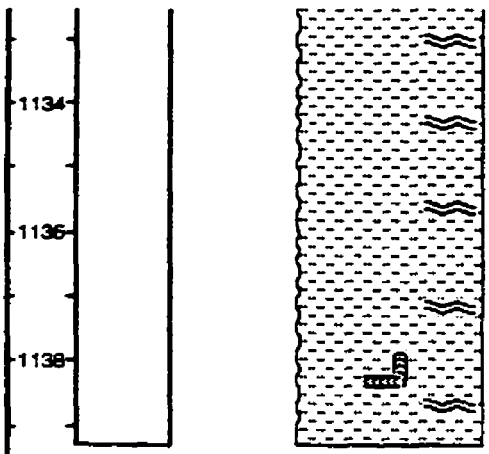
Detrital Formation. Medium green breccia with varying amounts of matrix-supported white leached microporous siliceous clasts 0.1-5cm long (tripolitic chert). Clasts make up approximately 15% of the total bulk rock composition. *Matrix is comprised of* frosted quartz grains floating in silty shale (cf.underlying shales). Siliceous clasts are absent in a 20cm thick interval of shale. Rare brachiopod shells and crinoid fragments. Local slickensides.

Altered Banff Formation. Light green mudstone with subhorizontal continuous and discontinuous mm-scale dark green shale laminae and shelly fragments. A 30cm long interval consists of crinoidal grainstone, possibly a boulder. Several 5cm chunks of this crinoidal grainstone are also observed throughout the interval. The middle 20cm of this interval contains abundant shelly material and is heavily bioturbated. Bottom 20cm of this interval has a mottled appearance and mud laminae are far less abundant.

Banff Formation. Homogeneous, light-brown, cross-bedded, crinoidal and shelly fragment grainstone. Continuous and discontinuous, subhorizontal, mm-scale laminae and 1cm wide shale horizons are present. A 3cm band of mud intraclasts is present. Possible hardground is marked by a large (5cm long) cracked mud nodule. One 10cm long, 1cm wide calcite filled subvertical fracture is present as are a number of mm-width fractures. Minor maroon weathering and pyrite mineralization. Rare stylolites. Contact with overlying unit not observed. Grainstone scours down into less competent underlying muds.

Banff Formation. *Light-gray/brown bioturbated mudstone with* occasional 1mm wide black mud laminae oriented in many directions. Crinoidal and brachiopod fragments <1% for the interval as a whole and up to 15-20% in several 5cm thick intervals. Local pyrite patches. Possible hardground with irregular shaped mud nodules and mud-filled shells (ie. formed in place). Hardground surface separates a dark gray mudstone from a medium gray mudstone. Rare calcite filled cavities and subhorizontal and subvertical fractures. Contact with underlying siltstone is undulatory. Contact difficult to pick because of transition zone 15 cm thick. Shelly concentration along contact may be a transgressive lag.

Banff Formation Siltstone. Light-gray/brown dolomitic siltstone with mm-scale, sub-horizontal, black continuous and discontinuous mud



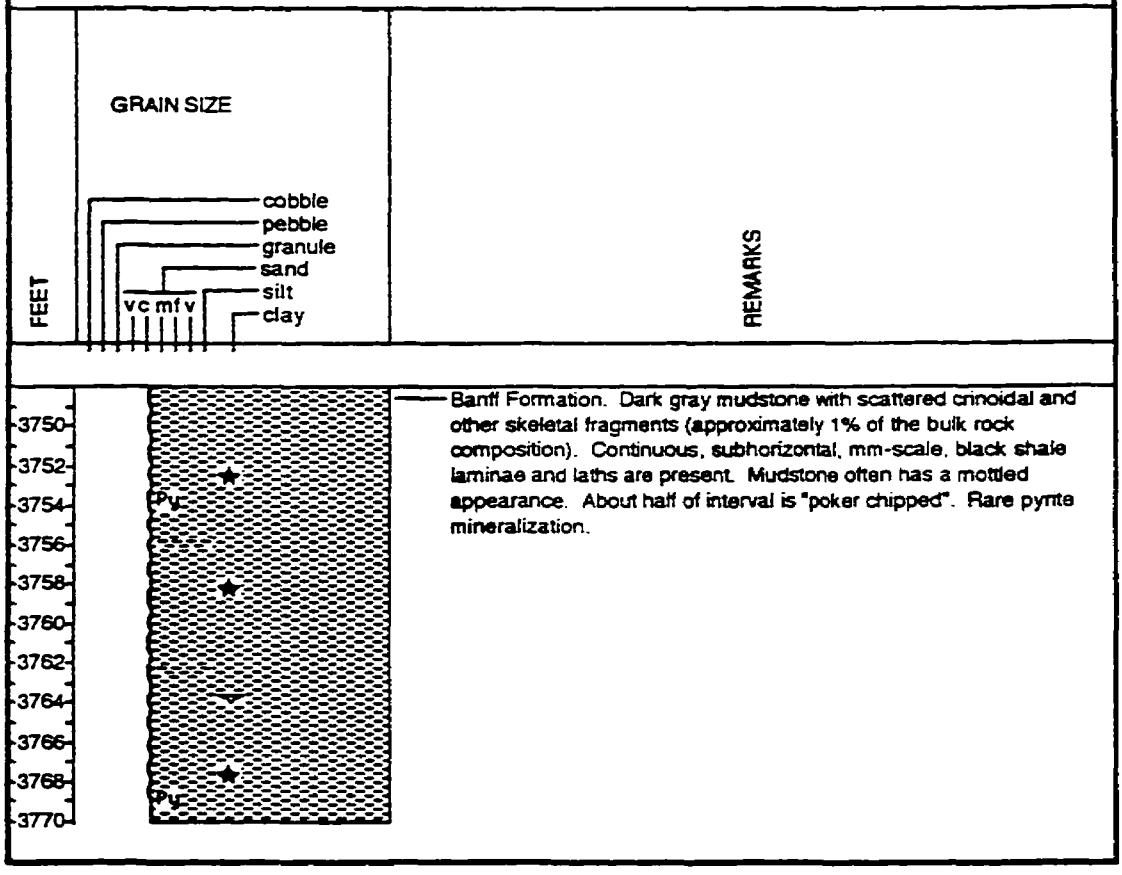
laminae. Laminae are partially stylolitized locally. Siltstone unit is shallowing and coarsening-upward. The base of the core is more heavily bioturbated and has a greater % of mud laminae than the upper parts. 1-10cm wide calcareous cemented zones lacking the shale laminae are present throughout the interval as are rare calcite filled cavities. Blip in porosity logs around 1133.0m seems to correspond to an interval with approximately 30-50% shale laminae. Zoophycos? Teichichnus? Lots of trace fossils in base of core, few to none in upper parts of siltstone unit. Trangressive contact with overlying unit.

Anglo-Sunnynook No. 1

02-31-26-12w4

Ground: 2461.00 ft KB: 2479.12 ft

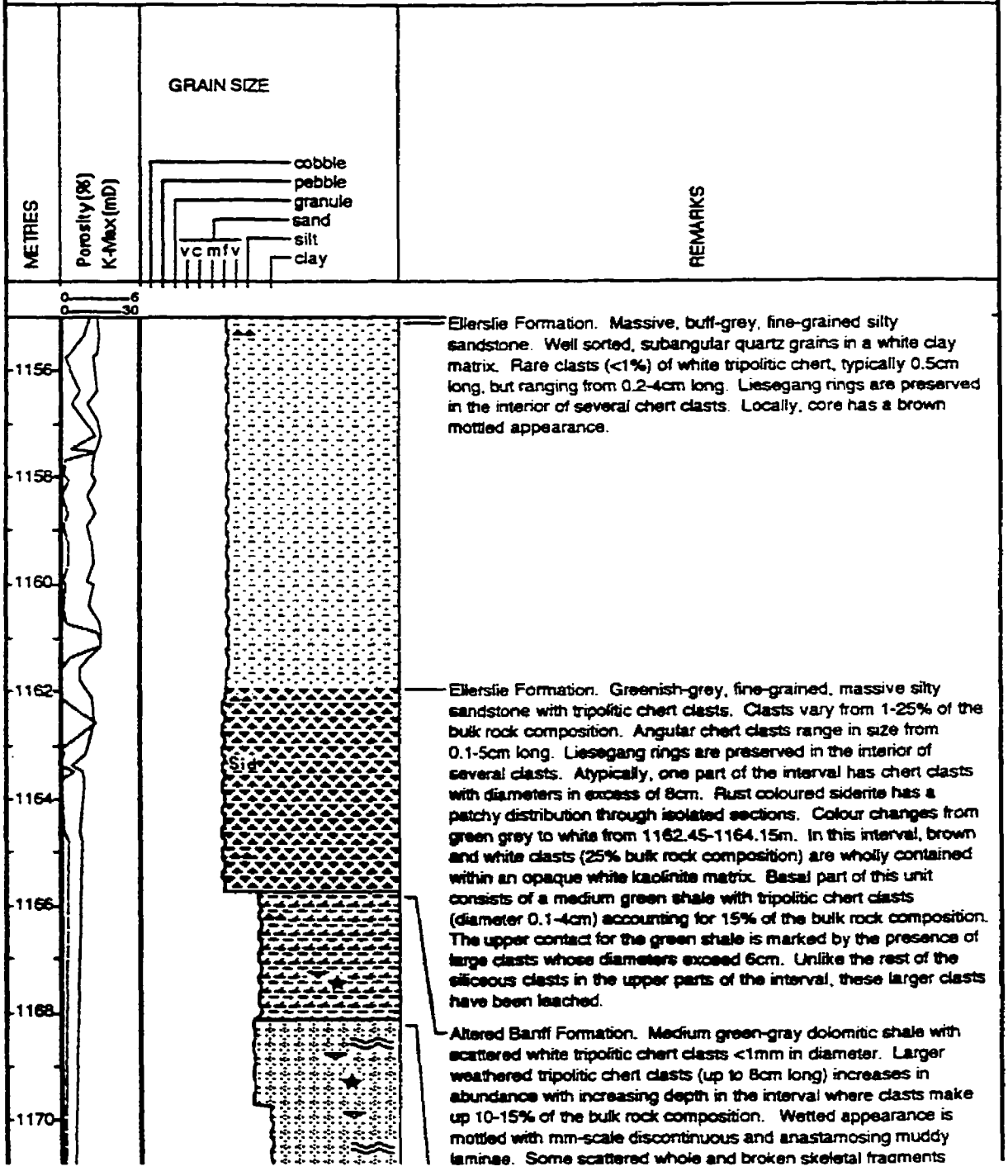
Remarks: 1 inch core, no core analysis.



Amerada Hess et al. Connors
06-22-26-16w4

Ground: 794.80 m KB: 799.20 m

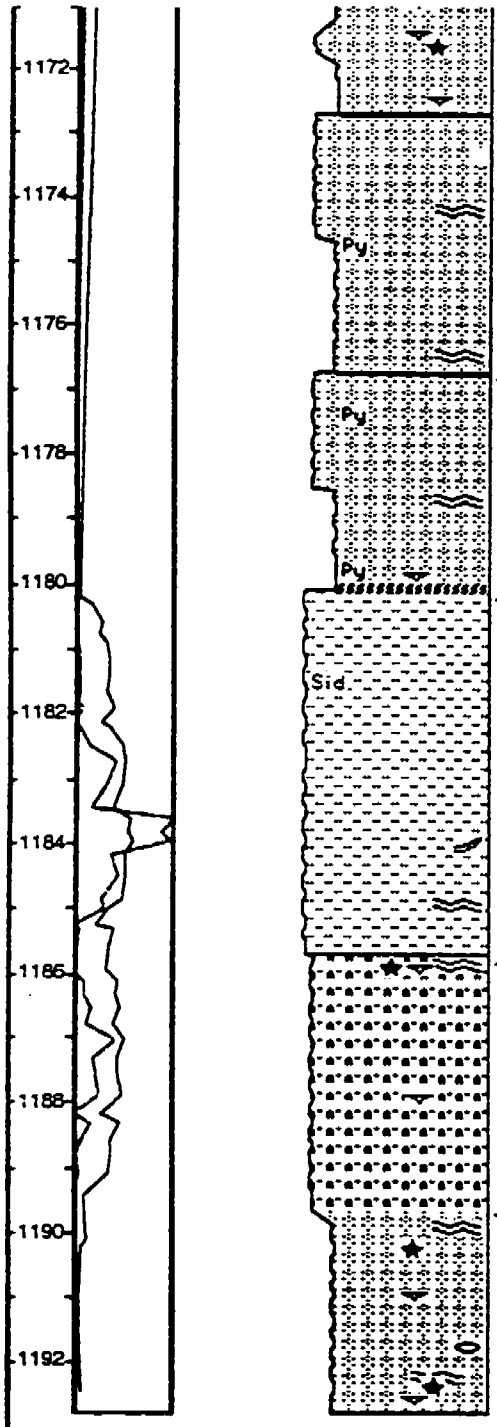
Remarks: The best core both for completeness and for showing metre-scale cyclicity and the Banff siltstone. Core depth is about 2m off of log depth.



Ellerslie Formation. Massive, buff-grey, fine-grained silty sandstone. Well sorted, subangular quartz grains in a white clay matrix. Rare clasts (<1%) of white tripolitic chert, typically 0.5cm long, but ranging from 0.2-4cm long. Liesegang rings are preserved in the interior of several chert clasts. Locally, core has a brown mottled appearance.

Ellerslie Formation. Greenish-grey, fine-grained, massive silty sandstone with tripolitic chert clasts. Clasts vary from 1-25% of the bulk rock composition. Angular chert clasts range in size from 0.1-5cm long. Liesegang rings are preserved in the interior of several clasts. Atypically, one part of the interval has chert clasts with diameters in excess of 8cm. Rust coloured siderite has a patchy distribution through isolated sections. Colour changes from green grey to white from 1162.45-1164.15m. In this interval, brown and white clasts (25% bulk rock composition) are wholly contained within an opaque white kaolinite matrix. Basal part of this unit consists of a medium green shale with tripolitic chert clasts (diameter 0.1-4cm) accounting for 15% of the bulk rock composition. The upper contact for the green shale is marked by the presence of large clasts whose diameters exceed 6cm. Unlike the rest of the siliceous clasts in the upper parts of the interval, these larger clasts have been leached.

Altered Banff Formation. Medium green-gray dolomitic shale with scattered white tripolitic chert clasts <1mm in diameter. Larger weathered tripolitic chert clasts (up to 8cm long) increases in abundance with increasing depth in the interval where clasts make up 10-15% of the bulk rock composition. Wetted appearance is mottled with mm-scale discontinuous and anastamosing muddy laminae. Some scattered whole and broken skeletal fragments



(crinoid platelets and brachiopod pieces). The base of this interval is marked by a number of vertisol cracks where green shale is penetrating into the underlying unaltered Banff wackestone.

Banff Formation. Light gray crinoidal wackestone with subhorizontal, continuous and discontinuous, mm-scale shale laminae. Whole and broken skeletal fragments are scattered throughout the interval as well as concentrated into 7-10cm thick packstone to grainstone beds. Maroon weathering is restricted to certain horizons. White calcite clasts ranging from 1cm in diameter to greater than the core diameter make up 5% of the interval. This interval is a coarsening and shoaling upward sequence.

Banff Formation. Maroon crinoidal wackestone coarsening-upward sequence. Skeletal debris is generally larger than in overlying sequence, typically 1mm long but commonly up to 8mm long. Several cm-scale bands of crinoidal grainstone are located near the top of the interval. Upper contact is somewhat debatable as a transition zone between the two sequences exists. Basal contact is sharp.

Banff Formation. Coarsening and shoaling upward sequence of light and dark gray crinoidal wackestone with dm-scale grainstone beds. Cross-bedded grainstone intervals are as little as 1mm thick but more typically are of dm-scale thicknesses. Grainstone packages are bound by a sharp green shale upper boundary (sometimes pyritized) and a lower boundary characterized by load casts Interval is bioturbated. 0.5-1cm thick bands of green shale are present. The base of the interval has less skeletal material and more subhorizontal continuous and discontinuous black mud laminae.

Banff Formation. Coarsening-upward sequence consisting of medium gray crinoidal wackestone with cm-scale thick packstone deposits. Packstone intervals have basal contacts characterized by soft sediment deformation. Mm-scale, subhorizontal, black shale laminae are concentrated into cm-wide bands. Some shale laminae are bifurcating. Interval is bioturbated. Pyrite mineralization patchily distributed. Rare calcite filled cavities and vertical fractures. Maroon weathering is absent.

Banff Formation Siltstone. Buff-brown, massive, calcareous cemented quartzose siltstone. Mm-scale, subhorizontal, discontinuous green muddy laminae comprise <1% of the bulk siltstone composition. Poorly developed flasers and doublets. Contact with overlying sequence is bioturbated and bored. Glossifungites? along contact. Brachiopod lag along top of contact and pyrite mineralization. Interval is bioturbated. Rare rusty weathering. The siltstone is the top of a coarsening upwards sequence beginning with the base of the core.

Banff Formation. Light to medium gray pelleted silty crinoidal packstone. Black, mm-scale subhorizontal, discontinuous mud laminae comprise up to 20% of the rock in some places, more typically 5%. Interval is bioturbated. Scattered skeletal fragments. Teichichnus?

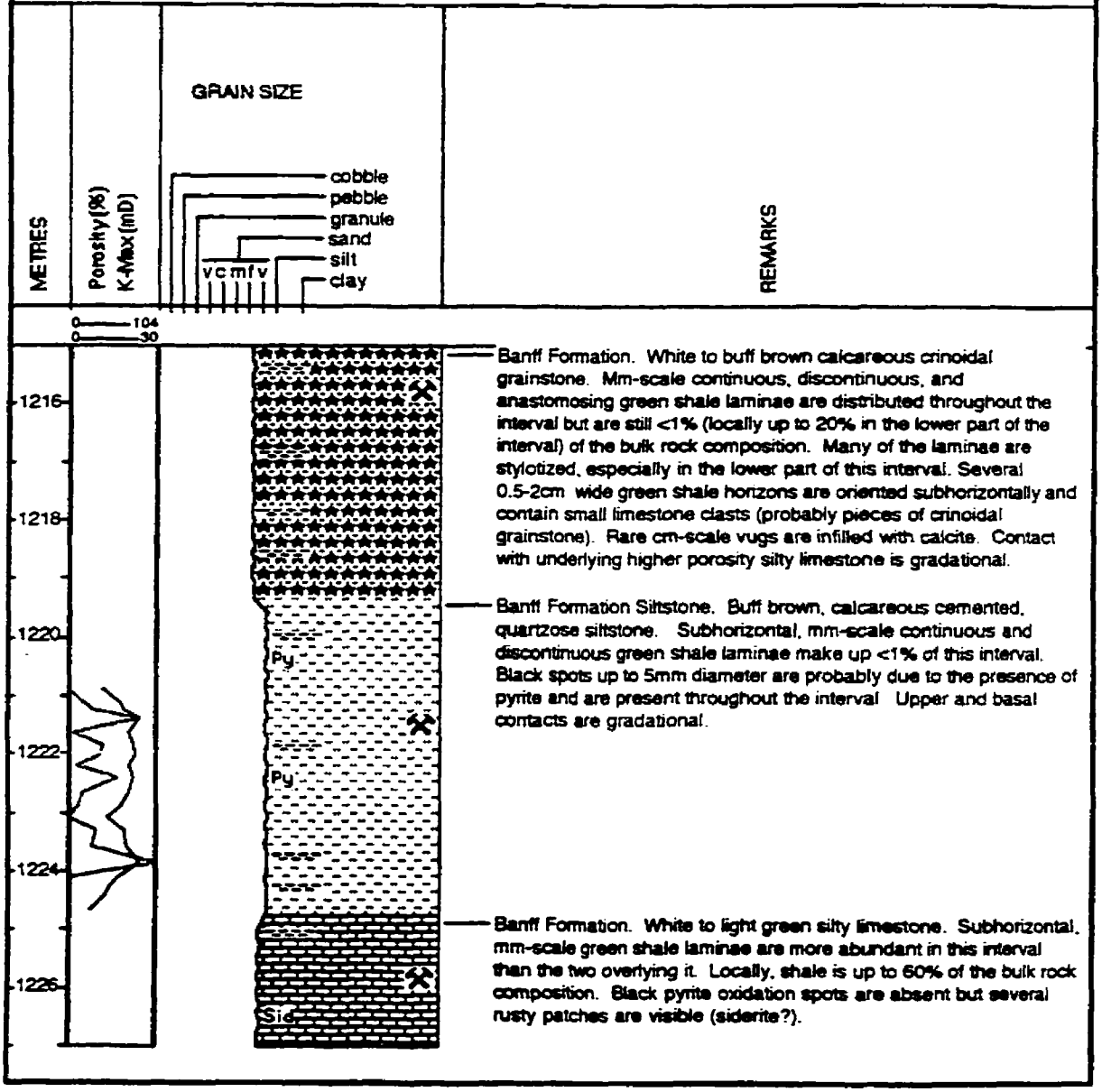
Banff Formation. Interval consists of two distinct lithologies. The first is similar to the overlying unit and consists of silty pelleted packstone. The second lithology is a lenticular bedded wackestone with scattered skeletal fragments. The pelleted lithology has sharp basal contacts and is massive. In contrast, the wackestone is highly deformed with a number of soft sediment deformation features developed. These two units are interbedded on a dm-scale. Continuous and discontinuous subhorizontal mm-scale shale laminae are present in the massive pelleted beds, as are rare calcite filled cavities. Horizontal bioturbation

Lockwood et al. Winterh.

10-29-26-16w4

Ground: 824.00 m KB: 828.30 m

Remarks: This is an 02/ location.

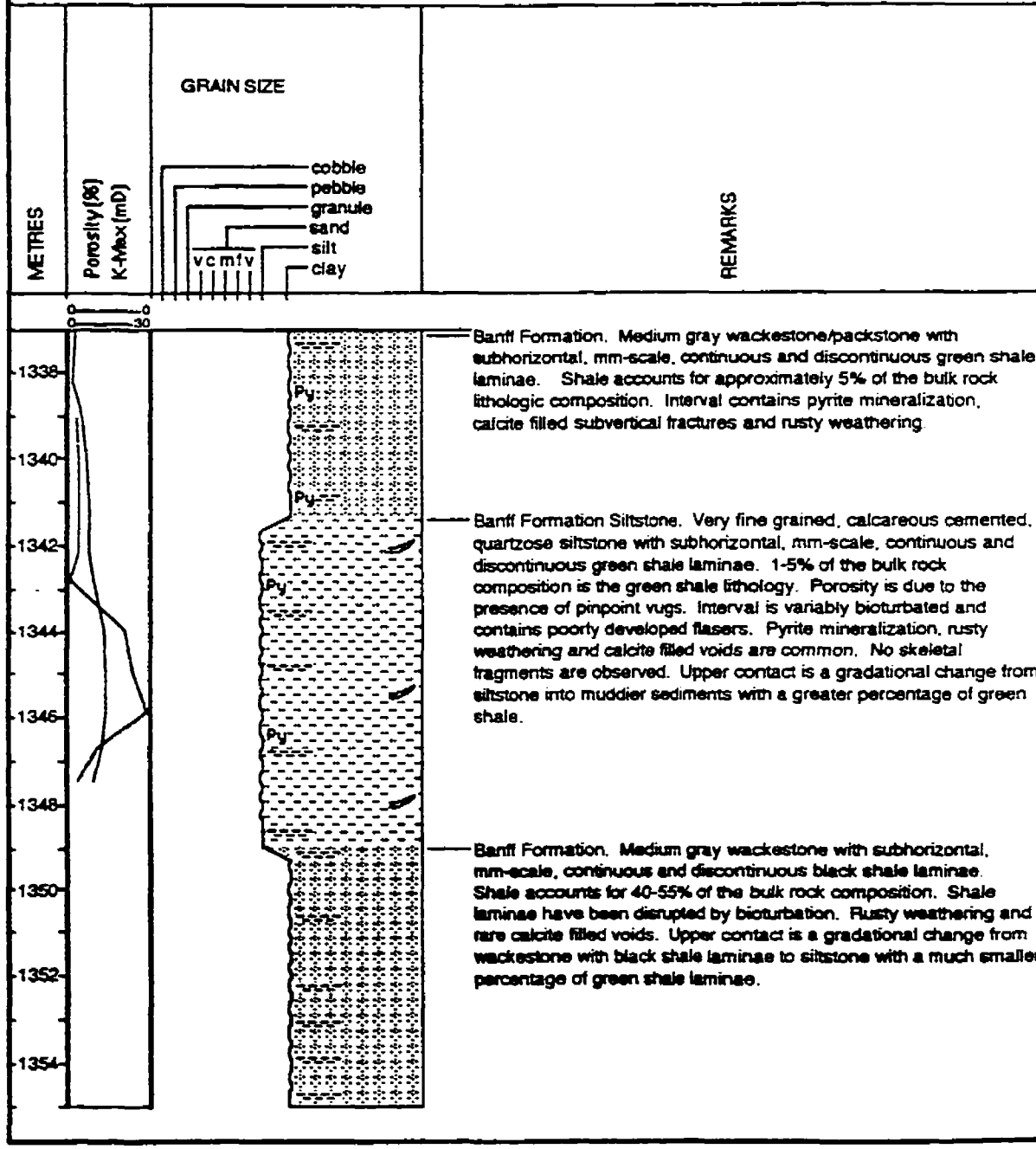


PCP Wayne

16-20-26-17w4

Ground: 902.90 m KB: 907.50 m

Remarks: Depth scale is 1:130 instead of standard 1:100.



Banff Formation. Medium gray wackestone/packstone with subhorizontal, mm-scale, continuous and discontinuous green shale laminae. Shale accounts for approximately 5% of the bulk rock lithologic composition. Interval contains pyrite mineralization, calcite filled subvertical fractures and rusty weathering.

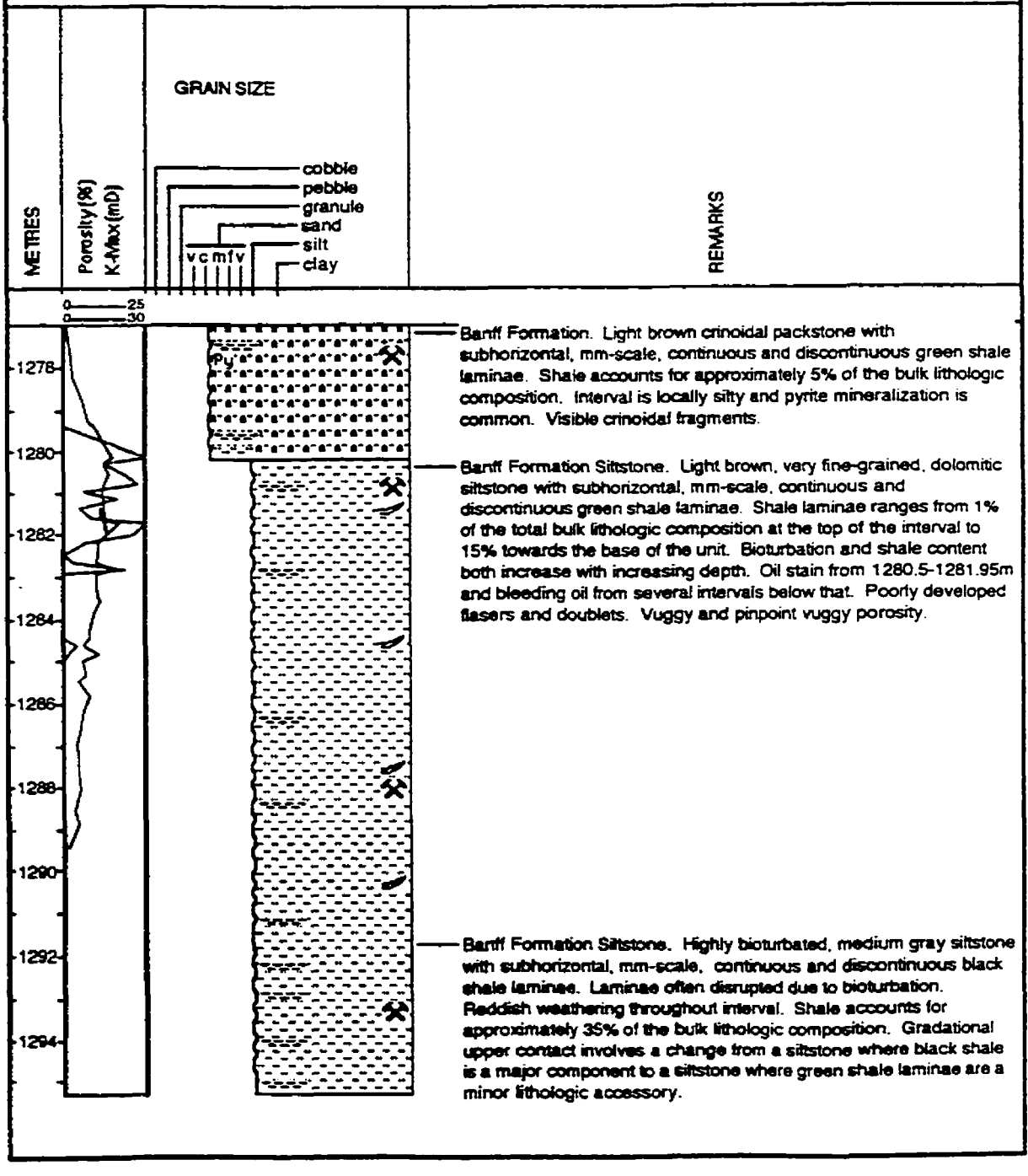
Banff Formation Siltstone. Very fine grained, calcareous cemented, quartzose siltstone with subhorizontal, mm-scale, continuous and discontinuous green shale laminae. 1-5% of the bulk rock composition is the green shale lithology. Porosity is due to the presence of pinpoint vugs. Interval is variably bioturbated and contains poorly developed flasers. Pyrite mineralization, rusty weathering and calcite filled voids are common. No skeletal fragments are observed. Upper contact is a gradational change from siltstone into muddier sediments with a greater percentage of green shale.

Banff Formation. Medium gray wackestone with subhorizontal, mm-scale, continuous and discontinuous black shale laminae. Shale accounts for 40-55% of the bulk rock composition. Shale laminae have been disrupted by bioturbation. Rusty weathering and rare calcite filled voids. Upper contact is a gradational change from wackestone with black shale laminae to siltstone with a much smaller percentage of green shale laminae.

Norwest et al Cessford
10-31-26-17w4

Ground: 839.20 m KB: 843.60 m

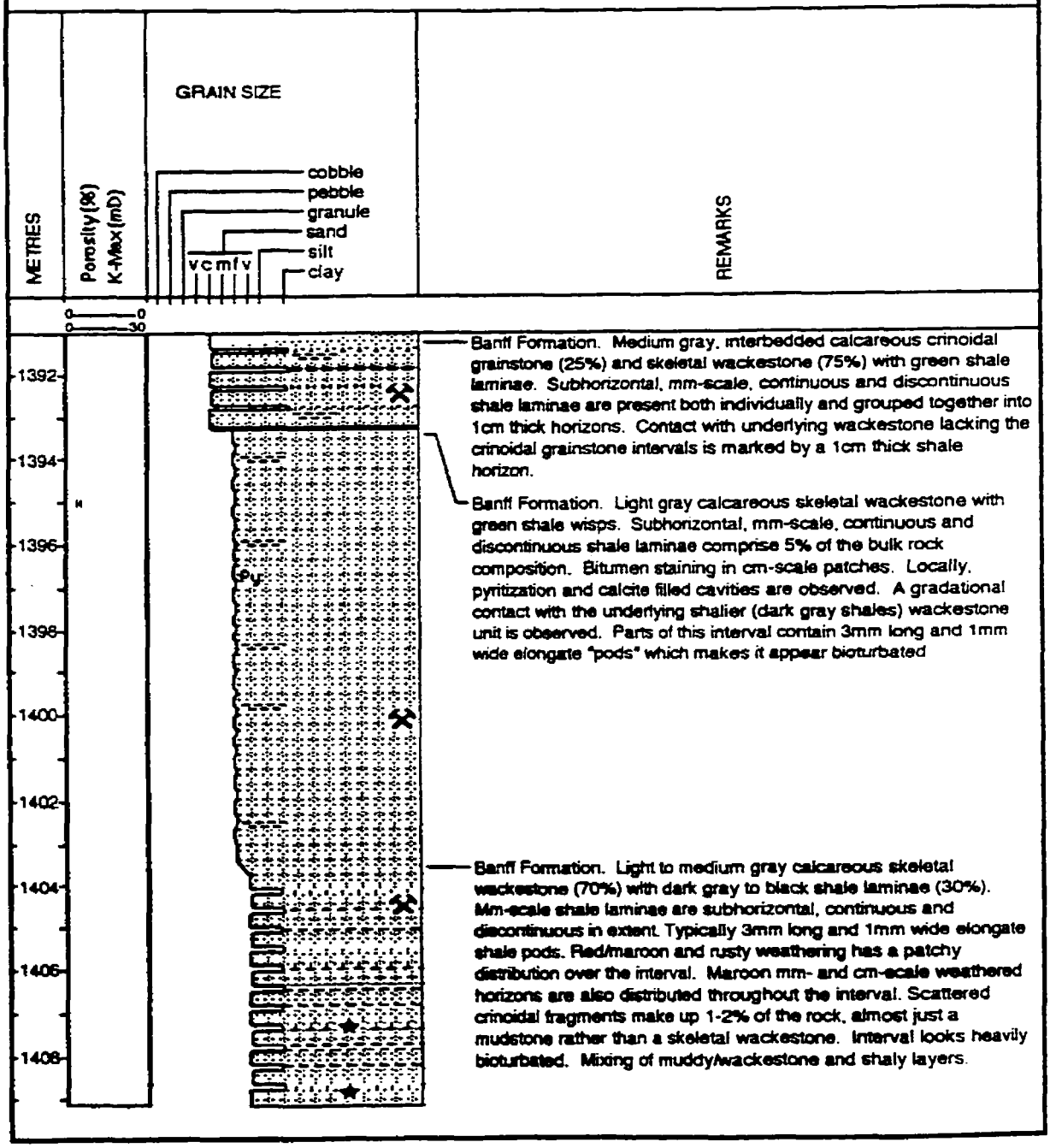
Remarks: This is an 02/ location. Depth scale is 1:130 instead of standard 1:100.

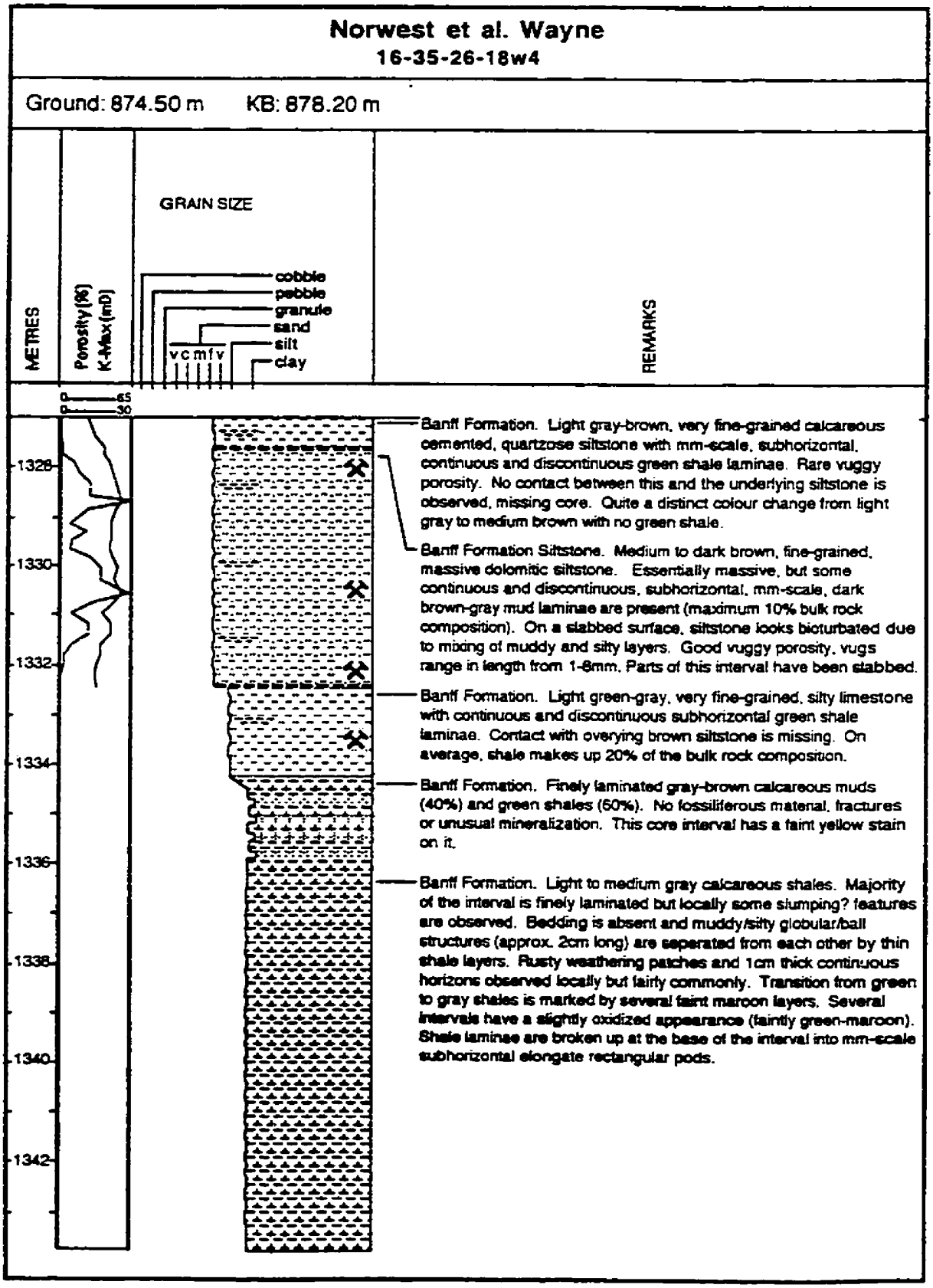


Sceptre et al. Rosedale
06-25-26-18w4

Ground: 942.40 m KB: 946.80 m

Remarks: Only 2 porosity and permeability measurements for the cored interval.
Depth scale is 1:130 instead of standard 1:100.



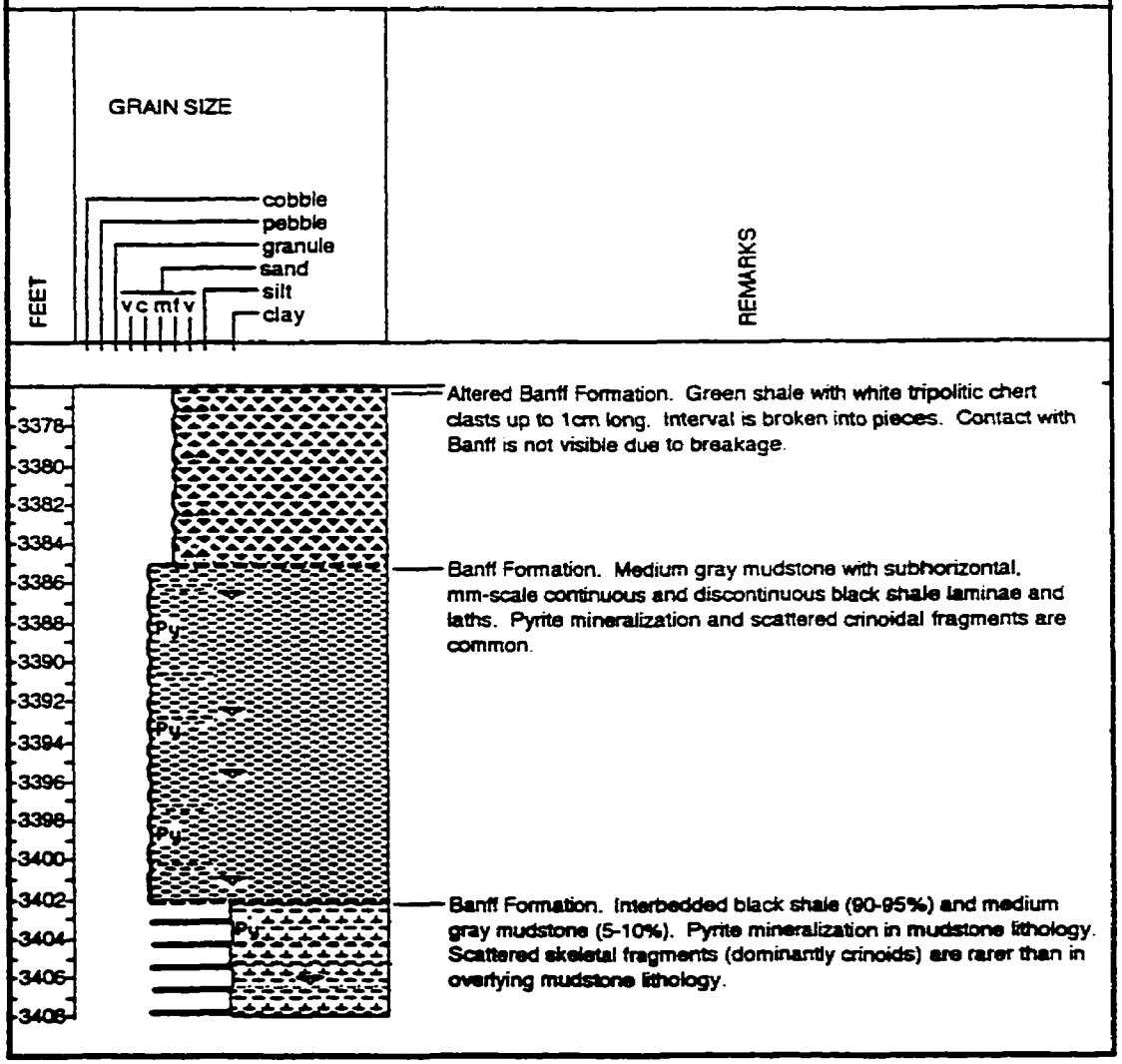

Norwest et al. Wayne
16-35-26-18w4
Ground: 874.50 m
KB: 878.20 m
METRES
Porosity (%)
K-Max (mD)
GRAIN SIZE
cobble
pebble
granule
sand
silt
clay
vc m f v
REMARKS
1328
1330
1332
1334
1336
1338
1340
1342
Banff Formation. Light gray-brown, very fine-grained calcareous cemented, quartzose siltstone with mm-scale, subhorizontal, continuous and discontinuous green shale laminae. Rare vuggy porosity. No contact between this and the underlying siltstone is observed, missing core. Quite a distinct colour change from light gray to medium brown with no green shale.
Banff Formation Siltstone. Medium to dark brown, fine-grained, massive dolomitic siltstone. Essentially massive, but some continuous and discontinuous, subhorizontal, mm-scale, dark brown-gray mud laminae are present (maximum 10% bulk rock composition). On a slabbed surface, siltstone looks bioturbated due to mixing of muddy and silty layers. Good vuggy porosity, vugs range in length from 1-6mm. Parts of this interval have been slabbed.
Banff Formation. Light green-gray, very fine-grained, silty limestone with continuous and discontinuous subhorizontal green shale laminae. Contact with overying brown siltstone is missing. On average, shale makes up 20% of the bulk rock composition.
Banff Formation. Finely laminated gray-brown calcareous muds (40%) and green shales (60%). No fossiliferous material, fractures or unusual mineralization. This core interval has a faint yellow stain on it.
Banff Formation. Light to medium gray calcareous shales. Majority of the interval is finely laminated but locally some slumping? features are observed. Bedding is absent and muddy/silty globular/ball structures (approx. 2cm long) are seperated from each other by thin shale layers. Rusty weathering patches and 1cm thick continuous horizons observed locally but fairly commonly. Transition from green to gray shales is marked by several faint maroon layers. Several intervals have a slightly oxidized appearance (faintly green-maroon). Shale laminae are broken up at the base of the interval into mm-scale subhorizontal elongate rectangular pods.

Anglo Heathdale No. 1

14-05-27-08w4

Ground: 0.00 ft KB: 2646.00 ft

Remarks: 1 inch diameter core. No core analysis. Logged 3 boxes.
Ground is blank on ticket.



Star Cessford

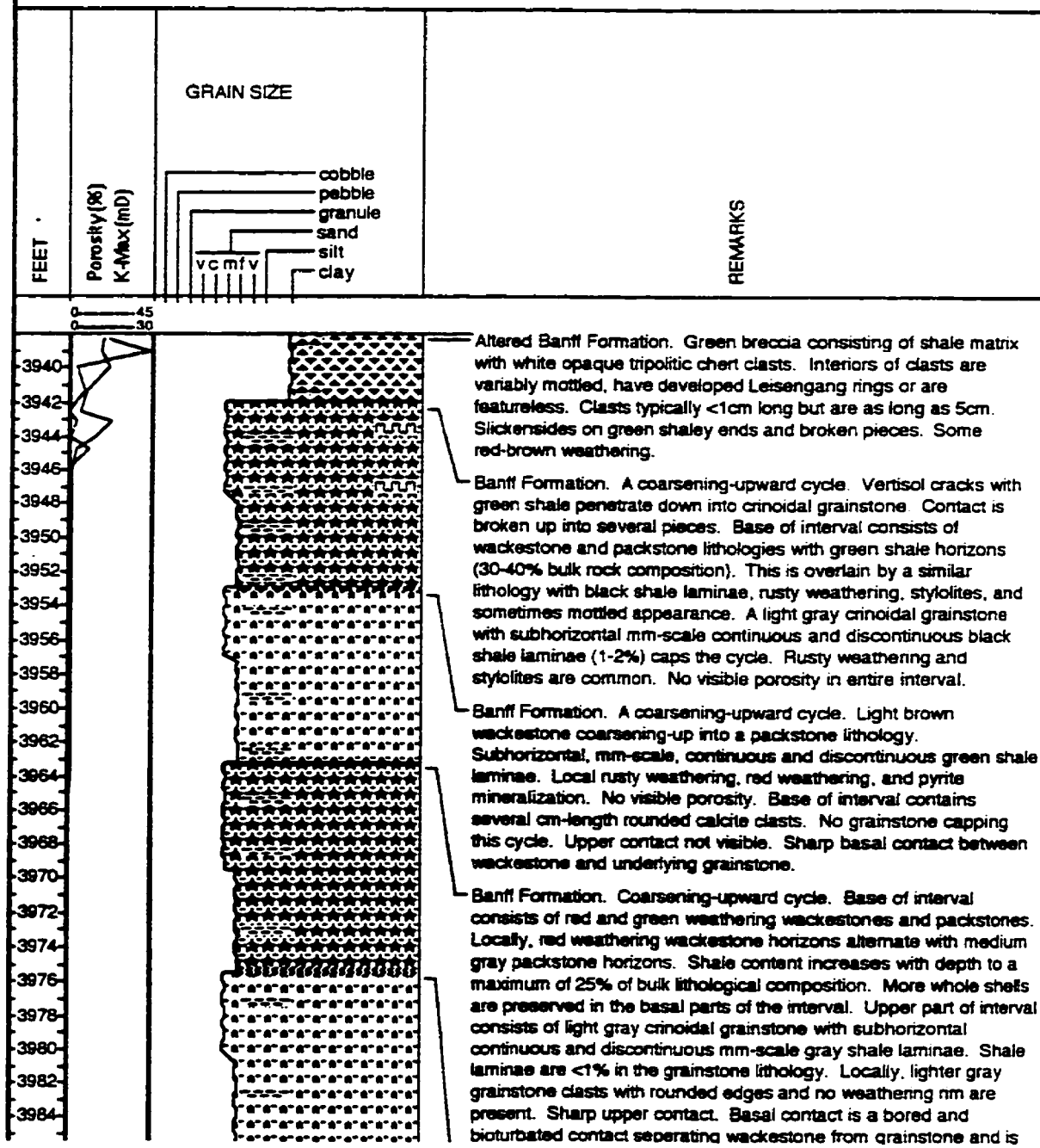
06-18-27-15w4

Date logged: September 11, 1996

Logged by: AGG

Ground: 2818.00 ft KB: 0.00 ft

Remarks: KB is not available. Series of coarsening-upward cycles.

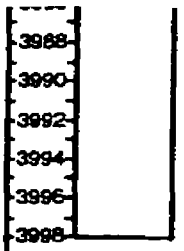


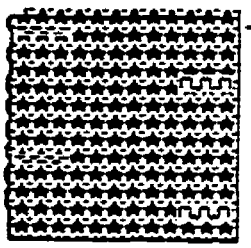
Altered Banff Formation. Green breccia consisting of shale matrix with white opaque tripolitic chert clasts. Interiors of clasts are variably mottled, have developed Leisengang rings or are featureless. Clasts typically <1cm long but are as long as 5cm. Slickensides on green shaley ends and broken pieces. Some red-brown weathering.

Banff Formation. A coarsening-upward cycle. Vertisol cracks with green shale penetrate down into crinoidal grainstone. Contact is broken up into several pieces. Base of interval consists of wackestone and packstone lithologies with green shale horizons (30-40% bulk rock composition). This is overlain by a similar lithology with black shale laminae, rusty weathering, stylolites, and sometimes mottled appearance. A light gray crinoidal grainstone with subhorizontal mm-scale continuous and discontinuous black shale laminae (1-2%) caps the cycle. Rusty weathering and stylolites are common. No visible porosity in entire interval.

Banff Formation. A coarsening-upward cycle. Light brown wackestone coarsening-up into a packstone lithology. Subhorizontal, mm-scale, continuous and discontinuous green shale laminae. Local rusty weathering, red weathering, and pyrite mineralization. No visible porosity. Base of interval contains several cm-length rounded calcite clasts. No grainstone capping this cycle. Upper contact not visible. Sharp basal contact between wackestone and underlying grainstone.

Banff Formation. Coarsening-upward cycle. Base of interval consists of red and green weathering wackestones and packstones. Locally, red weathering wackestone horizons alternate with medium gray packstone horizons. Shale content increases with depth to a maximum of 25% of bulk lithological composition. More whole shells are preserved in the basal parts of the interval. Upper part of interval consists of light gray crinoidal grainstone with subhorizontal continuous and discontinuous mm-scale gray shale laminae. Shale laminae are <1% in the grainstone lithology. Locally, lighter gray grainstone clasts with rounded edges and no weathering rim are present. Sharp upper contact. Basal contact is a bored and bioturbated contact seperating wackestone from grainstone and is





marked by a band of red mud intraclasts.

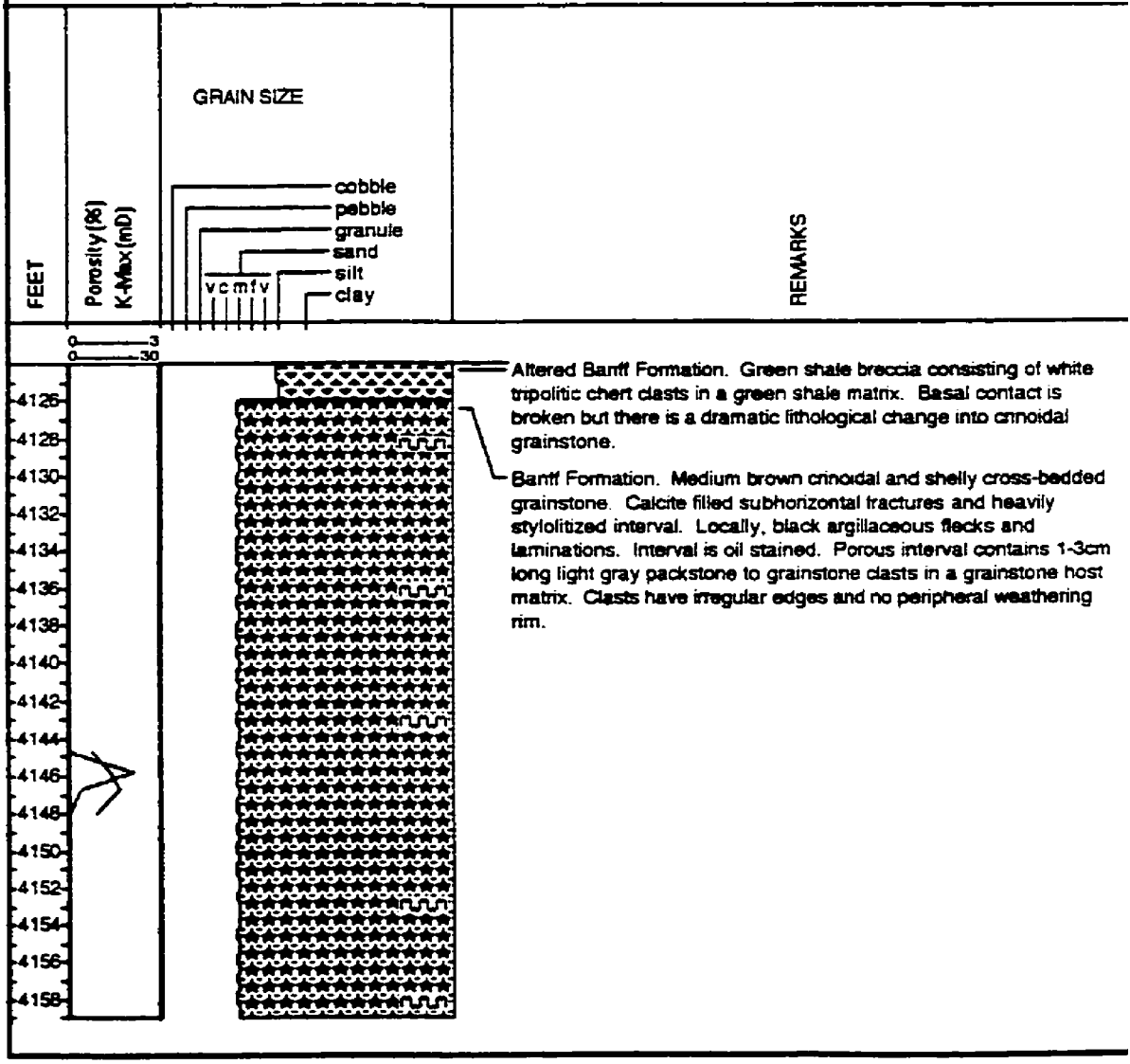
Banff Formation. Coarsening-upward cycle of wackestones, packstones and grainstones. Red and orange oxidation weathering wackestones and packstones with subhorizontal, continuous and discontinuous, mm-scale black shale laminae. Low gamma ray signature corresponds to an approximately 1ft thick grainstone package. Mixing of grainy and muddy lithologies due to bioturbation. Basal few feet of interval are lacking the oxidation weathering. Basal contact is broken; box break from wackestone above to white crinoidal grainstone below.

Banff Formation. White to light gray crinoidal grainstone with subhorizontal, continuous and discontinuous mm-scale green shale laminae. Shale is <1% of the bulk lithological composition. Massive, homogeneous interval with no visible porosity. Stylolites. Grainstone is likely the top of another coarsening-up cycle.

Kewanee C Cessford
11-35-27-16w4

Ground: 2961.00 ft KB: 0.00 ft

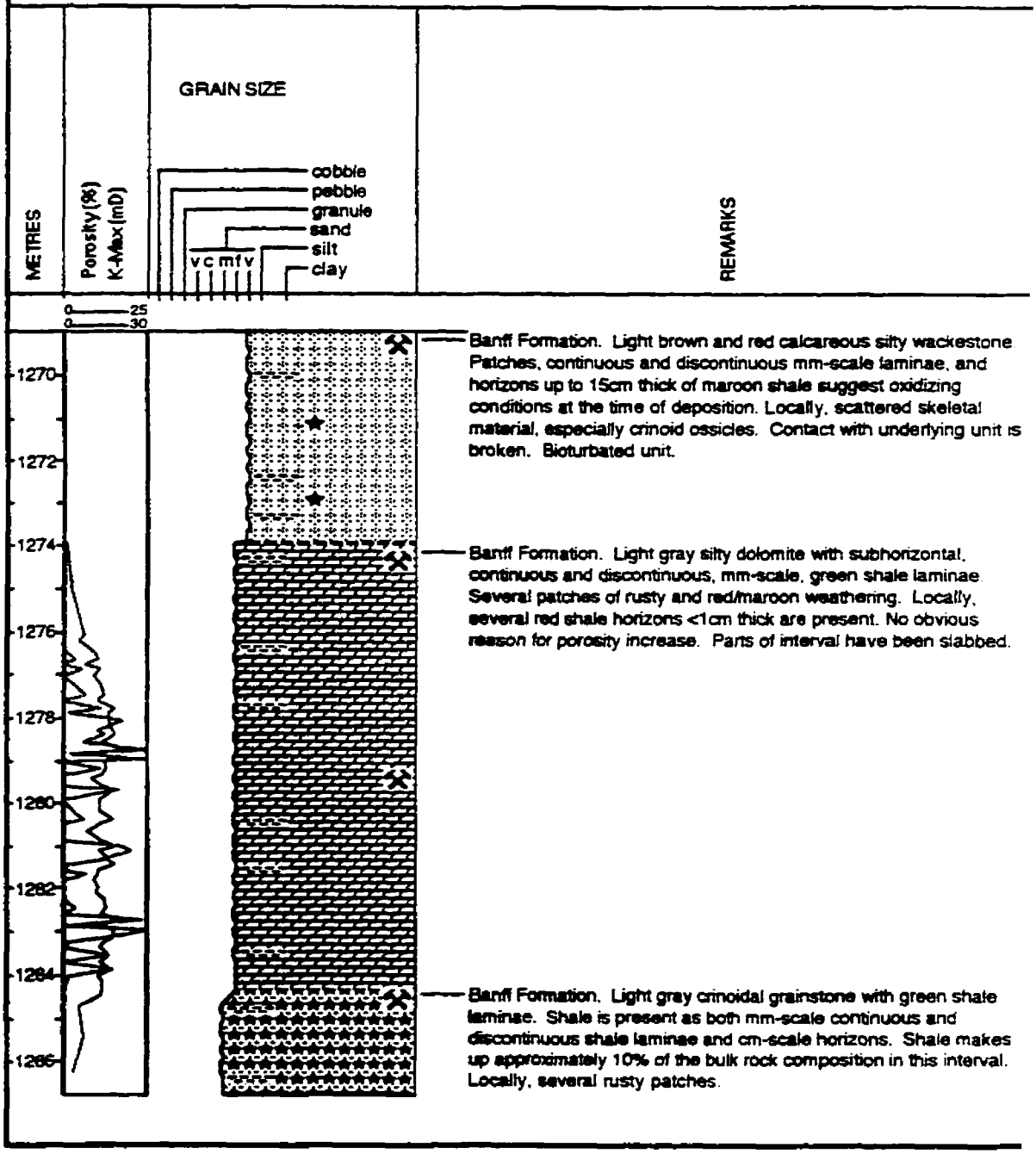
Remarks: KB is not available. Really dirty core, very hard to see features.



Norwest et al. Cessford
16-06-27-17w4

Ground: 826.90 m KB: 831.40 m

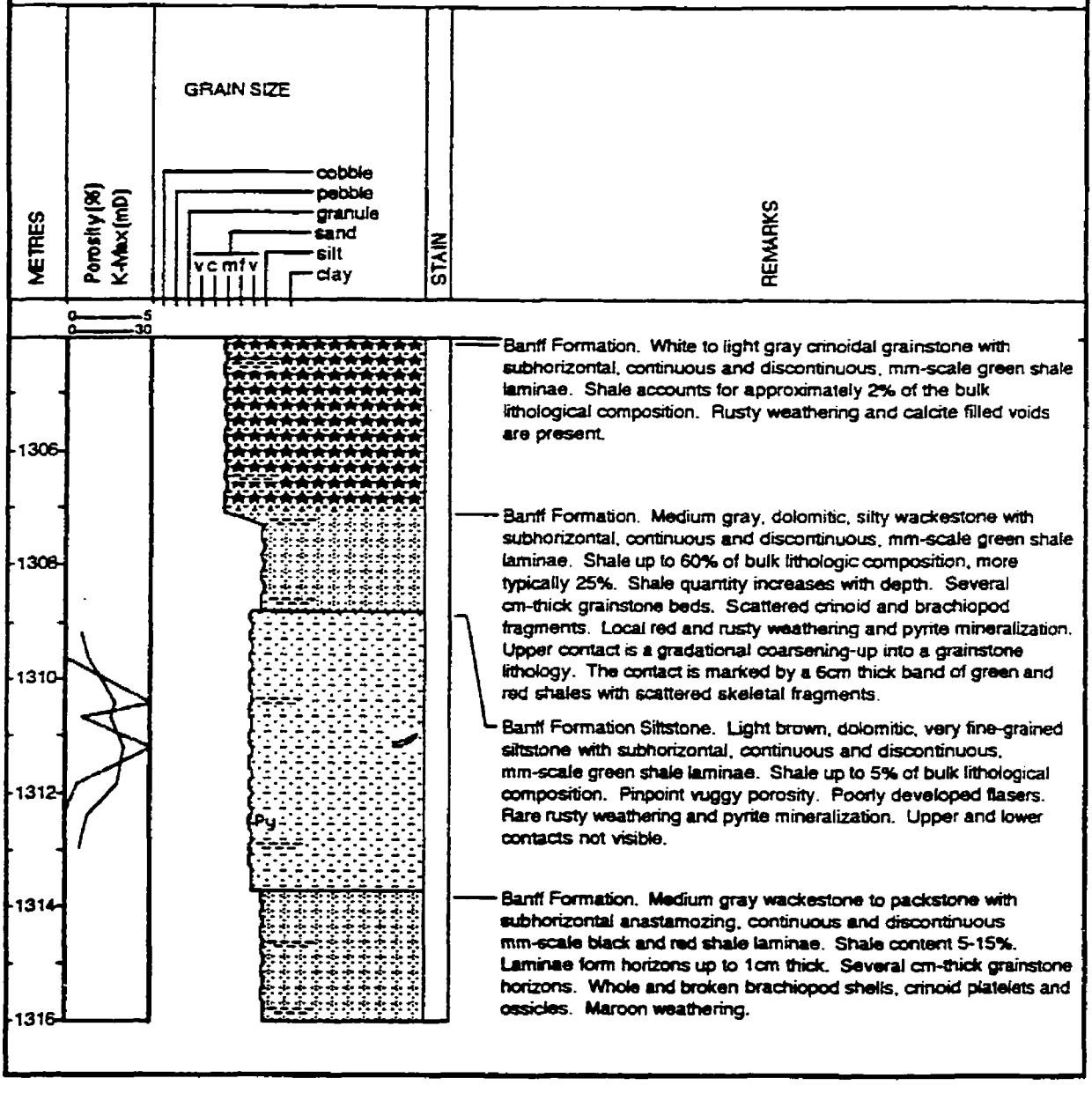
Remarks: Cessford producer. Depth scale is 1:130 instead of standard 1:100.



PCP Wayne
14-16-27-18w4

Ground: 824.00 m KB: 828.30 m

Remarks: Banff siltstone but no Banff Formation production.



Banff Formation. White to light gray crinoidal grainstone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale accounts for approximately 2% of the bulk lithological composition. Rusty weathering and calcite filled voids are present.

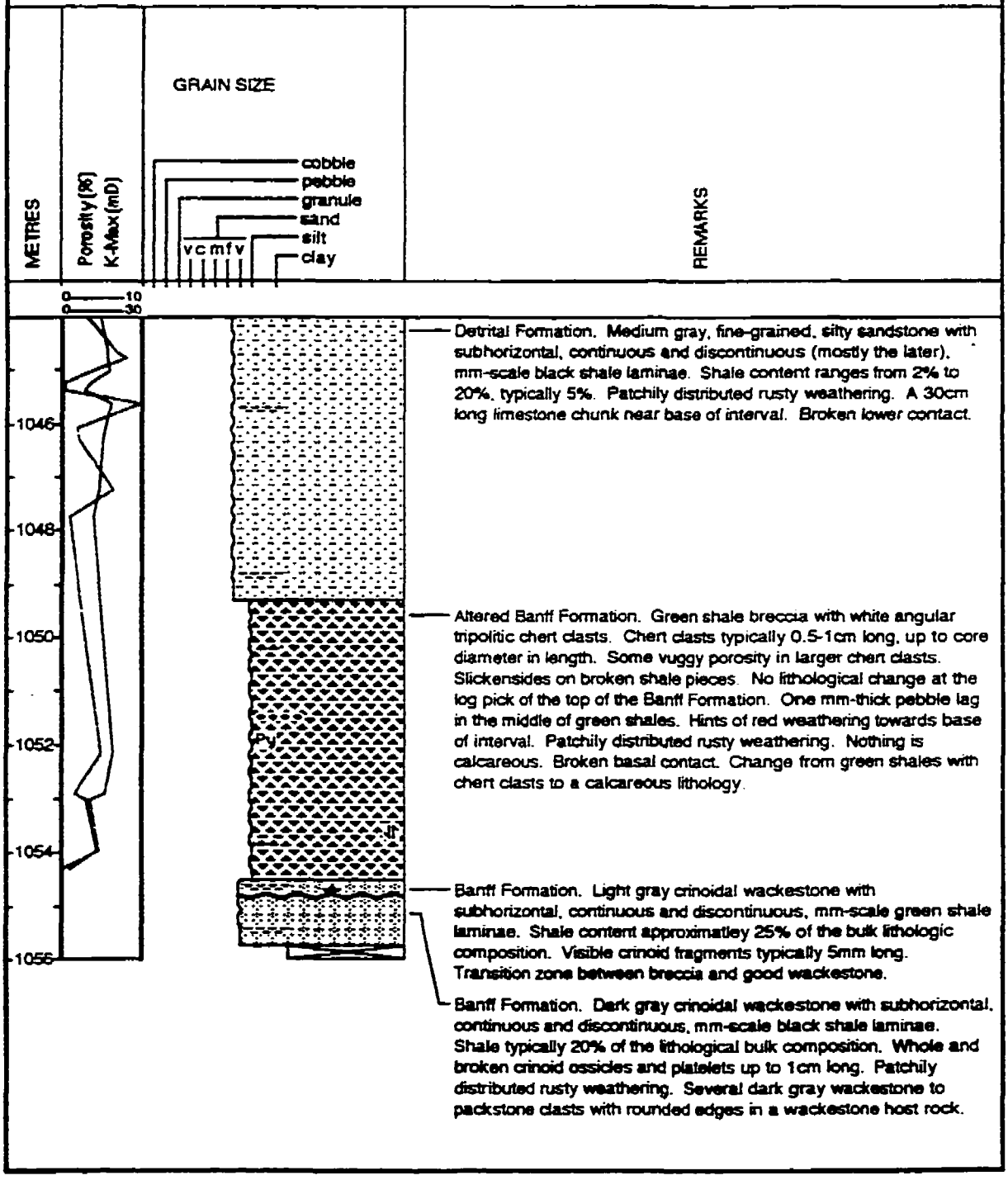
Banff Formation. Medium gray, dolomitic, silty wackestone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale up to 60% of bulk lithologic composition, more typically 25%. Shale quantity increases with depth. Several cm-thick grainstone beds. Scattered crinoid and brachiopod fragments. Local red and rusty weathering and pyrite mineralization. Upper contact is a gradational coarsening-up into a grainstone lithology. The contact is marked by a 6cm thick band of green and red shales with scattered skeletal fragments.

Banff Formation Siltstone. Light brown, dolomitic, very fine-grained siltstone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale up to 5% of bulk lithological composition. Pinpoint vuggy porosity. Poorly developed flasers. Rare rusty weathering and pyrite mineralization. Upper and lower contacts not visible.

Banff Formation. Medium gray wackestone to packstone with subhorizontal anastamozing, continuous and discontinuous mm-scale black and red shale laminae. Shale content 5-15%. Laminae form horizons up to 1cm thick. Several cm-thick grainstone horizons. Whole and broken brachiopod shells, crinoid platelets and ossicles. Maroon weathering.

Provident Merrill Shore
07-31-28-11w4

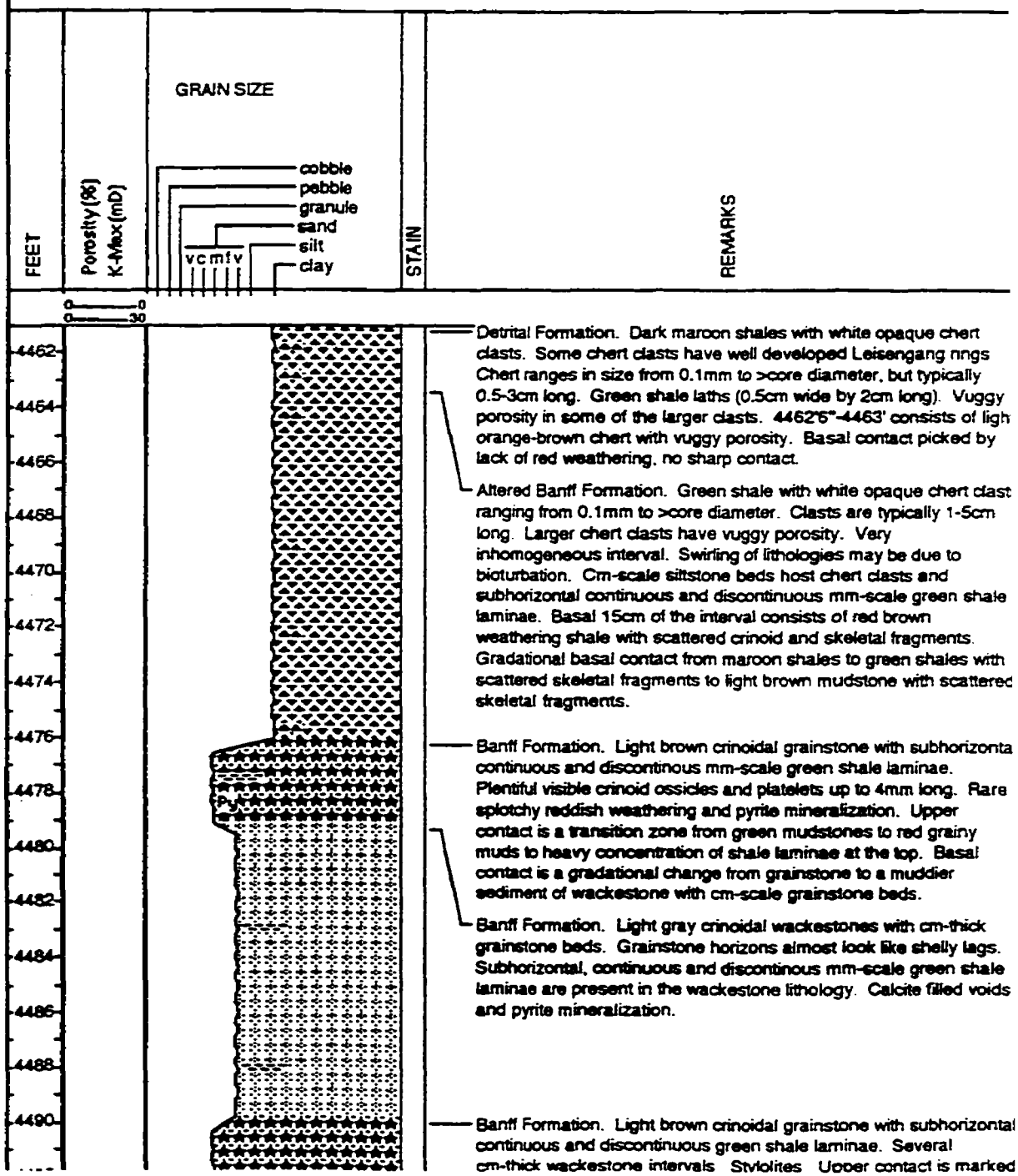
Ground: 765.40 m KB: 769.40 m

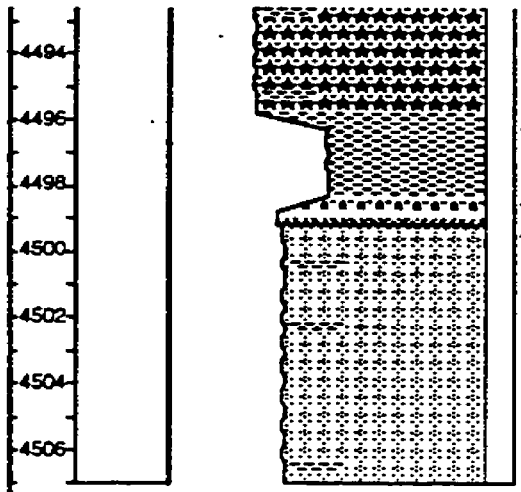


IOE Little Fish
10-32-28-16w4

Ground: 3200.00 ft KB: 3213.00 ft

Remarks: No core analysis for the Banff interval. Most of the core is slabbed. Note that scale of logged core below is 1:60 instead of 1:100 like most of the other logged cores.





contact is also transitional from a red weathering grainstone to red weathering mudstone.

Banff Formation. Maroon weathering mudstones with scattered skeletal fragments (up to 5%).

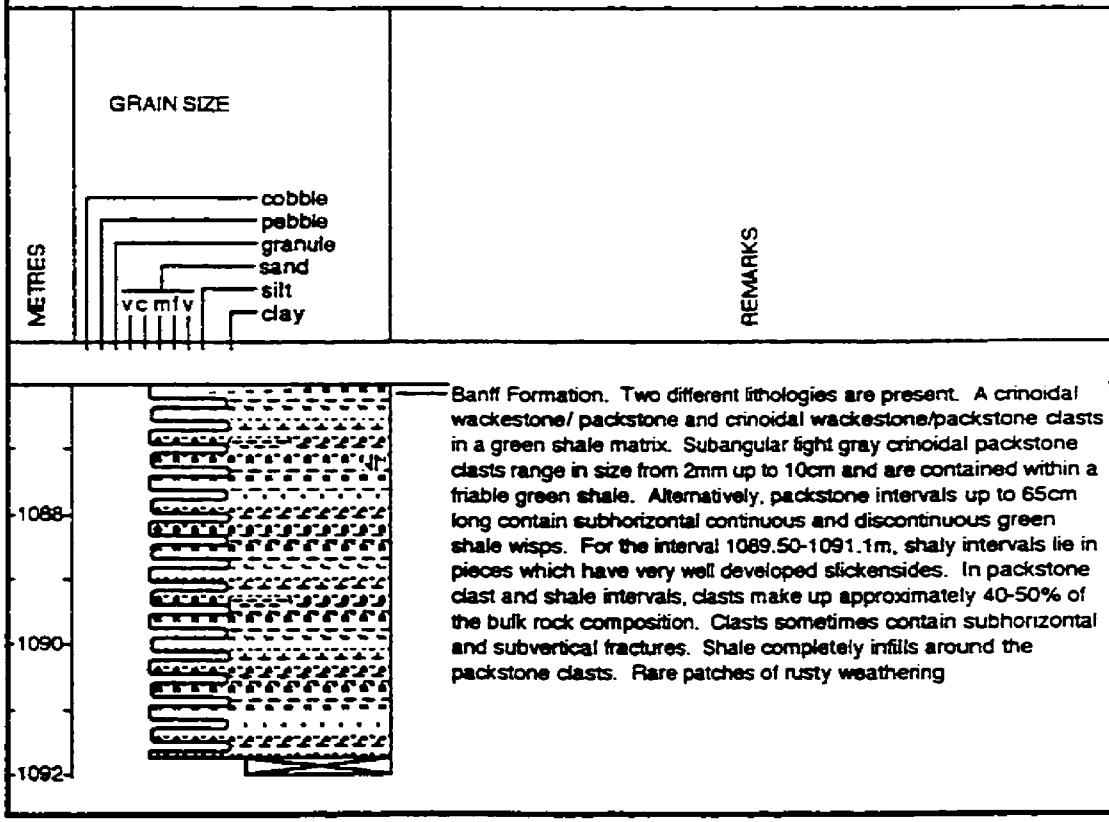
Banff Formation. Medium gray crinoidal packstone scours down into less competent muds. Red and rusty weathering locally.

Banff Formation. Medium gray crinoidal wackestone with subhorizontal, continuous and discontinuous, mm-scale black shale laminae and laths. Shale ranges from 2-20% of the bulk lithologic composition. Calcite filled subvertical fractures and voids. Rusty weathering throughout interval. Cm-thick limestone horizons have sharp upper and lower contacts with wackestone. Skeletal fragments are scattered through the wackestones as well as concentrated into cm-thick horizons. Core often has a mottled appearance. Disrupted shale laminae.

Quesada et al. Stanmore
06-15-29-10w4

Ground: 766.50 m KB: 770.10 m

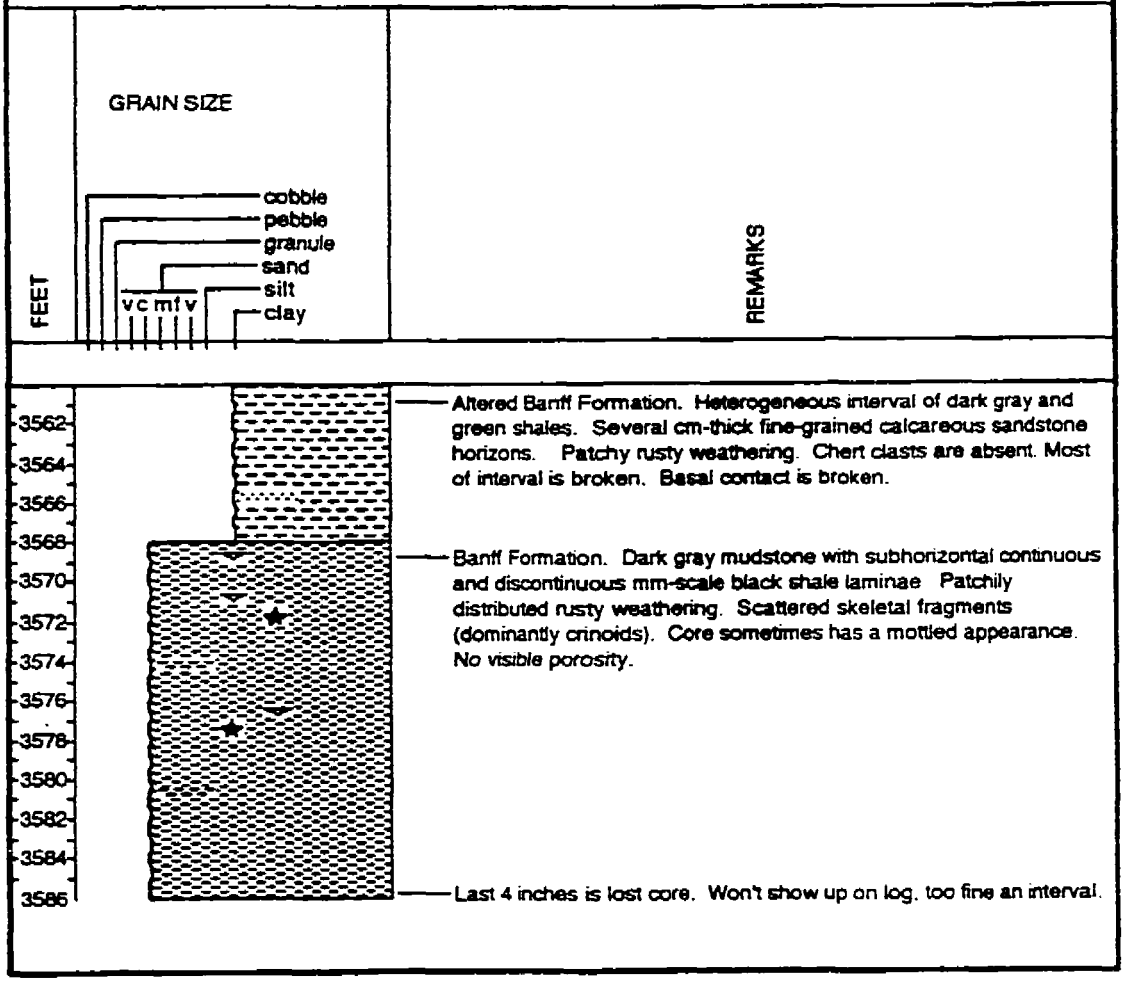
Remarks: This is an 02/ location.



Banff Formation. Two different lithologies are present. A crinoidal wackestone/ packstone and crinoidal wackestone/packstone clasts in a green shale matrix. Subangular light gray crinoidal packstone clasts range in size from 2mm up to 10cm and are contained within a friable green shale. Alternatively, packstone intervals up to 65cm long contain subhorizontal continuous and discontinuous green shale wisps. For the interval 1089.50-1091.1m, shaly intervals lie in pieces which have very well developed slickensides. In packstone clast and shale intervals, clasts make up approximately 40-50% of the bulk rock composition. Clasts sometimes contain subhorizontal and subvertical fractures. Shale completely infills around the packstone clasts. Rare patches of rusty weathering

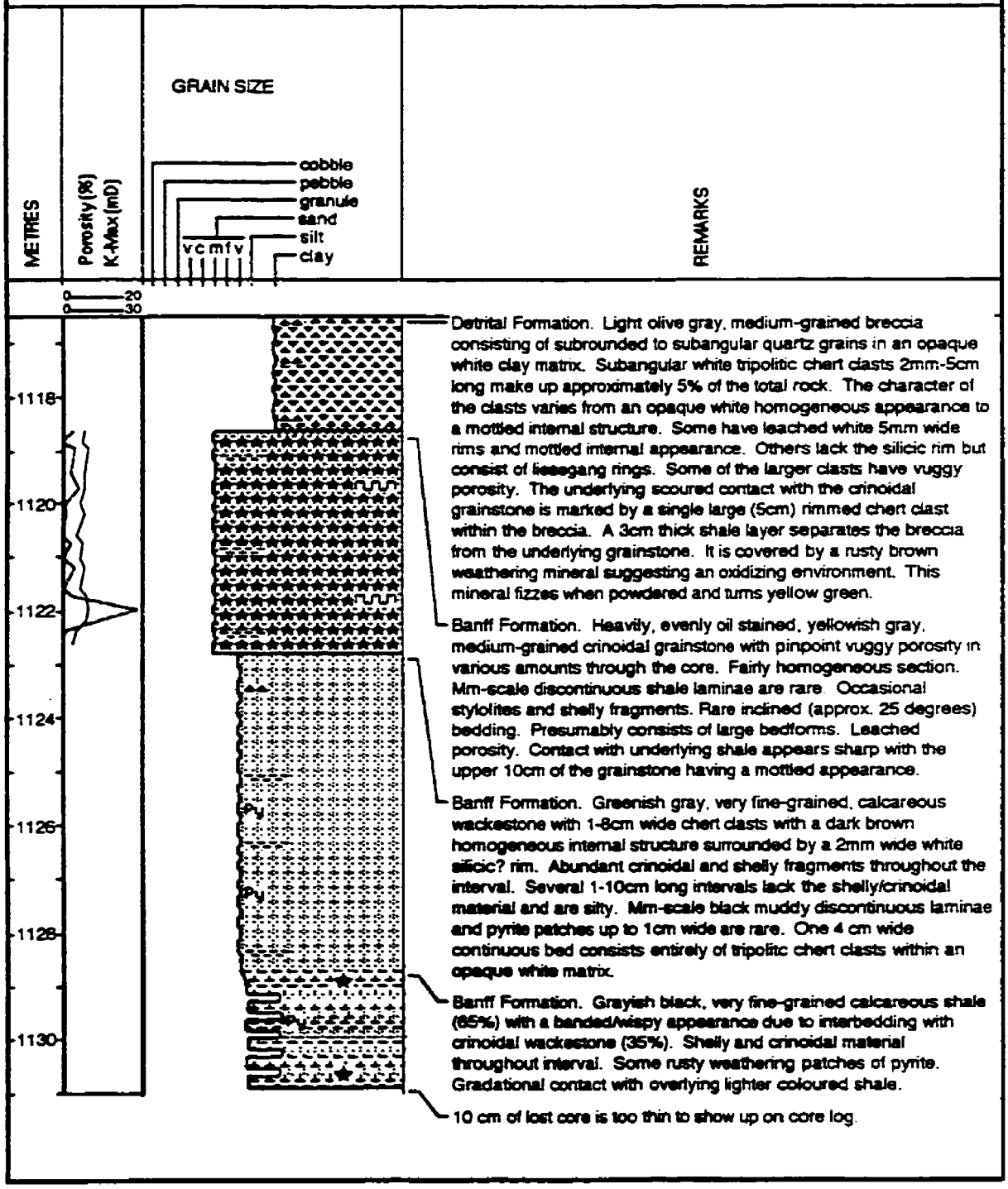
Canpet C.P.O.G. Sheerness
07-33-29-12w4

Ground: 2599.00 ft KB: 2611.02 ft



Archer Wildunn Creek
06-32-029-14w4

Ground: 792.70 m KB: 796.90 m



Detrital Formation. Light olive gray, medium-grained breccia consisting of subrounded to subangular quartz grains in an opaque white clay matrix. Subangular white tripolitic chert clasts 2mm-5cm long make up approximately 5% of the total rock. The character of the clasts varies from an opaque white homogeneous appearance to a mottled internal structure. Some have leached white 5mm wide rims and mottled internal appearance. Others lack the silicic rim but consist of liesegang rings. Some of the larger clasts have vuggy porosity. The underlying scoured contact with the crinoidal grainstone is marked by a single large (5cm) rimmed chert clast within the breccia. A 3cm thick shale layer separates the breccia from the underlying grainstone. It is covered by a rusty brown weathering mineral suggesting an oxidizing environment. This mineral fizzes when powdered and turns yellow green.

Banff Formation. Heavily, evenly oil stained, yellowish gray, medium-grained crinoidal grainstone with pinpoint vuggy porosity in various amounts through the core. Fairly homogeneous section. Mm-scale discontinuous shale laminae are rare. Occasional stylolites and shelly fragments. Rare inclined (approx. 25 degrees) bedding. Presumably consists of large bedforms. Leached porosity. Contact with underlying shale appears sharp with the upper 10cm of the grainstone having a mottled appearance.

Banff Formation. Greenish gray, very fine-grained, calcareous wackestone with 1-8cm wide chert clasts with a dark brown homogeneous internal structure surrounded by a 2mm wide white silicic? rim. Abundant crinoidal and shelly fragments throughout the interval. Several 1-10cm long intervals lack the shelly/crinoidal material and are silty. Mm-scale black muddy discontinuous laminae and pyrite patches up to 1cm wide are rare. One 4 cm wide continuous bed consists entirely of tripolitic chert clasts within an opaque white matrix.

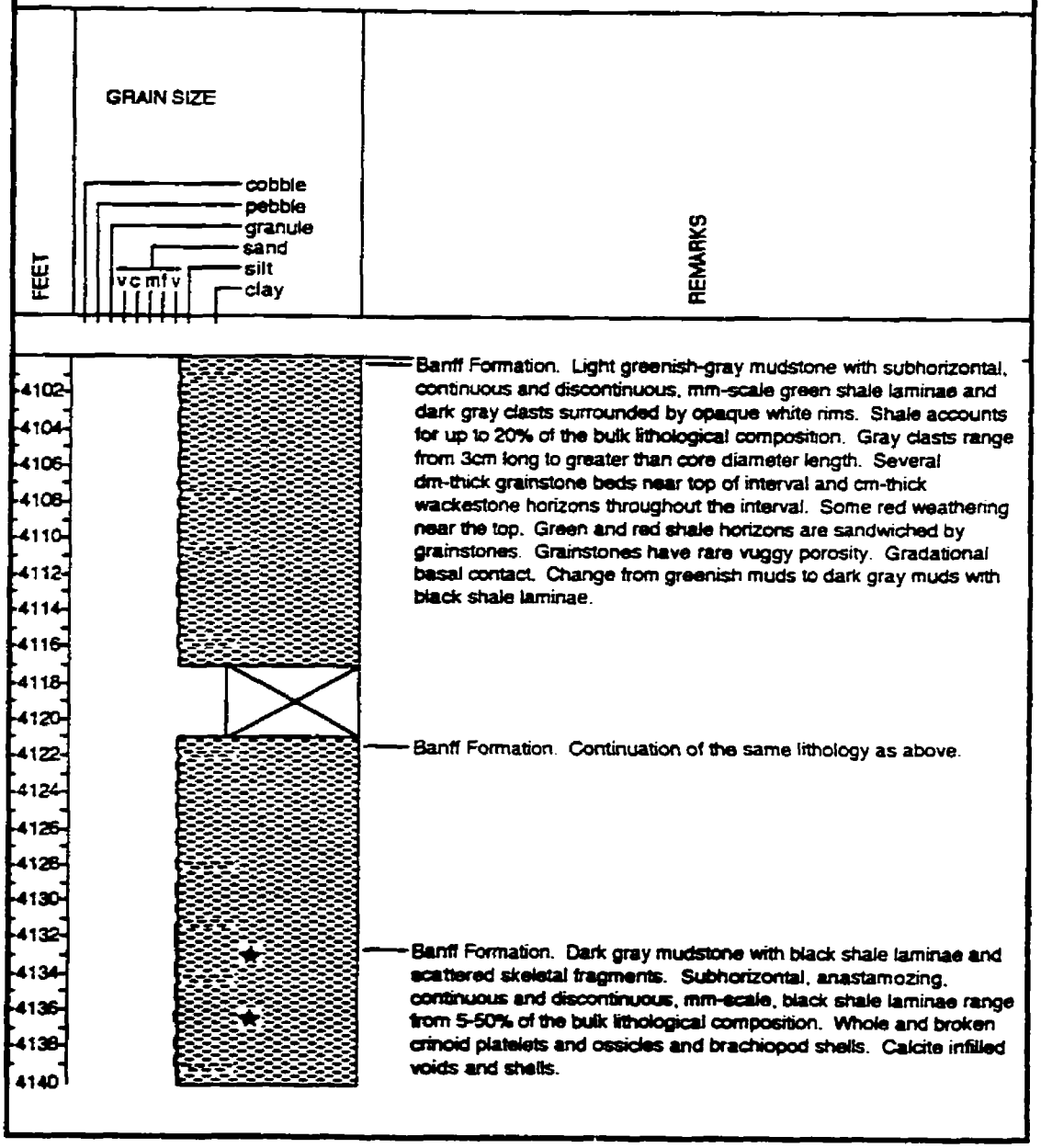
Banff Formation. Grayish black, very fine-grained calcareous shale (65%) with a banded/wispy appearance due to interbedding with crinoidal wackestone (35%). Shelly and crinoidal material throughout interval. Some rusty weathering patches of pyrite. Gradational contact with overlying lighter coloured shale.

10 cm of lost core is too thin to show up on core log.

Superior Handhills
14-34-29-15w4

Ground: 2982.00 ft KB: 2992.27 ft

Remarks: No core analysis. Full size core. Entire core is slabbed. One core box is missing (3) and alot of core pieces seem out of place.

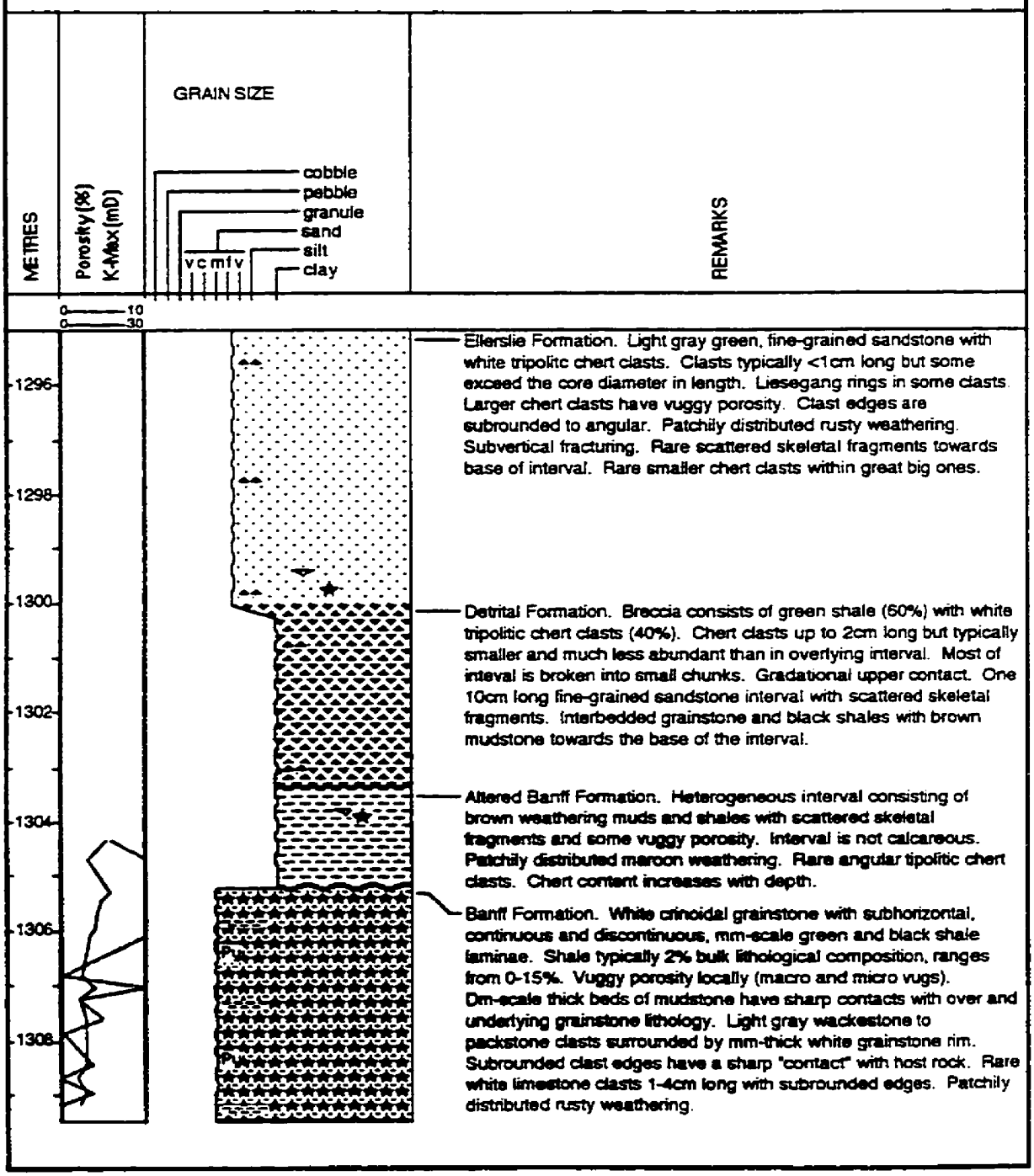


Tarragon Cessford9

06-02-29-16w4

Ground: 940.70 m KB: 943.10 m

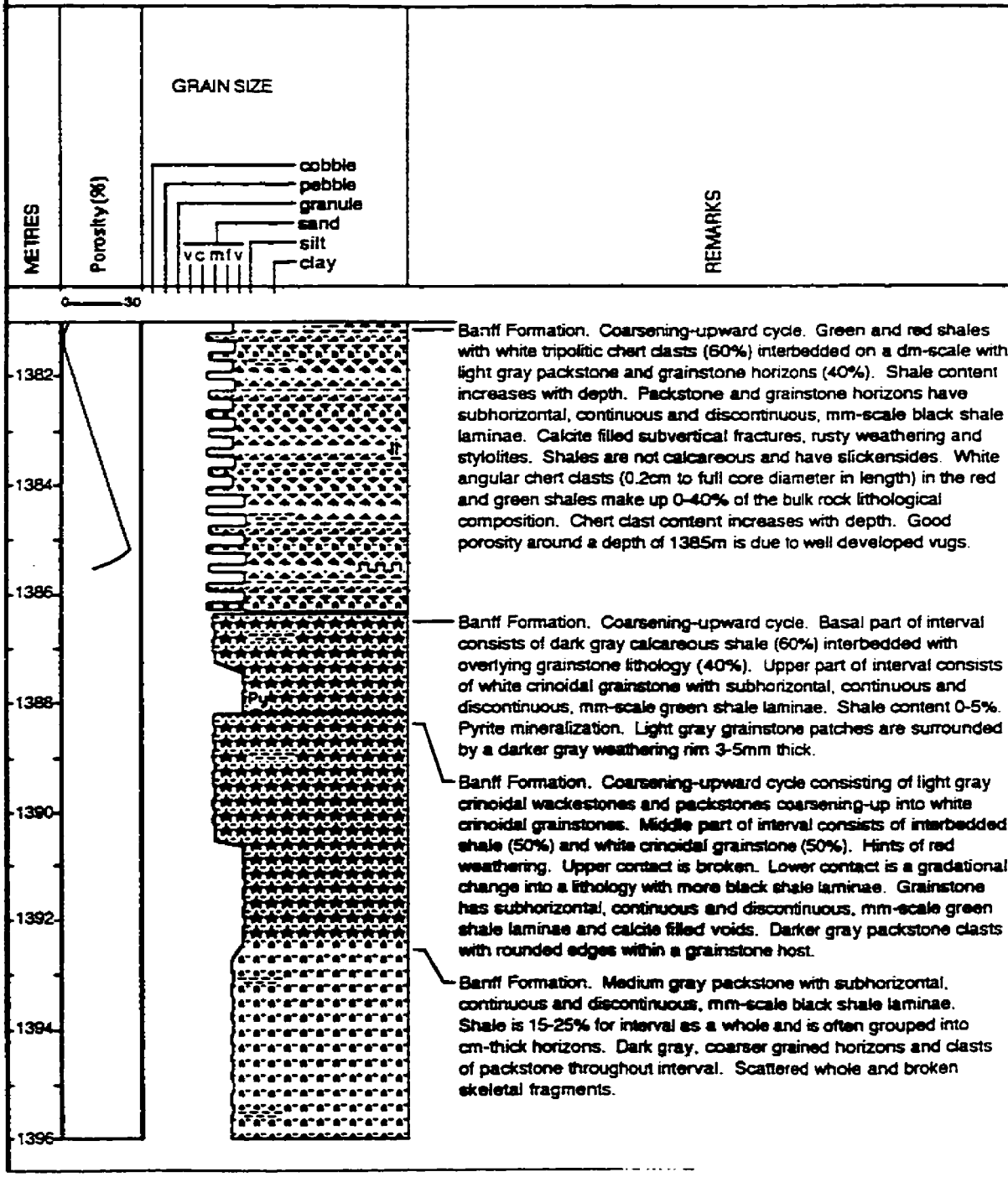
Remarks: Banff Formation producer from porous grainstones.



Soquip et al. Coyote
14-32-29-16w4

Ground: 988.40 m KB: 992.00 m

Remarks: Series of coarsening-upward cycles.



Banff Formation. Coarsening-upward cycle. Green and red shales with white tripolitic chert clasts (60%) interbedded on a dm-scale with light gray packstone and grainstone horizons (40%). Shale content increases with depth. Packstone and grainstone horizons have subhorizontal, continuous and discontinuous, mm-scale black shale laminae. Calcite filled subvertical fractures, rusty weathering and stylolites. Shales are not calcareous and have slickensides. White angular chert clasts (0.2cm to full core diameter in length) in the red and green shales make up 0-40% of the bulk rock lithological composition. Chert clast content increases with depth. Good porosity around a depth of 1385m is due to well developed vugs.

Banff Formation. Coarsening-upward cycle. Basal part of interval consists of dark gray calcareous shale (60%) interbedded with overlying grainstone lithology (40%). Upper part of interval consists of white crinoidal grainstone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale content 0-5%. Pyrite mineralization. Light gray grainstone patches are surrounded by a darker gray weathering rim 3-5mm thick.

Banff Formation. Coarsening-upward cycle consisting of light gray crinoidal wackestones and packstones coarsening-up into white crinoidal grainstones. Middle part of interval consists of interbedded shale (50%) and white crinoidal grainstone (50%). Hints of red weathering. Upper contact is broken. Lower contact is a gradational change into a lithology with more black shale laminae. Grainstone has subhorizontal, continuous and discontinuous, mm-scale green shale laminae and calcite filled voids. Darker gray packstone clasts with rounded edges within a grainstone host.

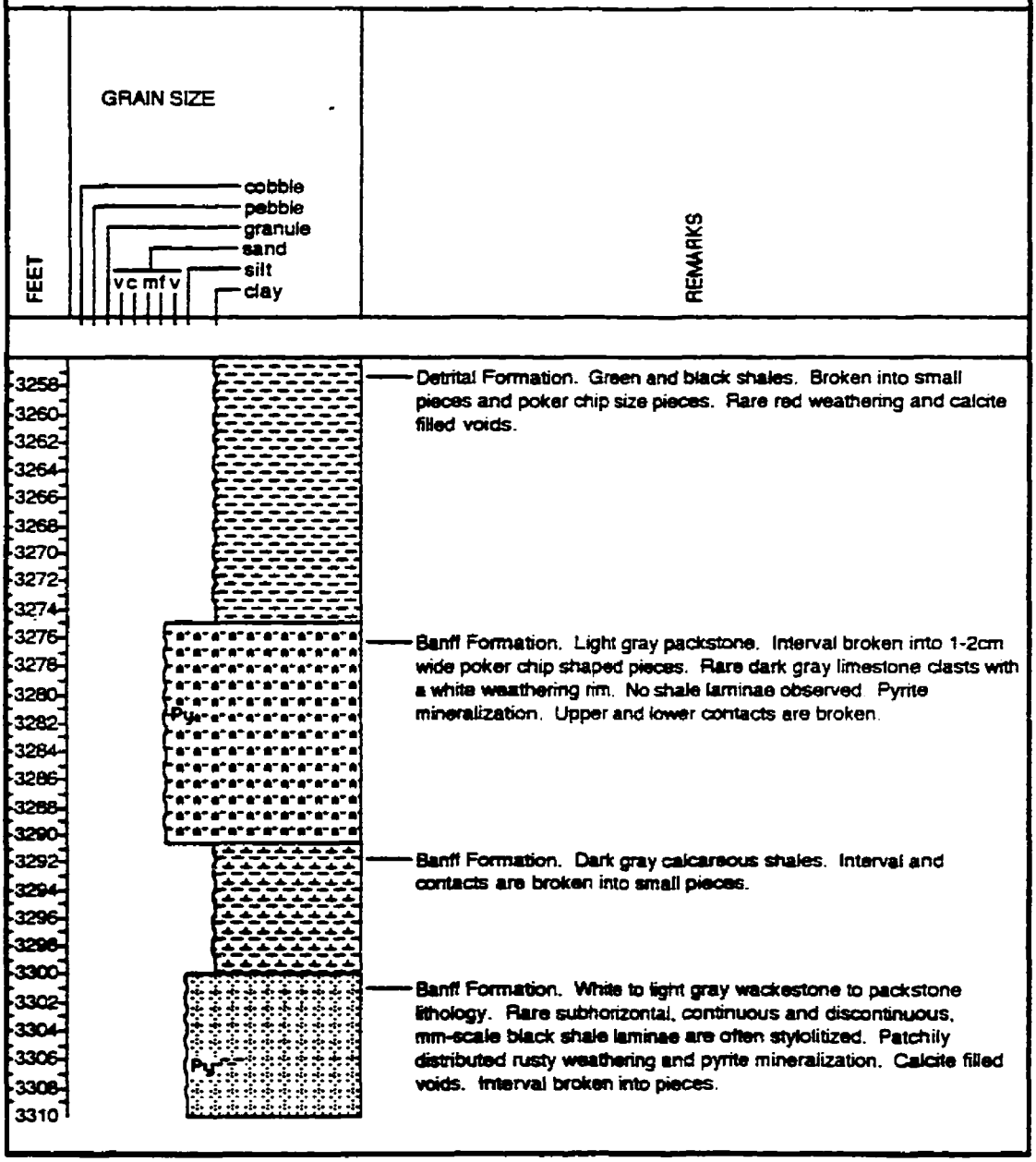
Banff Formation. Medium gray packstone with subhorizontal, continuous and discontinuous, mm-scale black shale laminae. Shale is 15-25% for interval as a whole and is often grouped into cm-thick horizons. Dark gray, coarser grained horizons and clasts of packstone throughout interval. Scattered whole and broken skeletal fragments.

Imperial Youngstown #1 Well

05-03-30-9w4

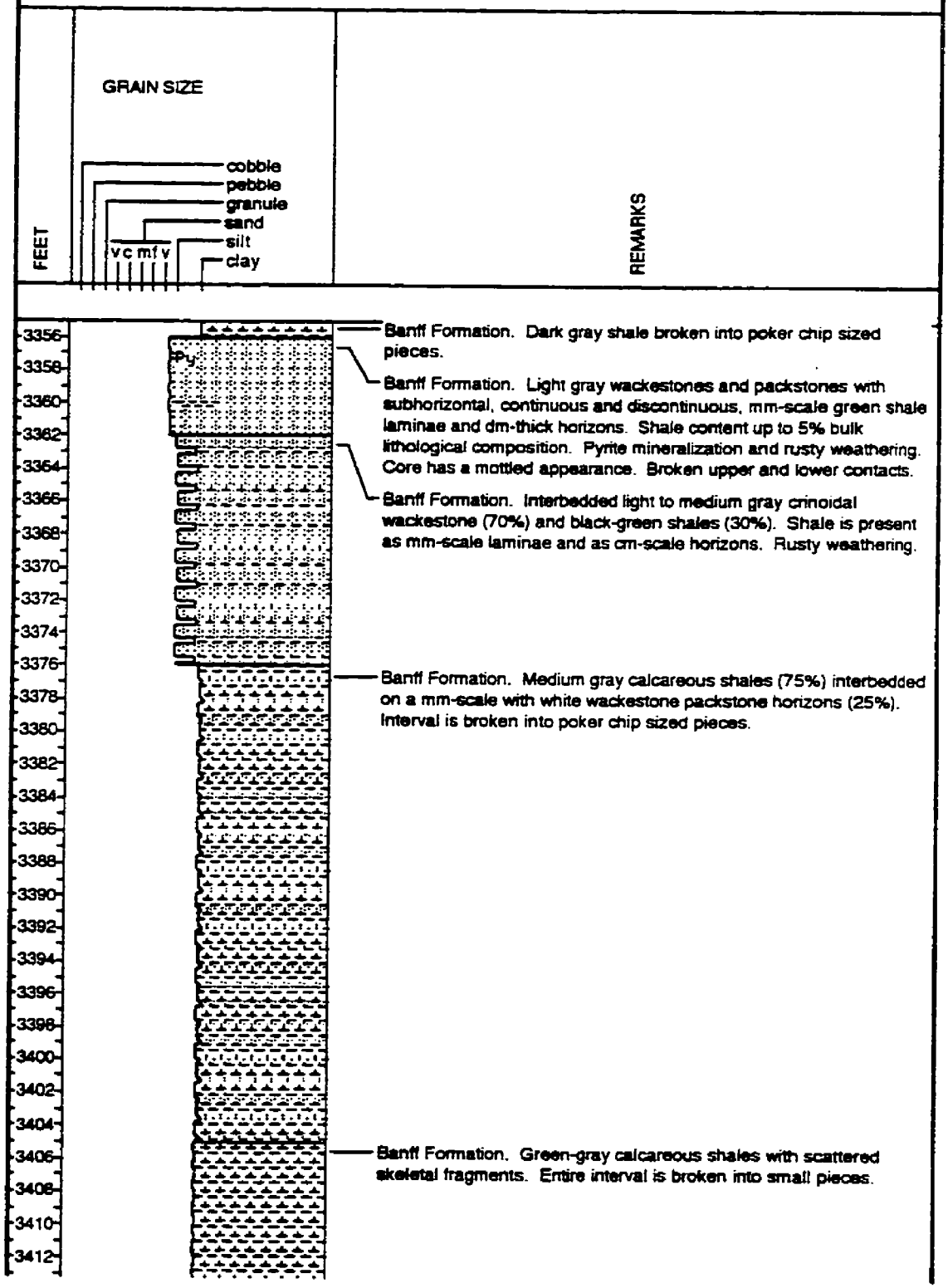
Ground: 2529.00 ft KB: 2535.00 ft

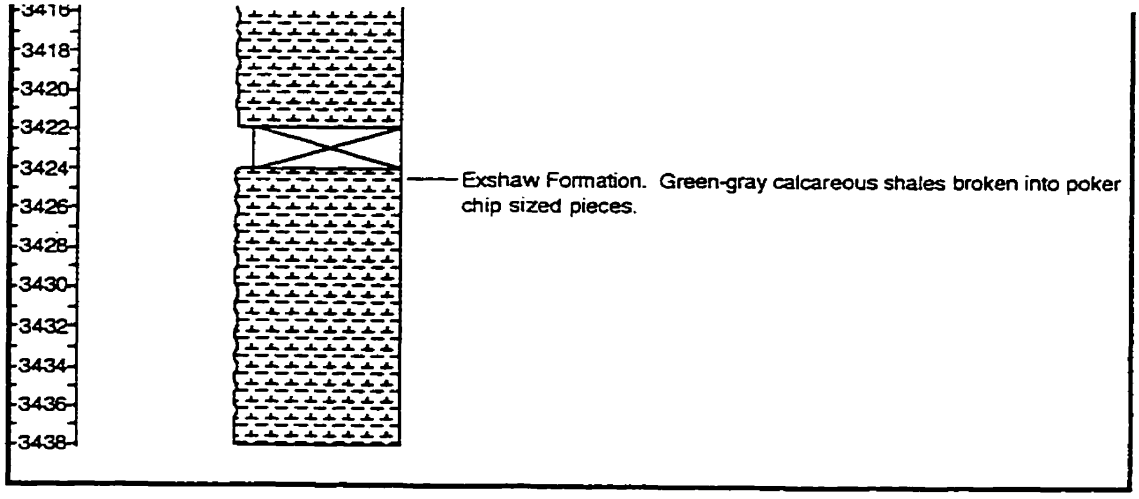
Remarks: 1 inch core. No core analysis (1947 well). 2 cores (3256-3310 ft, 3355-3438ft). Scale is 1:130 instead of standard 1:100.



Imperial Youngstown #1 Well
05-03-30-09w4

Ground: 2529.00 ft KB: 2535.00 ft




3416
3418
3420
3422
3424
3426
3428
3430
3432
3434
3436
3438
Exshaw Formation. Green-gray calcareous shales broken into poker chip sized pieces.

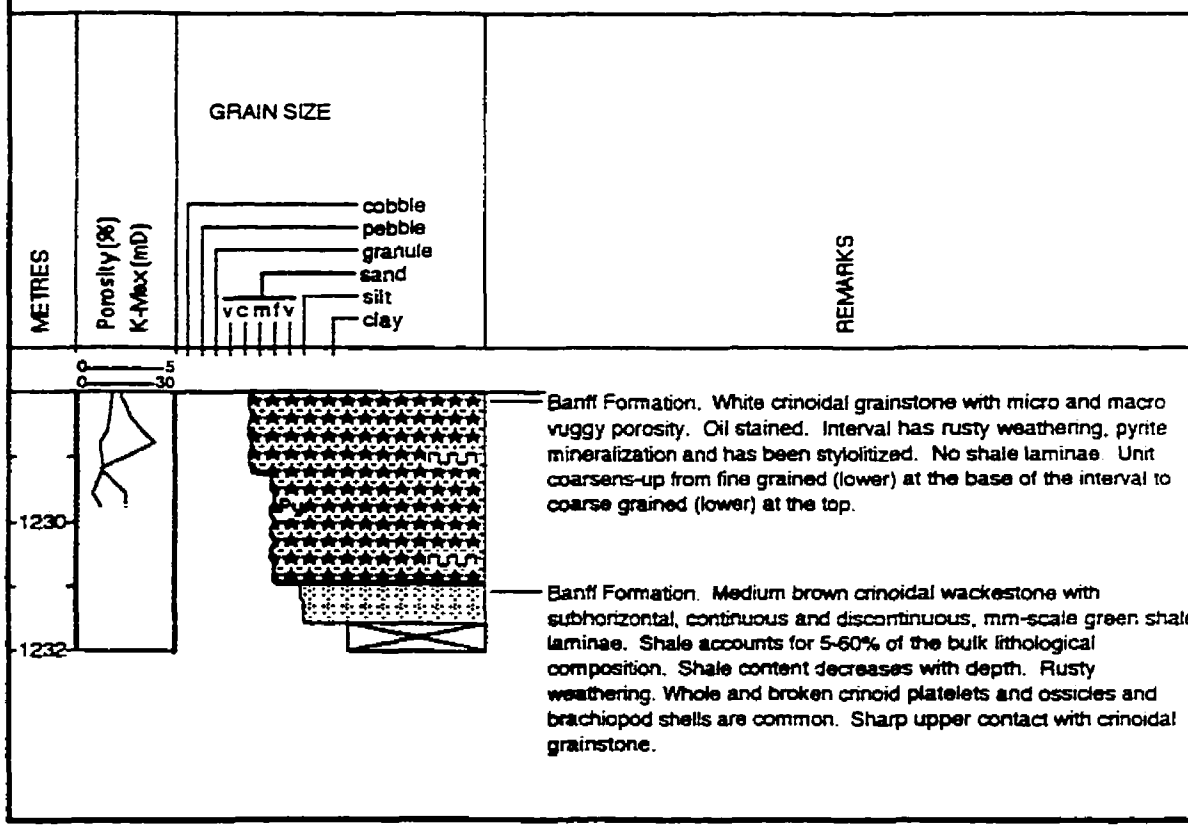
Poco Watts
06-31-30-15w4

Date logged: September 12, 1996

Logged by: AGG

Ground: 874.30 m KB: 878.70 m

Remarks: Banff gas producer. Core analysis indicates full recovery but core boxes indicate loss of 0.45m. Have assumed lost core is from bottom.

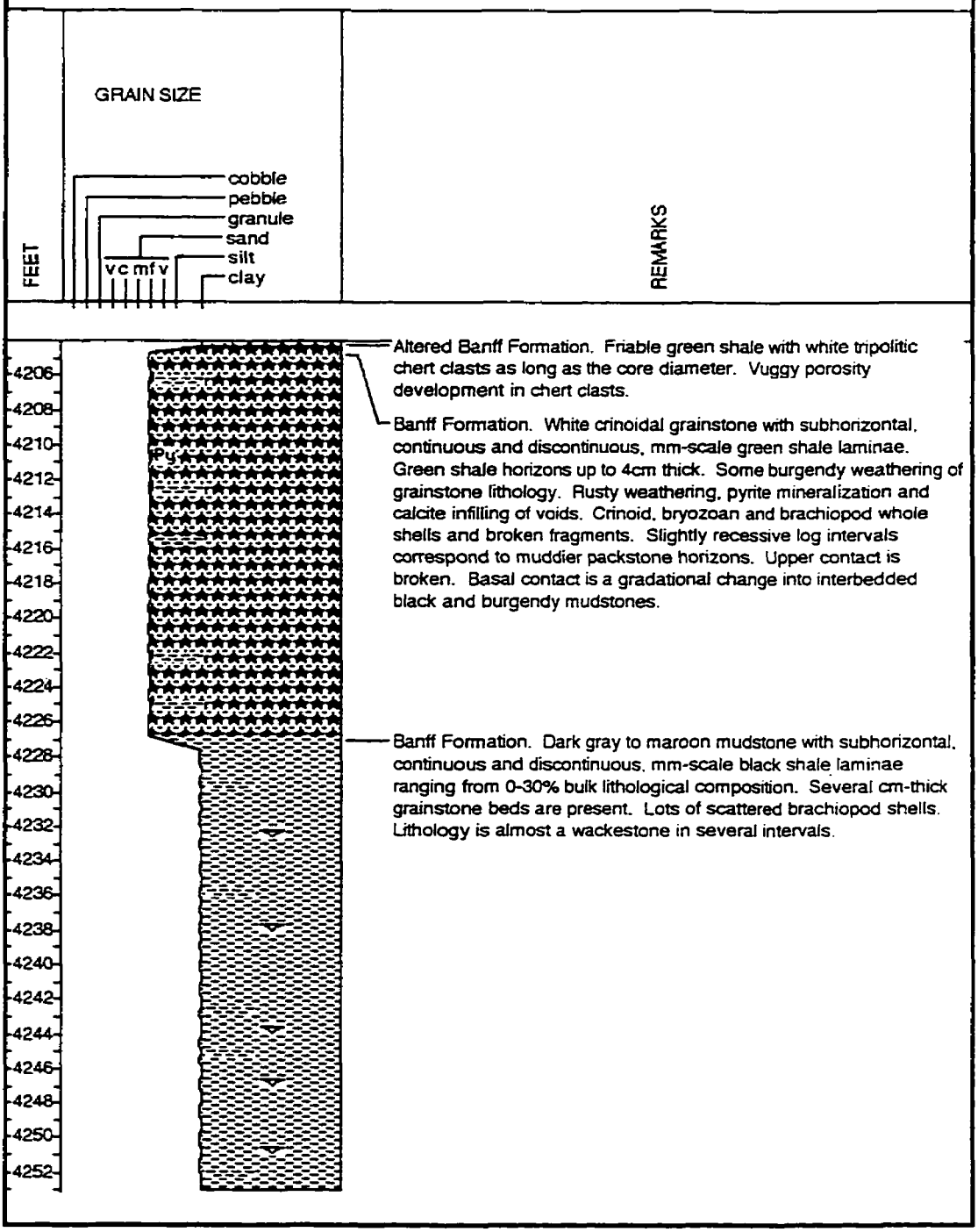


Banff Formation. White crinoidal grainstone with micro and macro vuggy porosity. Oil stained. Interval has rusty weathering, pyrite mineralization and has been stylolitized. No shale laminae. Unit coarsens-up from fine grained (lower) at the base of the interval to coarse grained (lower) at the top.

Banff Formation. Medium brown crinoidal wackestone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale accounts for 5-60% of the bulk lithological composition. Shale content decreases with depth. Rusty weathering. Whole and broken crinoid platelets and ossicles and brachiopod shells are common. Sharp upper contact with crinoidal grainstone.

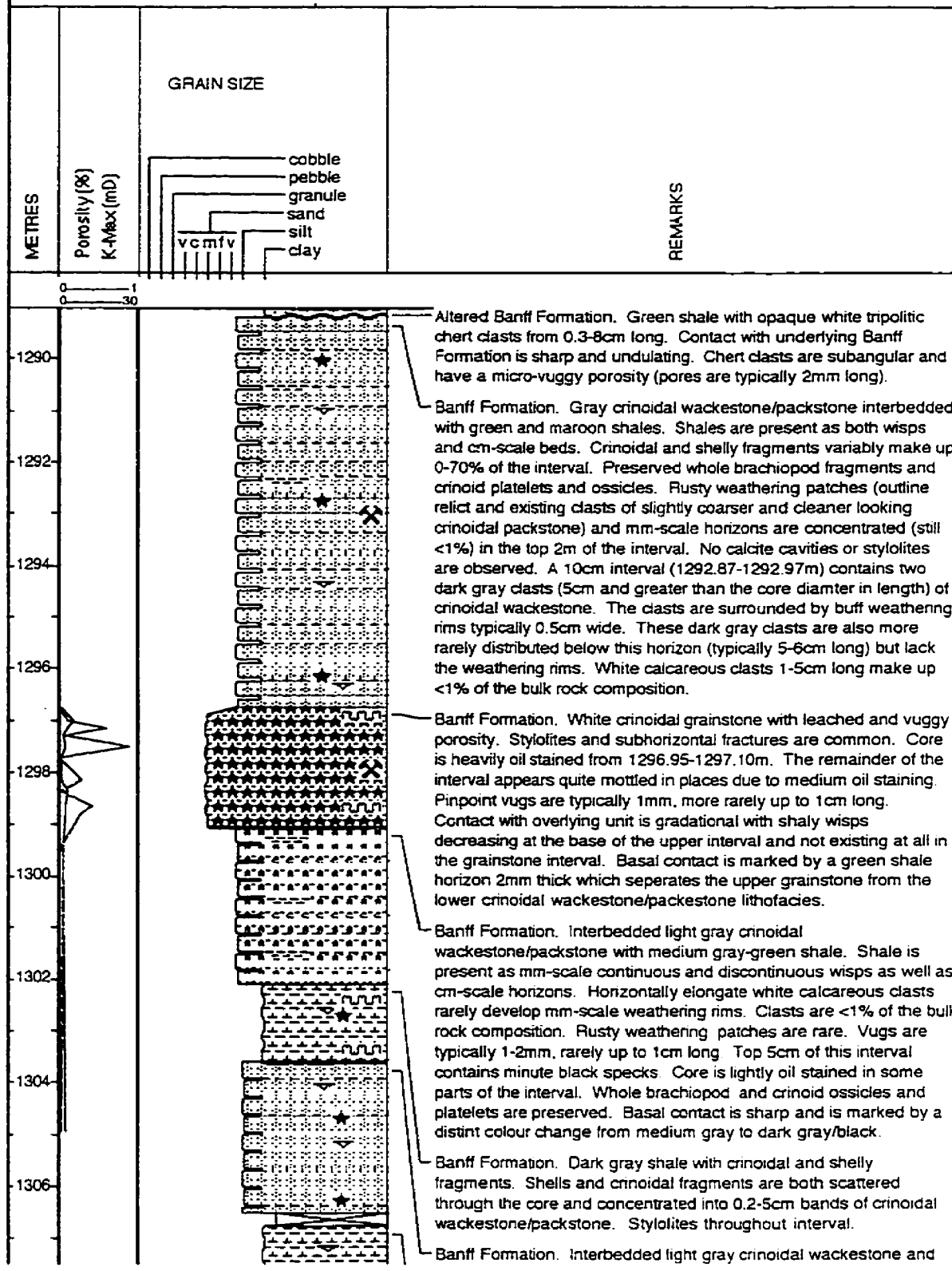
Imperial Golden Hill
12-02-30-16w4

Ground: 3037.00 ft KB: 3049.00 ft



Atcor et al. Pearl
06-14-30-16w4

Ground: 926.70 m KB: 930.70 m



Altered Banff Formation. Green shale with opaque white tripolitic chert clasts from 0.3-8cm long. Contact with underlying Banff Formation is sharp and undulating. Chert clasts are subangular and have a micro-vuggy porosity (pores are typically 2mm long).

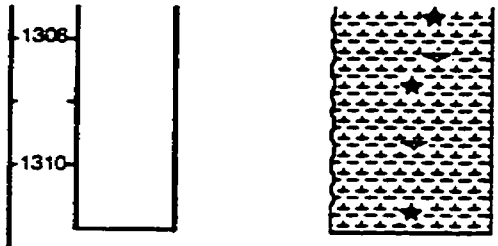
Banff Formation. Gray crinoidal wackestone/packstone interbedded with green and maroon shales. Shales are present as both wisps and cm-scale beds. Crinoidal and shelly fragments variably make up 0-70% of the interval. Preserved whole brachiopod fragments and crinoid platelets and ossicles. Rusty weathering patches (outline relict and existing clasts of slightly coarser and cleaner looking crinoidal packstone) and mm-scale horizons are concentrated (still <1%) in the top 2m of the interval. No calcite cavities or stylolites are observed. A 10cm interval (1292.87-1292.97m) contains two dark gray clasts (5cm and greater than the core diamter in length) of crinoidal wackestone. The clasts are surrounded by buff weathering rims typically 0.5cm wide. These dark gray clasts are also more rarely distributed below this horizon (typically 5-6cm long) but lack the weathering rims. White calcareous clasts 1-5cm long make up <1% of the bulk rock composition.

Banff Formation. White crinoidal grainstone with leached and vuggy porosity. Stylolites and subhorizontal fractures are common. Core is heavily oil stained from 1296.95-1297.10m. The remainder of the interval appears quite mottled in places due to medium oil staining. Pinpoint vugs are typically 1mm, more rarely up to 1cm long. Contact with overlying unit is gradational with shaly wisps decreasing at the base of the upper interval and not existing at all in the grainstone interval. Basal contact is marked by a green shale horizon 2mm thick which seperates the upper grainstone from the lower crinoidal wackestone/packestone lithofacies.

Banff Formation. Interbedded light gray crinoidal wackestone/packstone with medium gray-green shale. Shale is present as mm-scale continuous and discontinuous wisps as well as cm-scale horizons. Horizontally elongate white calcareous clasts rarely develop mm-scale weathering rims. Clasts are <1% of the bulk rock composition. Rusty weathering patches are rare. Vugs are typically 1-2mm, rarely up to 1cm long. Top 5cm of this interval contains minute black specks. Core is lightly oil stained in some parts of the interval. Whole brachiopod and crinoid ossicles and platelets are preserved. Basal contact is sharp and is marked by a distint colour change from medium gray to dark gray/black.

Banff Formation. Dark gray shale with crinoidal and shelly fragments. Shells and crinoidal fragments are both scattered through the core and concentrated into 0.2-5cm bands of crinoidal wackestone/packstone. Stylolites throughout interval.

Banff Formation. Interbedded light gray crinoidal wackestone and

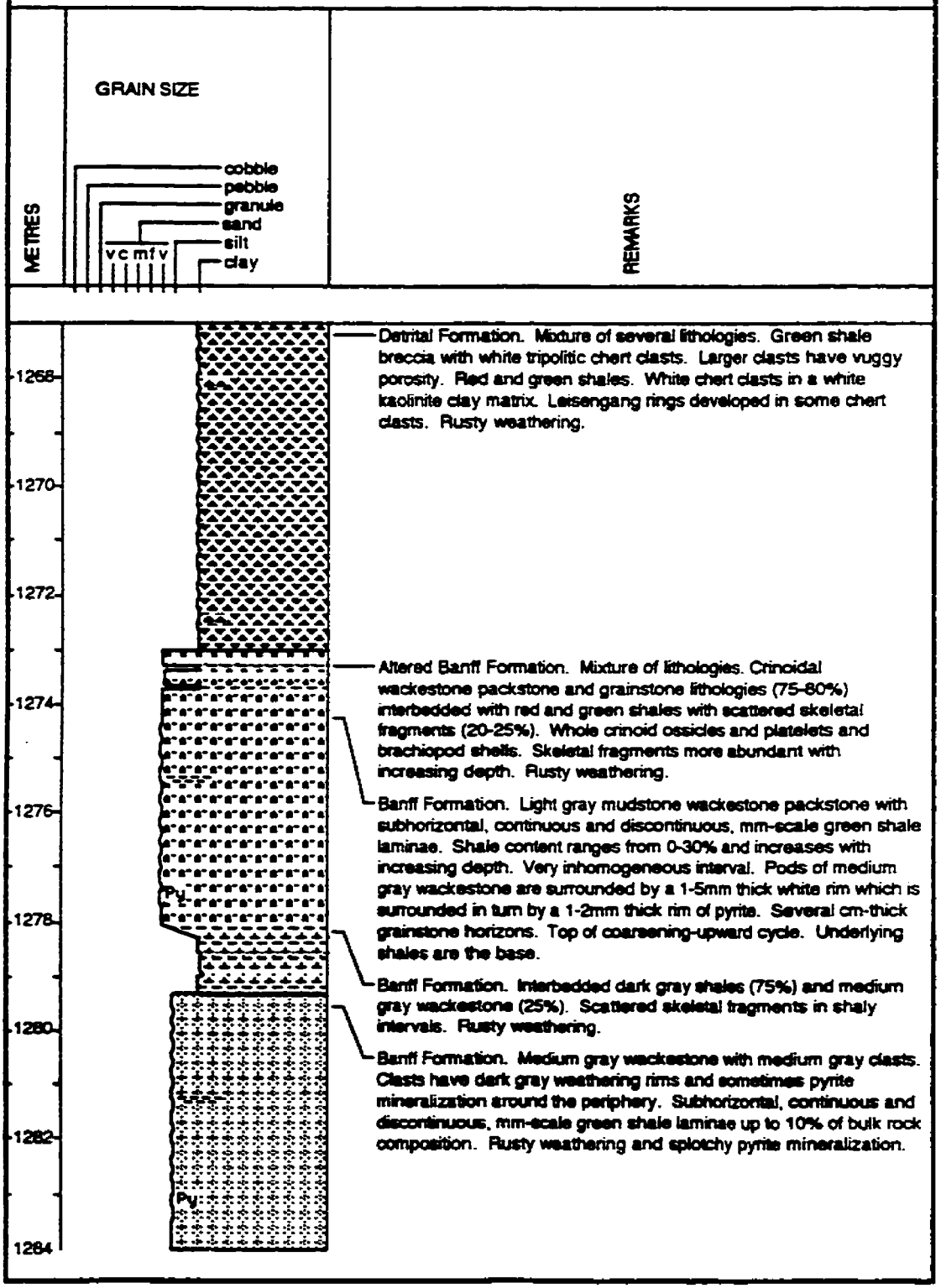


medium gray shale (10-15%). Shelly and crinoidal fragments are both scattered throughout the interval and concentrated into cm-scale bands of wackestone/packestone lithofacies. White opaque calcareous clasts 0.5-2cm long are present throughout the interval (<1% bulk rock composition). Parts of interval are lightly oil stained. Subvertical fractures are rare.

Banff Formation. Dark gray shale with scattered brachiopod shells and crinoidal fragments. Shelly material and crinoidal fragments make up 1-10% of the bulk rock composition. Large (up to 8cm long) dark gray rounded clasts are scattered throughout the interval. The calcareous clasts contain crinoidal and shelly fragments. Core is lightly oil stained near the top of this interval

Ladd Cwwe Watts
05-23-30-16w4

Ground: 907.30 m KB: 911.40 m



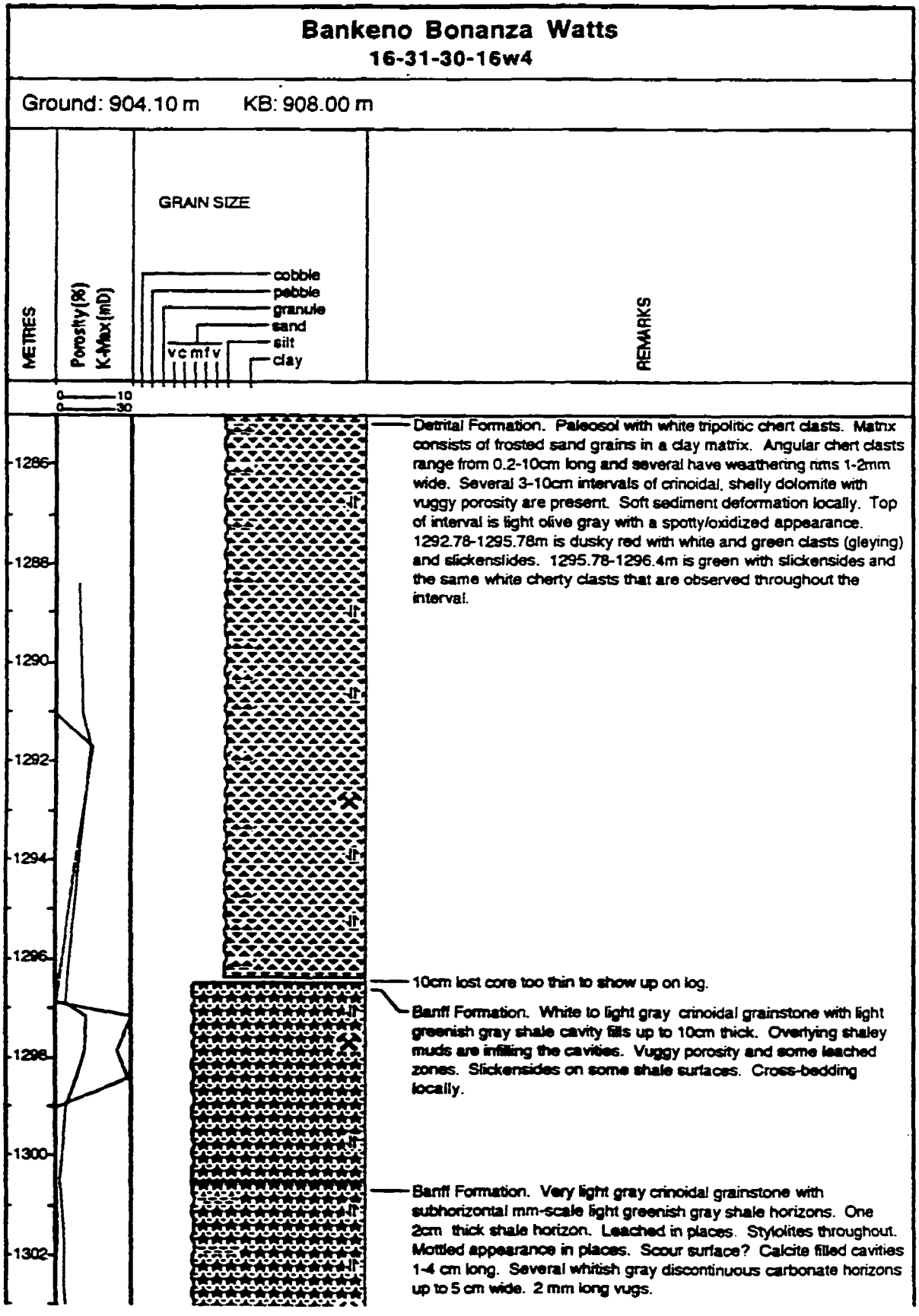
Detrital Formation. Mixture of several lithologies. Green shale breccia with white tripolitic chert clasts. Larger clasts have vuggy porosity. Red and green shales. White chert clasts in a white kaolinite clay matrix. Leisengang rings developed in some chert clasts. Rusty weathering.

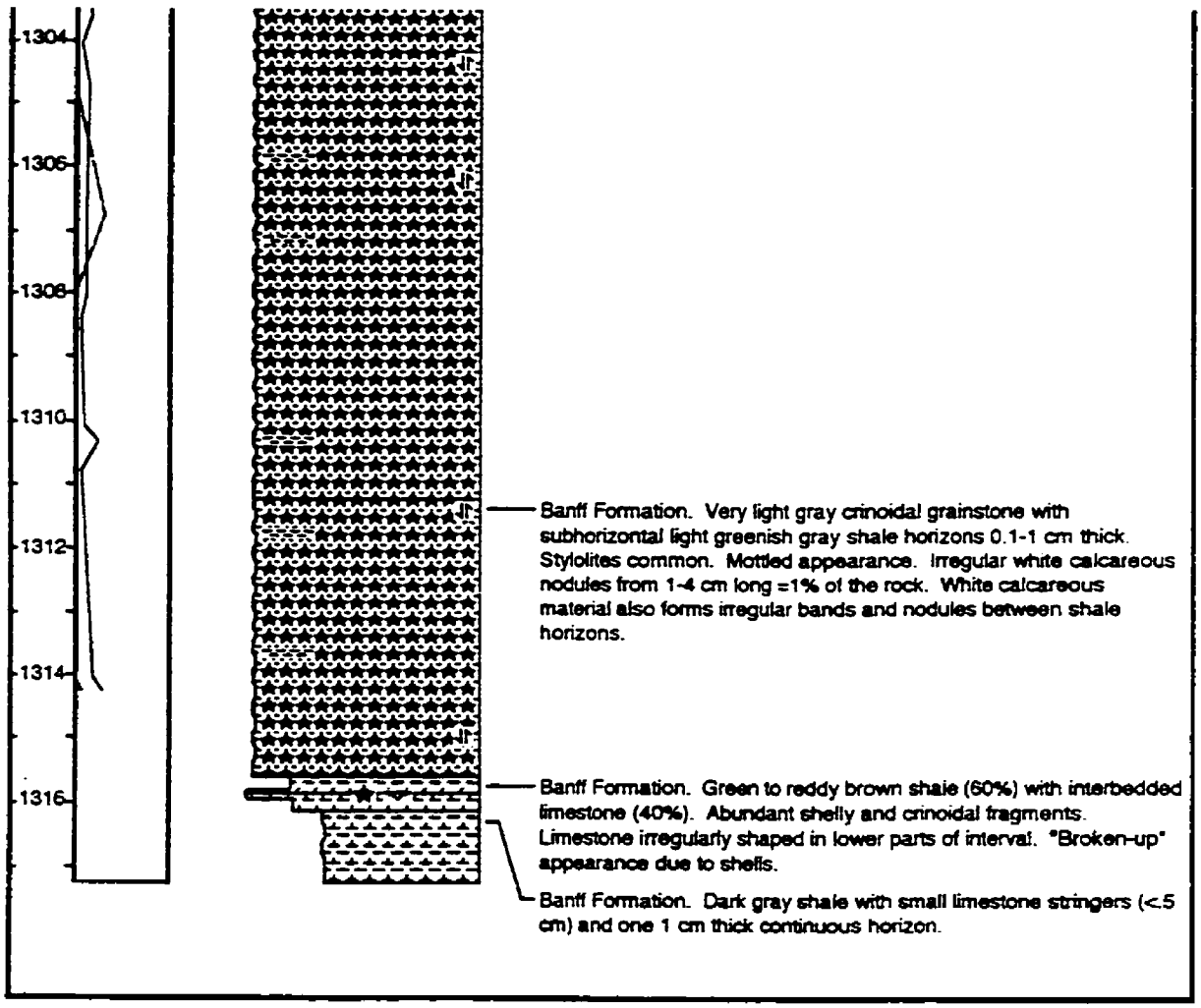
Altered Banff Formation. Mixture of lithologies. Crinoidal wackestone packstone and grainstone lithologies (75-80%) interbedded with red and green shales with scattered skeletal fragments (20-25%). Whole crinoid ossicles and platelets and brachiopod shells. Skeletal fragments more abundant with increasing depth. Rusty weathering.

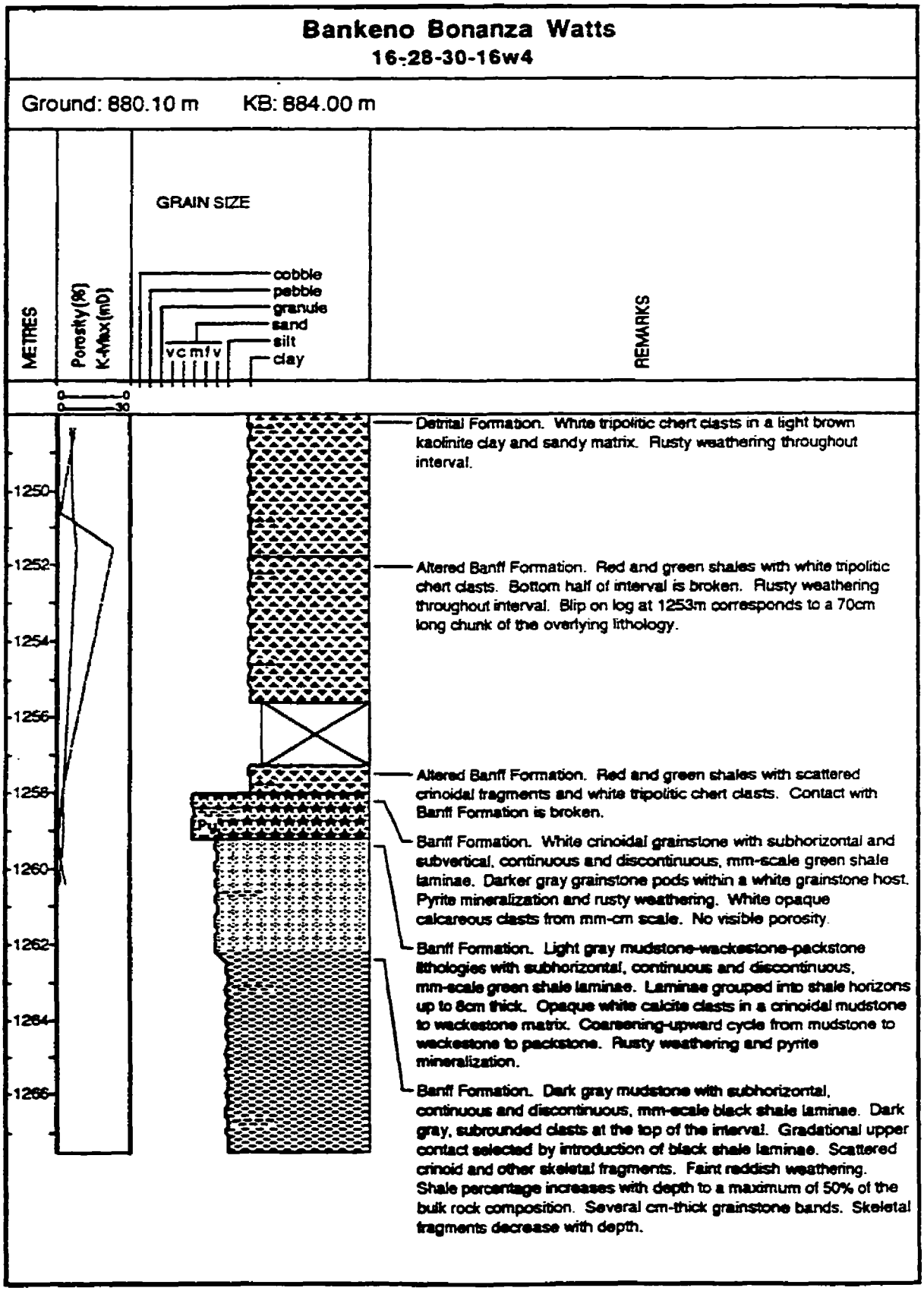
Banff Formation. Light gray mudstone wackestone packstone with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Shale content ranges from 0-30% and increases with increasing depth. Very inhomogeneous interval. Pods of medium gray wackestone are surrounded by a 1-5mm thick white rim which is surrounded in turn by a 1-2mm thick rim of pyrite. Several cm-thick grainstone horizons. Top of coarsening-upward cycle. Underlying shales are the base.

Banff Formation. Interbedded dark gray shales (75%) and medium gray wackestone (25%). Scattered skeletal fragments in shaly intervals. Rusty weathering.

Banff Formation. Medium gray wackestone with medium gray clasts. Clasts have dark gray weathering rims and sometimes pyrite mineralization around the periphery. Subhorizontal, continuous and discontinuous, mm-scale green shale laminae up to 10% of bulk rock composition. Rusty weathering and splotchy pyrite mineralization.


Bankeno Bonanza Watts
16-31-30-16w4
Ground: 904.10 m
KB: 908.00 m
METRES
Porosity(%)
K-Max(mD)
GRAIN SIZE
cobble
pebble
granule
sand
silt
clay
vc m f v
REMARKS
0
10
0
30
1286
1288
1290
1292
1294
1296
1298
1300
1302
Detrital Formation. Paleosol with white tripolitic chert clasts. Matrix consists of frosted sand grains in a clay matrix. Angular chert clasts range from 0.2-10cm long and several have weathering rims 1-2mm wide. Several 3-10cm intervals of crinoidal, shelly dolomite with vuggy porosity are present. Soft sediment deformation locally. Top of interval is light olive gray with a spotty/oxidized appearance. 1292.78-1295.78m is dusky red with white and green clasts (gleying) and slickenslides. 1295.78-1296.4m is green with slickensides and the same white cherty clasts that are observed throughout the interval.
10cm lost core too thin to show up on log.
Banff Formation. White to light gray crinoidal grainstone with light greenish gray shale cavity fills up to 10cm thick. Overlying shaley muds are infilling the cavities. Vuggy porosity and some leached zones. Slickensides on some shale surfaces. Cross-bedding locally.
Banff Formation. Very light gray crinoidal grainstone with subhorizontal mm-scale light greenish gray shale horizons. One 2cm thick shale horizon. Leached in places. Stylolites throughout. Mottled appearance in places. Scour surface? Calcite filled cavities 1-4 cm long. Several whitish gray discontinuous carbonate horizons up to 5 cm wide. 2 mm long vugs.

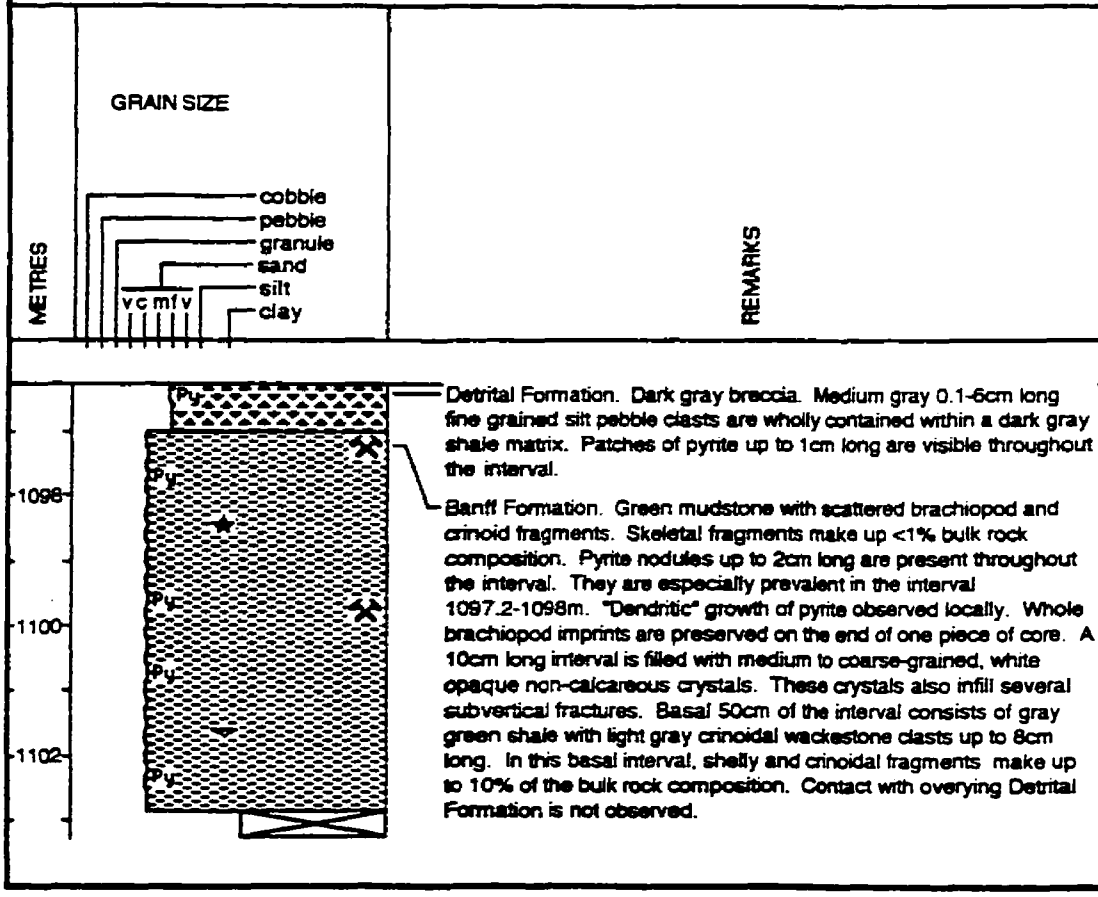

1304
1306
1308
1310
1312
1314
1316
Banff Formation. Very light gray crinoidal grainstone with subhorizontal light greenish gray shale horizons 0.1-1 cm thick. Stylolites common. Mottled appearance. Irregular white calcareous nodules from 1-4 cm long =1% of the rock. White calcareous material also forms irregular bands and nodules between shale horizons.
Banff Formation. Green to reddy brown shale (60%) with interbedded limestone (40%). Abundant shelly and crinoidal fragments. Limestone irregularly shaped in lower parts of interval. "Broken-up" appearance due to shells.
Banff Formation. Dark gray shale with small limestone stringers (<.5 cm) and one 1 cm thick continuous horizon.


Bankeno Bonanza Watts
16-28-30-16w4
Ground: 880.10 m
KB: 884.00 m
METRES
Porosity(%)
K-Max(mD)
GRAIN SIZE
cobble
pebble
granule
sand
silt
clay
vc m f v
REMARKS
0
0
30
1250
1252
1254
1256
1258
1260
1262
1264
1266
Py
Detrital Formation. White tripolitic chert clasts in a light brown kaolinite clay and sandy matrix. Rusty weathering throughout interval.
Altered Banff Formation. Red and green shales with white tripolitic chert clasts. Bottom half of interval is broken. Rusty weathering throughout interval. Blip on log at 1253m corresponds to a 70cm long chunk of the overlying lithology.
Altered Banff Formation. Red and green shales with scattered crinoidal fragments and white tripolitic chert clasts. Contact with Banff Formation is broken.
Banff Formation. White crinoidal grainstone with subhorizontal and subvertical, continuous and discontinuous, mm-scale green shale laminae. Darker gray grainstone pods within a white grainstone host. Pyrite mineralization and rusty weathering. White opaque calcareous clasts from mm-cm scale. No visible porosity.
Banff Formation. Light gray mudstone-wackestone-packstone lithologies with subhorizontal, continuous and discontinuous, mm-scale green shale laminae. Laminae grouped into shale horizons up to 8cm thick. Opaque white calcite clasts in a crinoidal mudstone to wackestone matrix. Coarsening-upward cycle from mudstone to wackestone to packstone. Rusty weathering and pyrite mineralization.
Banff Formation. Dark gray mudstone with subhorizontal, continuous and discontinuous, mm-scale black shale laminae. Dark gray, subrounded clasts at the top of the interval. Gradational upper contact selected by introduction of black shale laminae. Scattered crinoid and other skeletal fragments. Faint reddish weathering. Shale percentage increases with depth to a maximum of 50% of the bulk rock composition. Several cm-thick grainstone bands. Skeletal fragments decrease with depth.

Westmin Racosta
16-04-31-11w4

Ground: 794.60 m KB: 798.30 m

Remarks: Entire Banff Formation including upper contact with the Ellerslie Formation.

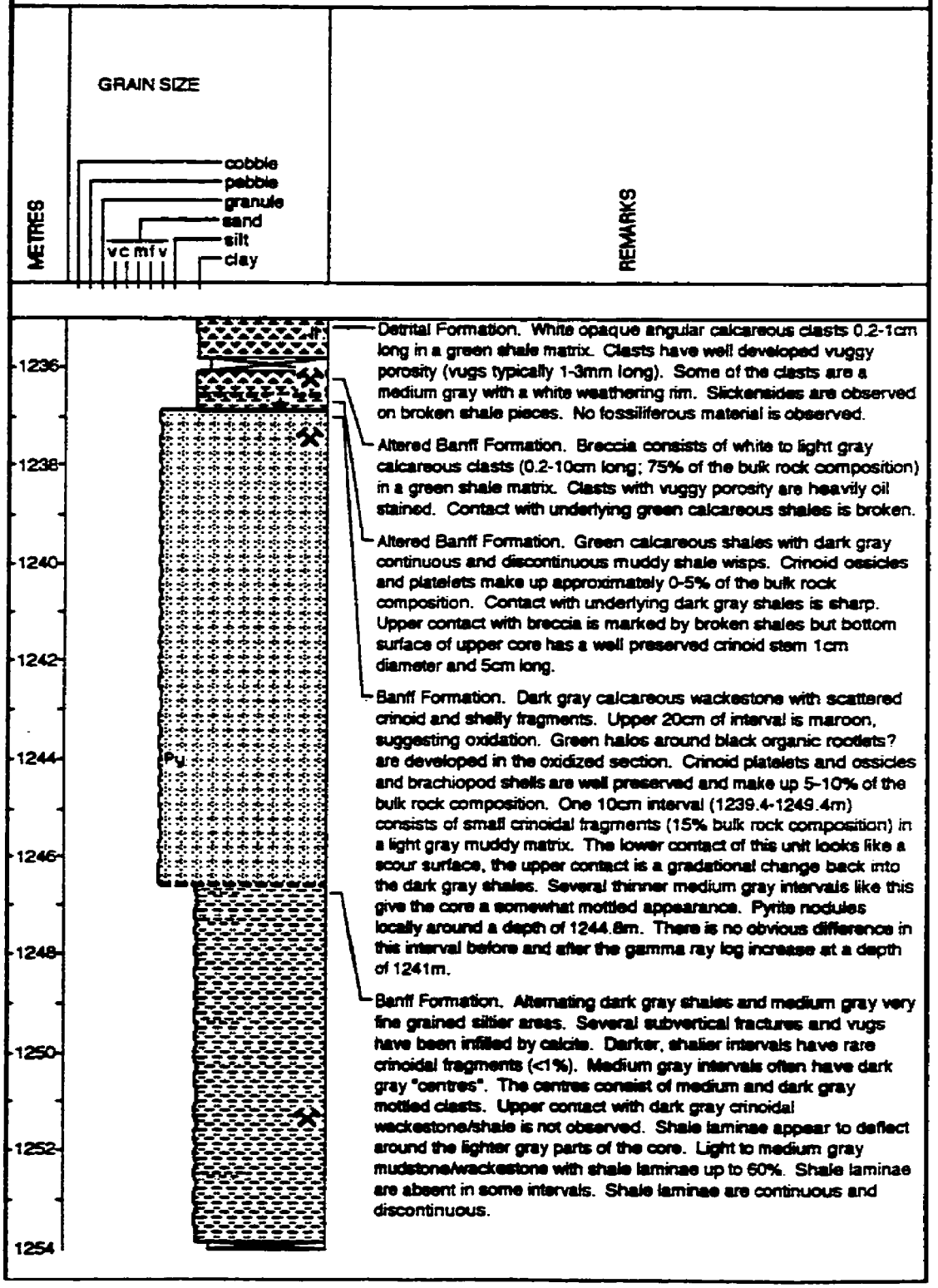


Detrital Formation. Dark gray breccia. Medium gray 0.1-6cm long fine grained silt pebble clasts are wholly contained within a dark gray shale matrix. Patches of pyrite up to 1cm long are visible throughout the interval.

Banff Formation. Green mudstone with scattered brachiopod and crinoid fragments. Skeletal fragments make up <1% bulk rock composition. Pyrite nodules up to 2cm long are present throughout the interval. They are especially prevalent in the interval 1097.2-1098m. "Dendritic" growth of pyrite observed locally. Whole brachiopod imprints are preserved on the end of one piece of core. A 10cm long interval is filled with medium to coarse-grained, white opaque non-calcareous crystals. These crystals also infill several subvertical fractures. Basal 50cm of the interval consists of gray green shale with light gray crinoidal wackestone clasts up to 8cm long. In this basal interval, shelly and crinoidal fragments make up to 10% of the bulk rock composition. Contact with overying Detrital Formation is not observed.

Poco Watts
06-15-31-16w4

Ground: 850.10 m KB: 854.50 m



Detrital Formation. White opaque angular calcareous clasts 0.2-1cm long in a green shale matrix. Clasts have well developed vuggy porosity (vugs typically 1-3mm long). Some of the clasts are a medium gray with a white weathering rim. Slickensides are observed on broken shale pieces. No fossiliferous material is observed.

Altered Banff Formation. Breccia consists of white to light gray calcareous clasts (0.2-10cm long; 75% of the bulk rock composition) in a green shale matrix. Clasts with vuggy porosity are heavily oil stained. Contact with underlying green calcareous shales is broken.

Altered Banff Formation. Green calcareous shales with dark gray continuous and discontinuous muddy shale wisps. Crinoid ossicles and platelets make up approximately 0-5% of the bulk rock composition. Contact with underlying dark gray shales is sharp. Upper contact with breccia is marked by broken shales but bottom surface of upper core has a well preserved crinoid stem 1cm diameter and 5cm long.

Banff Formation. Dark gray calcareous wackestone with scattered crinoid and shelly fragments. Upper 20cm of interval is maroon, suggesting oxidation. Green halos around black organic rootlets? are developed in the oxidized section. Crinoid platelets and ossicles and brachiopod shells are well preserved and make up 5-10% of the bulk rock composition. One 10cm interval (1239.4-1249.4m) consists of small crinoidal fragments (15% bulk rock composition) in a light gray muddy matrix. The lower contact of this unit looks like a scour surface, the upper contact is a gradational change back into the dark gray shales. Several thinner medium gray intervals like this give the core a somewhat mottled appearance. Pyrite nodules locally around a depth of 1244.8m. There is no obvious difference in this interval before and after the gamma ray log increase at a depth of 1241m.

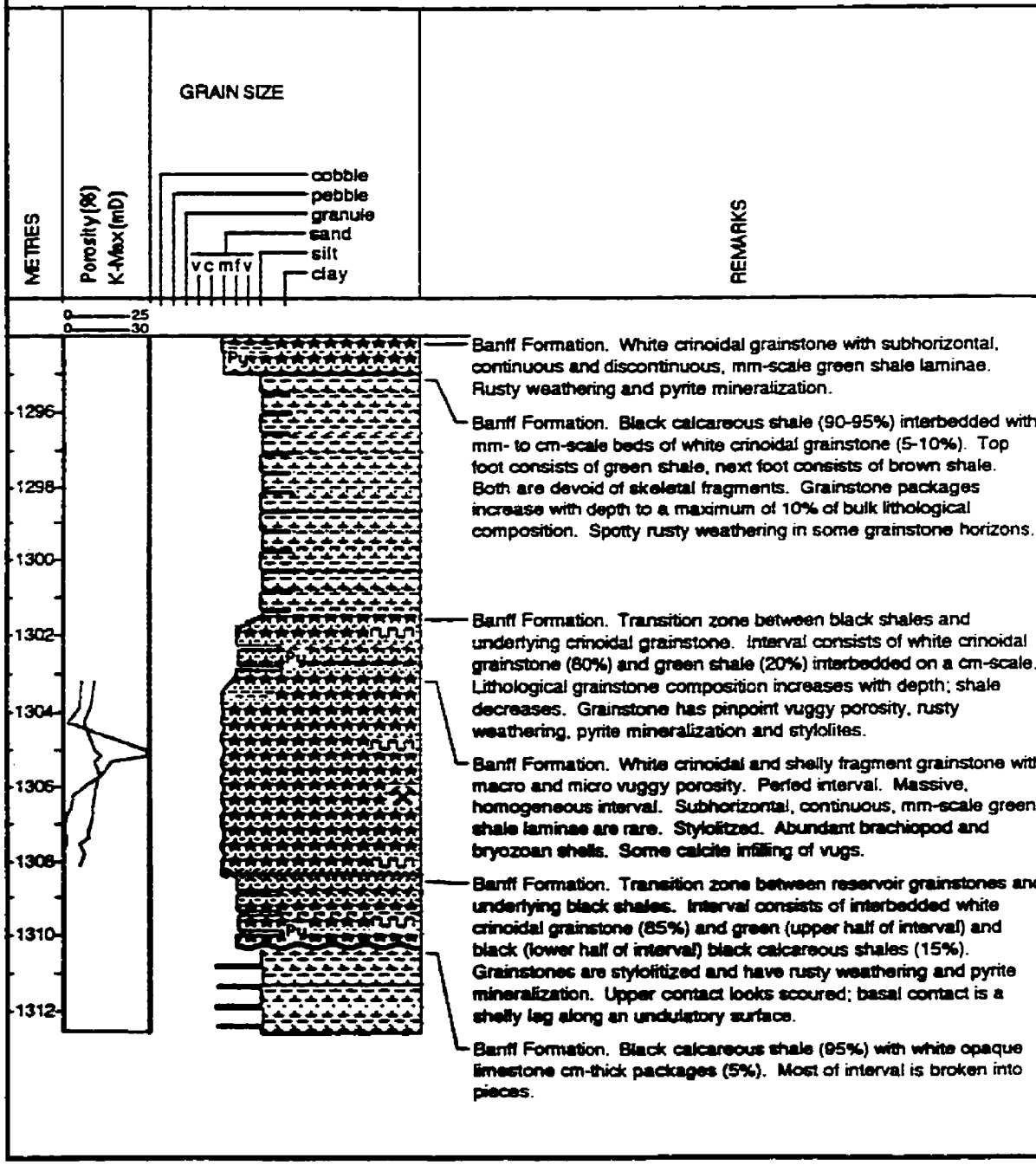
Banff Formation. Alternating dark gray shales and medium gray very fine grained siltier areas. Several subvertical fractures and vugs have been infilled by calcite. Darker, shalier intervals have rare crinoidal fragments (<1%). Medium gray intervals often have dark gray "centres". The centres consist of medium and dark gray mottled clasts. Upper contact with dark gray crinoidal wackestone/shale is not observed. Shale laminae appear to deflect around the lighter gray parts of the core. Light to medium gray mudstone/wackestone with shale laminae up to 60%. Shale laminae are absent in some intervals. Shale laminae are continuous and discontinuous.

Poco Watts

16-31-31-16w4

Ground: 844.30 m KB: 848.10 m

Remarks: Banff "N" production from porous crinoidal grainstones. Core is through one of seven perfed Banff intervals. Scale is 1:150 instead of 1:100 as are the majority of cores presented here.



APPENDIXE

THIN SECTION DESCRIPTIONS

APPENDIX E: THIN SECTION DESCRIPTIONS

Well Location: 14-34-023-09W4 **Framework:** 15%
Depth (m): 974.24 **Cement:** 35%
Formation: Banff **Matrix:** 50%
Rock Classification: CRINOIDAL PELLETED WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	75	Clays	20
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	04
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	10	Fish Scales	00
Bryozoans	00	Ostracods	05
Corals	00	Pelecypods	00
Echinoderms	55	Pellets	30

Cement:
One generation of coarsely crystalline calcite cement infills intergranular spaces and leached out shells. Calcite grain size increases towards the center of leached out and infilled shells.

Porosity:
Secondary leached porosity is 1%.

Comments:
Heterogeneous section. Rock consists of scattered shelly and pelleted material in a muddy micritic matrix. Bioturbation of muddier and not so muddy areas. Selective microcrystalline quartz replacement of parts of echinoderm and brachiopod skeletal fragments. Quartz is also present as rare subrounded heavily included detrital grains. Calcite overgrowths on quartz grains. Calcite cemented fracture within muddy matrix and finer grained calcite cement. A brachiopod fragment shelters a muddier part of the section.

Well Location: 14-34-023-09W4 **Framework:** 15%
Depth (m): 978.50 **Cement:** 50%
Formation: Banff **Matrix:** 35%
Rock Classification: CRINOIDAL PELLETED WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	80	Clays	19
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	00
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	05	Fish Scales	00
Bryozoans	00	Ostracods	12
Corals	00	Pelecypods	00
Echinoderms	26	Pellets	57

Cement:

One generation of coarsely crystalline calcite cement. Calcite crystals are typically 40 μm long.

Porosity:

Secondary leached porosity is typically 1%.

Comments:

2 lithologies in this thin section. Dark gray clast and lighter gray groundmass. The clast has a sharp anastomosing contact with the groundmass. The mineralogy is the same for both lithologies. The zone of changing lithologies is characterized by pyrite mineralization and porosity up to 8-10%. The clast is characterized by 5% porosity due to secondary leaching and coarser grained crystals (typically 70 μm long) than the groundmass.

Well Location: 14-34-023-09W4
Depth (m): 987.00
Formation: Banff
Framework: 27%
Cement: 43%
Matrix: 30%
Rock Classification: CRINOIDAL PELLETED WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	75	Clays	20
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	09	Fish Scales	00

Bryozoans	00	**Ostracods**	02
Corals	00	**Pelecypods**	00
Echinoderms	65	**Pellets**	24

Cement:
2 generations of calcite cement are present. The first generation consists of pyramidal isopachous cement which crystallizes on skeletal surfaces. The second generation consists of coarsely crystalline cement which crystallizes in intergranular spaces. Both generations have few to no inclusions. The first and second generation cements are 8% and 92% of the total cement content respectively.

Porosity:
Selective secondary leached porosity is <1%.

Comments:
Heterogeneous, extensively bioturbated section. Muddier and essentially mud-free portions. Microcrystalline quartz selective replacement of echinoderm fragments. Rare micritic envelopes around calcite grains. Whole and broken skeletal fragments vary widely in size. Larger shell fragments shelter muddier sections of the slide. Calcite cemented fractures cross-cut existing skeletal fragments and coarsely crystalline calcite cement.

Well Location: 16-06-025-08W4 **Framework:** 05%
Depth (m): 1077.10 **Cement:** 35%
Formation: Bakken **Matrix:** 60%
Rock Classification: CALCAREOUS SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	36	**Clays**	00
Fe-calcite	00	**Opaques**	01
Dolomite	00	**Quartz**	63
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	100

Cement:

One generation of crystalline calcite cement. Calcite grains are typically 50μm long. Calcite cement as a percentage of bulk rock composition is highly variable, ranging fror 25-55%, but typically 30%.

Porosity:
Selective secondary leaching yields a porosity of approximately 8-10%.

Comments:
Moderately sorted siltstone consists of subangular quartz grains typically 40μm lon with anhedral calcite crystals. Bitumen filled fracture.

Well Location: 16-06-025-08W4 **Framework:** 00%
Depth (m): 1091.95 **Cement:** 35%
Formation: Bakken **Matrix:** 65%
Rock Classification: CALCAREOUS SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	09	Clays	04
Fe-calcite	26	Opaques	01
Dolomite	00	Quartz	60
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Ferroan calcite and calcite coarsely crystalline cement.

Porosity:
Secondary leaching intergranular solution enlarged porosity is approximately 7-10%.

Comments:
Moderately well sorted sample consists of subangular quartz grains 30μm long, euhedral ferroan calcite rhombs, and anhedral witherite? calcite grains. Carbonate stain is dark pink to red. Suggests that there may be a witherite (Ba substitution) component to the mineralogy. Discontinuous, subhorizontal shale wisps approximately 150μm wide

account for 5% of the bulk rock composition. Some shale horizons have porosities up to 20%. Finer grained quartz and calcite grains than in overlying section.

Well Location: 02/16-14-025-12W4
Depth (m): 1045.20
Formation: Banff
Rock Classification: MUDSTONE

Framework: 08%
Cement: 00%
Matrix: 92%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	85	Clays	12
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	02
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	100

Cement:
None observed.

Porosity:
Discontinuous subhorizontal and subvertical fractures <20μm wide give specimen <1% porosity.

Comments:
Rock has a patchy appearance due to micrite pockets within a wholly recrystallized micro and pseudospar rock. Sparry calcite consists of grains ranging from 10-55μm long, typically 20μm long. Discontinuous muddy wisps (typically 208μm wide) give rock a stratified appearance. These wisps make up approximately 5% of the bulk rock composition. Subangular quartz grains are scattered throughout the slide.

Well Location: 02/16-14-025-12W4
Depth (m): 1047.50
Formation: Banff
Rock Classification: CRINOIDAL WACKESTONE

Framework: 38%
Cement: 02%
Matrix: 60%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%

Calcite	94	**Clays**	05
Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	01
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	16	**Fish Scales**	00
Bryozoans	00	**Ostracods**	11
Corals	00	**Pelecypods**	05
Echinoderms	65	**Pellets**	03

Cement:
One generation of coarsely crystalline calcite cement makes up 0-5% of the bulk rock composition. Cement is inhomogeneously distributed over the section.

Porosity:
Several fractures (20μm wide) obliquely cross-cut the section give specimen <1% porosity.

Comments:
Inhomogeneous section due to bioturbation. Bioturbation has resulted in the mixing of wackestone, packstone, and grainstone lithologies. Rock consists of skeletal fragments in a muddy, micritic matrix. Micritic matrix has been leached out in some places and infilled with coarsely crystalline calcite cement. A punctate, highly ornamented brachiopod shell shelters a muddy portion of the slide. Rare subhedral quartz grains are observed along fracture planes. Some echinoderm fragments (approximately 2%) are iron rich.

Well Location: 02/16-14-025-12W4
Depth (m): 1049.52
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 04%
Cement: 62%
Matrix: 34%

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	21	**Clays**	15
Fe-calcite	01	**Opaques**	00
Dolomite	28	**Quartz**	35
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	40	**Fish Scales**	00
Bryozoans	00	**Ostracods**	60

Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
Euhedral dolomite and calcite rhombs, typically 50μm long, cement up a quartz matrix.

Porosity:
Secondary, leached interparticle porosity (8%) is patchily distributed. Dolomite cement has infilled the primary porosity.

Comments:
Very fine grained, well sorted siltstone consisting of subangular quartz grains and euhedral dolomite rhombs. Section is highly bioturbated. Several 200μm wide subhorizontal, discontinuous wisps of muddier material are inhomogeneously distributed throughout the section. Some calcite grains are iron rich. Rare broken ostracod and brachiopod shells are scattered through the section.

Well Location: 02/16-14-025-12W4
Depth (m): 1051.5
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 01%
Cement: 61%
Matrix: 38%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	12	**Clays**	10
Fe-calcite	00	**Opaques**	01
Dolomite	45	**Quartz**	32
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	80	**Fish Scales**	00
Bryozoans	00	**Ostracods**	05
Corals	00	**Pelecypods**	00
Echinoderms	15	**Pellets**	00

Cement:
Euhedral dolomite rhombs range in size from 20-85μm long.

Porosity:
Very patchily distributed secondary, leached interparticle porosity. Porosity ranges from 0-15%, typically 5%. Muddier areas of section have 0% porosity.

Comments:
Very fine grained subangular quartz grains and euhedral dolomite rhombs. Rare (<1%) larger (400-625 μm wide) leached ferroan calcite grains have dolomite rhombs growing over them. Section has been heavily bioturbated as demonstrated by the mixing of muddy and clean layers.

Well Location: 16-22-025-12W4
Depth (m): 1041.5
Formation: Banff
Rock Classification: SILTY MUDSTONE

Framework: 01%
Cement: 00%
Matrix: 99%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	00	Clays	10
Fe-calcite	65	Opaques	01
Dolomite	00	Quartz	24
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	50	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	50	Pellets	00

Cement:
None observed.

Porosity:
Secondary leached interparticle porosity is 1-2%.

Comments:
Rock consists of subangular to subrounded quartz grains (20-50μm long, typically 25μm) in a ferroan calcite micritic mud matrix. Several micritic wisps and pockets up to 200μm wide.

Well Location: 16-22-025-12W4
Depth (m): 1044.75
Formation: Banff
Rock Classification: CRINOIDAL WACKESTONE

Framework: 15%
Cement: 01%
Matrix: 84%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%

Calcite	41	**Clays**	28
Fe-calcite	00	**Opaques**	00
Dolomite	12	**Quartz**	19
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	20	**Fish Scales**	00
Bryozoans	00	**Ostracods**	05
Corals	00	**Pelecypods**	00
Echinoderms	48	**Pellets**	27

Cement:
Two types of calcite cement are observed, both are rare. Pyramidal, bladed cement developed along some brachiopod shells, while equant, coarsely crystalline cement observed on one echinoderm fragment.

Porosity:
None visible.

Comments:
Poorly sorted section consisting of subangular quartz grains (10-100μm long, typically 30μm) and scattered skeletal material in a micritic muddy matrix. Skeletal fragments are aligned in some portions of the slide. Several echinoderm fragments look iron rich. Brachiopods consist of whole, delicate walled shells.

Well Location: 14-35-025-15W4 **Framework:** 65%
Depth (m): 1121.47 **Cement:** 35%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	79	**Clays**	19
Fe-calcite	00	**Opaques**	00
Dolomite	01	**Quartz**	01
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	15	**Fish Scales**	00
Bryozoans	07	**Ostracods**	04
Corals	03	**Pelecypods**	03
Echinoderms	65	**Pellets**	00

Cement:
2 generations of calcite cement. First generation consists of pyramidal, included, isopachous cement which is present on the surface of the majority of skeletal components. The second generation cement consists of equant, coarsely crystalline cement (not as iron rich as the primary cement) which crystallizes in intergranular spaces. The pyramidal and equant calcite cements make up 25% and 75% of the total cements respectively.

Porosity:
Rare secondary leached porosity <1%.

Comments:
Syntaxial overgrowths on echinoderm and brachiopod skeletal fragments. Microcrystalline green quartz selectively replaces portions of some echinoderm fragments, others look iron rich. Finely crystalline dolomite cement infills obliquely oriented fractures. Bryozoans are fenestrate.

Well Location: 14-35-025-15W4
Depth (m): 1126.00
Formation: Banff
Rock Classification: CRINOIDAL PACKSTONE

Framework: 10-55%
Cement: 00-45%
Matrix: 15-90%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	84	Clays	07
Fe-calcite	03	Opaques	01
Dolomite	00	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	30	Fish Scales	00
Bryozoans	02	Ostracods	05
Corals	00	Pelecypods	00
Echinoderms	35	Pellets	28

Cement:
2 calcite cement generations are developed in the packstone. The first generation consists of pyramidal, isopachous cement on skeletal surfaces. It is slightly iron rich. The second generation is restricted to intergranular spaces and leached out portions of skeletal fragments and consists of equant, coarsely crystalline cement. First and second generations of cement account for 20% and 80% of total cements respectively.

Porosity:
Secondary leached porosity is 1-2%.

Comments:
Section is highly bioturbated and shows transition from wackestone (no pellets and little skeletal material, no cement) to packstone (25% pellets, 35% skeletal material, and 2 cement generations). Green, microcrystalline quartz partially replaces echinoderm fragments. Some echinoderm fragments are iron rich. Syntaxial overgrowths on echinoderm fragments. Subangular quartz grains are scattered through the packstone lithofacies. Whole and broken skeletal material.

Well Location: 14-35-025-15W4
Depth (m): 1128.00
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 65%
Matrix: 35%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	24	Clays	00
Fe-calcite	00	Opaques	01
Dolomite	40	Quartz	35
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs and subhedral calcite grains cement up a quartzose matrix. Dolomite rhombs variably overgrow quartz grains or have a sutured contact.

Porosity:
Homogeneously distributed, secondary leached interparticle porosity is 8%.

Comments:
Well sorted, homogeneous section. Subangular quartz grains (range 15-90μm, typically 25μm long) and euhedral dolomite and calcite rhombs (typically 45μm long). Rare micritic wisps and patches 200-400μm long are present. Micrite crystals can be seen in the pore space at high magnification (25X).

Well Location: 14-35-025-15W4 **Framework:** 00%
Depth (m): 1134.0 **Cement:** 58%
Formation: Banff **Matrix:** 42%
Rock Classification: DOLOMITIC SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	00	Clays	20
Fe-calcite	00	Opaques	02
Dolomite	38	Quartz	40
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	TR
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs and subhedral calcite cement up a quartzose matrix. Dolomite overgrows quartz grain edges as well as has sutured contacts with quartz grains.

Porosity:
Local subhorizontal fracture porosity <1%.

Comments:
Moderately sorted. Rock consists of subangular quartz grains (range 10-50μm, typically 25μm long) and euhedral dolomite rhombs (range 15-60μm, typically 30μm long). Muddy laminae (zones of laminae up to 800μm wide) make up approximately 10% of the bulk composition of the slide. Subhorizontal fractures cut these muddy laminae only. Locally, quartz and dolomite grains are elongated. Bitumen in some fractures.

Well Location: 06-22-026-16W4 **Framework:** 60%
Depth (m): 1168.63 **Cement:** 35%
Formation: Banff **Matrix:** 05%
Rock Classification: CHERTY CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	05	Clays	00

Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	95
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	15	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	85	**Pellets**	00

Cement:
2 types of quartz cement are present. The first consists of chalcedony and the second is a coarser-grained mega-quartz cement. Chalcedony cement between skeletal grains as well as along the shell interior of voids. Mega-quartz infills voids and gets coarser-grained towards the void center.

Porosity:
Secondary leaching of echinoderm fragments yields 1-2% porosity.

Comments:
Entire section has been silicified. Microcrystalline quartz has replaced 95% of all skeletal fragments. One 1cm long ostracod.

Well Location: 06-22-026-16W4 **Framework:** 55%
Depth (m): 1171.65 **Cement:** 45%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	90	**Clays**	07
Fe-calcite	00	**Opaques**	01
Dolomite	00	**Quartz**	02
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	08	**Fish Scales**	00
Bryozoans	06	**Ostracods**	05
Corals	04	**Pelecypods**	02
Echinoderms	75	**Pellets**	00

Cement:

2 generations of calcite cement are present. The first generation grows on skeletal surfaces and consists of pyramidal, isopachous cement (5% of total cements). The second generation cement is well cleaved and coarsely crystalline (95% of total cements). Some shell interiors are dissolved and infilled with the two cement generations. Grain size increases towards the shell center.

Porosity:
Rare secondary leached porosity <1%.

Comments:
Syntaxial overgrowths and selective quartz replacement of echinoderm fragments are common. Whole and fragmented shells.

Well Location: 06-22-026-16W4
Depth (m): 1174.85
Formation: Banff
Framework: 75%
Cement: 20%
Matrix: 05%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	85	Clays	09
Fe-calcite	00	Opaques	02
Dolomite	00	Quartz	04
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	05	Fish Scales	00
Bryozoans	10	Ostracods	03
Corals	00	Pelecypods	02
Echinoderms	80	Pellets	00

Cement:
2 generations of calcite cement are present. The first generation is essentially inclusion free and consists of pyramidal, isopachous cement (5% of the total cements). The second generation cement is moderately to heavily included and consists of coarsely crystalline cement (95% of the total cements).

Porosity:
Fracture porosity is 1%. Porosity for the entire slide consists of one 330µm wide fracture which runs the length of the slide. Rare secondary leaching of echinoderm fragments.

Comments:
Microcrystalline quartz selectively replaces portions of echinoderm fragments (10-80% of the grain is replaced). Locally, a black opaque mineral (pyrite?) partially replaces echinoderm and other skeletal fragments. Syntaxial overgrowths and micritic envelopes are common around echinoderm fragments. Several calcite cemented fractures cross-cut skeletal fragments.

Well Location: 06-22-026-16W4
Depth (m): 1178.78
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 03%
Cement: 62%
Matrix: 35%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	15	Clays	05
Fe-calcite	00	Opaques	01
Dolomite	44	Quartz	35
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	02	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	98

Cement:
Euhedral dolomite rhombs and subhedral calcite grains cement up a quartzose matrix.

Porosity:
Selective secondary leaching creates approximately 5% porosity.

Comments:
Moderately well sorted rock consists of subangular quartz grains (typically 40μm long) and subhedral calcite and dolomite rhombs (typically 35μm long). Section is highly bioturbated. Two brachiopod fragments are present.

Well Location: 06-22-026-16W4
Depth (m): 1183.30
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 60%
Matrix: 40%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	12	Clays	05
Fe-calcite	00	Opaques	00
Dolomite	45	Quartz	38
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	TR	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs and subhedral calcite grains cement up a quartzose matrix.

Porosity:
Porosity is highly variable over the slide. Selective secondary leaching yields a typical porosity of 1% but may be as high as 7% in certain spots.

Comments:
Rock consists of subangular quartz grains (typically 50μm long) and euhedral dolomite rhombs (40μm long). Some of the calcite looks iron rich. Section is bioturbated. One brachiopod fragment.

Well Location: 06-22-026-16W4
Depth (m): 1188.00
Formation: Banff
Rock Classification: SILTY WACKESTONE

Framework: 02-10%
Cement: 30%
Matrix: 65%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	13	Clays	10
Fe-calcite	00	Opaques	02
Dolomite	45	Quartz	30
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	38	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	62

Cement:
Coarsely crystalline calcite cement developed on some skeletal fragments.

Porosity:
Inhomogeneously distributed secondary leached porosity typically 1% but up to 5% in some patchy areas of the slide.

Comments:
Rock consists of subangular quartz grains (20-50μm long) and calcite in granular masses. Pellets and brachiopod fragments range from 2-10% of the total bulk rock composition. Framework grains are concentrated in certain portions of the slide, and are extremely sparse in others. Section is highly bioturbated.

Well Location: 06-22-026-16W4 **Framework:** 05%
Depth (m): 1191.90 **Cement:** 70%
Formation: Banff **Matrix:** 25%
Rock Classification: SILTY SKELETAL PELLETED PACKSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	05	Clays	15
Fe-calcite	00	Opaques	00
Dolomite	70	Quartz	10
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	85	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	10	Pellets	05

Cement:
Coarsely crystalline calcite cement developed both externally on grain surfaces and internally where skeletal fragments have been mostly leached away. Grain size increases towards the center of shell interiors.

Porosity:
Selective secondary leaching and fractures yields 1% porosity.

Comments:
Moderately sorted rock consists of subangular quartz grains (typically 30μm long), pellets, and skeletal fragments in a dolomitic groundmass.

=

Well Location: 02/10-29-026-16W4 **Framework:** 68%
Depth (m): 1215.75 **Cement:** 27%
Formation: Banff **Matrix:** 05%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	95	Clays	05
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	00
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	04	Fish Scales	00
Bryozoans	08	Ostracods	03
Corals	00	Pelecypods	00
Echinoderms	85	Pellets	00

Cement:
2 generations of calcite cement. First generation accounts for 2% of the total cements and consists of prismatic isopachous cement which develops on selected skeletal fragments. Coarsely crystalline second generation cement is variably included (slight to heavily) and crystallizes in intergranular spaces as well as along skeletal fragment edges.

Porosity:
Secondary selective leaching of echinoderm fragments and rare fracturing yields a porosity of approximately 1%.

Comments:
Syntaxial overgrowths and selective quartz replacement of echinoderm fragments.

Well Location: 02/10-29-026-16W4 **Framework:** 02%
Depth (m): 1221.45 **Cement:** 45%
Formation: Banff **Matrix:** 53%
Rock Classification: CALCAREOUS SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	25	Clays	02
Fe-calcite	00	Opaques	01

Dolomite	18	**Quartz**	55
Fe-dolomite	00	**Feldspars**	<1

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	100

Cement:
Subhedral calcite and euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
Very sparsely distributed secondary leached porosity is <1% for the slide as a whole. Small pores (<10μm long) are concentrated in patches.

Comments:
Quartz grains are scattered individually as well as grouped into clusters with sutured contacts. Average quartz grain size is 70μm long. Opaque mineral is probably pyrite. Fractures bleeding bitumen.

Well Location: 02/10-29-026-16W4
Depth (m): 1225.80
Formation: Banff
Rock Classification: SILTY LIMESTONE

Framework: 02%
Cement: 13%
Matrix: 85%

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	55	**Clays**	09
Fe-calcite	00	**Opaques**	01
Dolomite	20	**Quartz**	15
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
Euhedral dolomite rhombs and anhedral calcite crystals cement up a quartzose matrix. Rhombs overgrow or have undulatory contacts with quartz grains.

Porosity:
Selective secondary leaching yields a porosity 1-2%.

Comments:
Well sorted, fairly homogeneous section. Some calcite grains look iron rich. Finer grained than overlying section. Typical grain size is <10μm.

Well Location: 02/10-31-26-17W4
Depth (m): 1277.70
Formation: Banff
Rock Classification: SILTY PELLETED PACKSTONE

Framework: 12%
Cement: 25%
Matrix: 63%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	53	Clays	06
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	40
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	10	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	100

Cement:
Anhedral calcite grains cement up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Well sorted rock consists of subangular quartz grains (30-90μm long), calcite grains typically 30μm but up to 1.25mm long and pellets 50-100μm long.

Well Location: 02/10-31-26-17W4
Depth (m): 1280.80
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 01%
Cement: 55%
Matrix: 44%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	10	Clays	08
Fe-calcite	00	Opaques	01
Dolomite	46	Quartz	35
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	70	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	25	Pellets	05

Cement:
Euhedral dolomite and anhedral calcite rhombs cement up a quartzose matrix.

Porosity:
1-2% secondary leached porosity. Up to 15% in some portions of the slide.

Comments:
Section consists of subangular quartz grains 50-55μm long, calcite grains 40μm long and dolomite rhombs 50-60μm long. Finer grained than overlying section and pellets are a much smaller component.

Well Location: 02/10-31-26-17W4
Depth (m): 1288.00
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 01%
Cement: 65%
Matrix: 44%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	02	Clays	10
Fe-calcite	00	Opaques	01
Dolomite	65	Quartz	22
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	100

Cement:

Subhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Rock consists of subangular quartz grains typically 50μm long and dolomite rhombs 55μm long. Muddy wisps.

Well Location: 02/10-31-26-17W4
Depth (m): 1293.30
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 60%
Matrix: 40%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	15	Clays	05
Fe-calcite	00	Opaques	02
Dolomite	48	Quartz	30
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs and subhedral calcite grains cement up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Rock consists of 40-50μm long dolomite rhombs, 30μm long subangular quartz grains and 20-30μm long calcite rhombs. Muddy wisps. Finer grained section than overlying three.

Well Location: 06-25-026-18W4
Depth (m): 1392.44
Formation: Banff

Framework: 35%
Cement: 65%
Matrix: 00%

Rock Classification: CRINOIDAL PELLETED GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	90	Clays	05
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	19	Fish Scales	00
Bryozoans	04	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	63	Pellets	14

Cement:

2 generations of calcite cement are present. The first generation consists of inclusion free, pyramidal, isopachous cement which developed along skeletal fragment edges. The second generation consists of heavily included, coarsely crystalline cement which crystallizes in intergranular spaces (calcite crystals typically 190μm long but range from 20μm-1.40mm long). The first and second generation cements account for 12% and 88% of the total cements respectively.

Porosity:

No visible porosity.

Comments:

Floating subrounded quartz grains (typically 40-60μm long) are occasionally scattered in the second generation cement. Selective quartz replacement of echinoderm and brachiopod fragments. Larger (typically 216μm long) rounded grains of chalcedony selectively replaces portions of echinoderm fragments. Syntaxial overgrowths on echinoderm fragments.

Well Location: 06-25-026-18W4
Depth (m): 1400.10
Formation: Banff
Framework: 10%
Cement: 62%
Matrix: 28%
Rock Classification: PELLETED SILTY PACKSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	60	Clays	05

Fe-calcite	00	**Opaques**	00
Dolomite	10	**Quartz**	25
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	100

Cement:
Anhedral calcite and euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Moderately well sorted rock consists of pellets and subangular quartz grains (typically 45μm long) cemented by euhedral dolomite rhombs (typically 40μm long) and subhedral calcite rhombs (typically 30μm long). 1/3 of the thin section is stratified into a pelleted silty packstone as described above and a fine grained, poorly sorted, dolomitic packstone which lacks both the calcite and pelleted material. Grain size in this second minor lithology ranges from 10-50μm long. Patches of wackestone lithology. Bioturbated section.

Well Location: 06-25-026-18W4 **Framework:** 12%
Depth (m): 1404.44 **Cement:** 60%
Formation: Banff **Matrix:** 28%
Rock Classification: SILTY PELLETED WACKESTONE

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	46	**Clays**	14
Fe-calcite	00	**Opaques**	01
Dolomite	21	**Quartz**	18
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	100

Cement:
Anhedral calcite and euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Rock consists of subhedral calcite grains (typically 40μm long), subhedral dolomite rhombs (typically 50μm long), and subangular quartz grains typically 30-40μm long in a muddy micritic matrix. Subhorizontal, discontinuous muddy wisps (typically 400μm wide) make up 15% of the bulk rock composition. Bioturbated section.

Well Location: 16-35-026-18W4 **Framework:** 00%
Depth (m): 1328.00 **Cement:** 35%
Formation: Banff **Matrix:** 65%
Rock Classification: DOLOMITIC SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	02	Clays	06
Fe-calcite	00	Opaques	01
Dolomite	33	Quartz	58
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs 60μm long.

Porosity:
Homogeneously distributed secondary leached porosity is 20%. No porosity development in shale horizons and muddier areas.

Comments:

Well sorted siltstone consisting of subangular quartz grains (typically 40-50μm long) and euhedral dolomite rhombs (typically 60μm long). Discontinuous shale horizons typically 350μm wide comprise 8% of the bulk rock composition. Section is bioturbated.

Well Location: 16-35-026-18W4 **Framework:** 00%
Depth (m): 1330.44 **Cement:** 40%
Formation: Banff **Matrix:** 60%
Rock Classification: DOLOMITIC SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	02	Clays	00
Fe-calcite	00	Opaques	01
Dolomite	36	Quartz	60
Fe-dolomite	00	Feldspars	01

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
Homogeneously distributed secondary leached porosity is 25%.

Comments:
Well sorted siltstone consisting of subangular quartz grains (typically 30-40μm long) and euhedral dolomite rhombs (typically 50-70μm long). Section is bioturbated. A 1cm wide band has a clay content of approximately 10% and <1% porosity.

Well Location: 16-35-026-18W4 **Framework:** 00%
Depth (m): 1332.08 **Cement:** 44%
Formation: Banff **Matrix:** 66%
Rock Classification: DOLOMITIC SILTSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	05	Clays	08

Fe-calcite	00	**Opaques**	02
Dolomite	30	**Quartz**	55
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
Euhedral dolomite rhombs cement up a quartzose matrix. Dolomite variably overgrow and has undulatory contacts with quartz grains.

Porosity:
Secondary leaching yields a porosity of 12%.

Comments:
Well sorted siltstone consisting of subangular quartz grains (typically 40μm long) an euhedral dolomite rhombs (typically 55μm long). Calcite grains are anhedral an individual grains are hard to distinguish from one another. Porosity appears to be due t leaching of calcite grains and/or calcite cements up existing porosity. In one part of th section, calcite is 20% of the mineralogical composition and porosity is 1%. Shalie horizons, typically 300μm wide account for approximately 10% of the bulk roc composition.

Well Location: 16-35-026-18W4
Depth (m): 1333.48
Formation: Banff
Rock Classification: SILTY LIMESTONE

Framework: 03%
Cement: 30%
Matrix: 67%

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	57	**Clays**	10
Fe-calcite	00	**Opaques**	01
Dolomite	10	**Quartz**	22
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00

Echinoderms	00	**Pellets**	100

Cement:
Anhedral calcite cements up a quartzose matrix.

Porosity:
No visible porosity.

Comments:
Moderately well sorted limestone consists of anhedral calcite grains typically 35μm long subangular quartz grains typically 45μm long and euhedral dolomite rhombs 60μm long Discontinuous subvertical and subhorizontal shale horizons typically 300μm wide mak up 10-15% of the bulk composition. One 0.7cm long black opaque grain (pyrite) wit quartz inclusions is present.

Well Location: 16-06-027-17W4
Depth (m): 1269.30
Formation: Banff
Rock Classification: CRINOIDAL WACKESTONE

Framework: 18%
Cement: 02%
Matrix: 80%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	85	**Clays**	15
Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	00
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	15	**Fish Scales**	00
Bryozoans	12	**Ostracods**	05
Corals	00	**Pelecypods**	00
Echinoderms	68	**Pellets**	00

Cement:
Coarsely crystalline calcite cement infills leached pockets in skeletal fragments.

Porosity:
No visible porosity.

Comments:

Rock consists of skeletal fragments scattered in a micritic mud matrix. Echinoderm and other broken fragments range in size from 5-100μm, more typically 23μm. Several large bryozoan fragments 2-9mm long are present, as is one large (945μm long) crinoid plate.

Well Location: 16-06-027-17W4
Depth (m): 1274.30
Formation: Banff
Rock Classification: CRINOIDAL WACKESTONE

Framework: 12%
Cement: 01%
Matrix: 87%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	82	Clays	15
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	02
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	07	Fish Scales	00
Bryozoans	08	Ostracods	10
Corals	00	Pelecypods	00
Echinoderms	75	Pellets	00

Cement:
Very rare coarsely crystalline calcite cement infills shell cavities.

Porosity:
No visible porosity.

Comments:
Scattered broken skeletal fragments in a micritic mud matrix. Chalcedony replacement of the interior of one large (3.5mm long) shell.

Well Location: 16-06-027-17W4
Depth (m): 1279.40
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 25%
Matrix: 75%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	05	Clays	08
Fe-calcite	20	Opaques	01

Dolomite	44	**Quartz**	22
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
Cementing mineral grains have overgrown some quartz grains and have undulatory contacts with others. Euhedral dolomite rhombs>Fe-calcite>calcite in terms of compositional percentage and grain size.

Porosity:
Selective secondary leaching yields 1-3% porosity (up to 10% in selected parts of the section). Muddier patches have 0% porosity.

Comments:
Moderately well sorted rock consists of subhedral dolomite and calcite rhombs (40-50μm long) and subangular quartz grains (50-70μm long). Rare green quartz grains.

Well Location: 16-06-027-17W4
Depth (m): 1284.50
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 65%
Matrix: 35%

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	08	**Clays**	04
Fe-calcite	15	**Opaques**	01
Dolomite	42	**Quartz**	30
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
Euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
Porosity ranges from 1-15%, typically 4% due to selective secondary intergranular leaching.

Comments:
Moderately well sorted rock consists of subhedral calcite and dolomite rhombs (typically 30-35μm long with dolomite typically bigger than calcite rhombs) with subangular quartz grains (typically 40-50μm long).

Well Location: 02/06-15-029-10W4 **Framework:** 68%
Depth (m): 1086.22 **Cement:** 30%
Formation: Banff **Matrix:** 02%
Rock Classification: CRINOIDAL PACKSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	86	Clays	10
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	04
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	09	Fish Scales	00
Bryozoans	06	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	85	Pellets	00

Cement:
2 generations of calcite cement are developed. The first generation consists of pyramidal, isopachous fringes on skeletal grains (02% total cements). The second generation consists of coarsely crystalline cement which infills intergranular spaces and shell interiors (98% of total cements).

Porosity:
Fracture porosity is <1%.

Comments:
Syntaxial overgrowths are developed on some echinoderm fragments. Microcrystalline quartz selectively replaces portions of skeletal fragments.

Well Location: 02/06-15-029-10W4 **Framework:** 65%

Depth (m): 1086.59 **Cement:** 30%
Formation: Banff **Matrix:** 05%
Rock Classification: CRINOIDAL PACKSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	82	Clays	15
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	03
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	06	Fish Scales	00
Bryozoans	09	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	80	Pellets	05

Cement:
2 generations of calcite cement are developed. Pyramidal, isopachous calcite grains form fringes on skeletal fragments (03% total cements). The second generation cement consists of coarsely crystalline calcite grains which crystallize in intergranular spaces and shell interiors.

Porosity:
No visible porosity.

Comments:
Inhomogeneous slide. Mixing of grainstone, packstone, and wackestone lithologies due to bioturbation. Micritic mud content is highly variable from 0-25%. Microcrystalline quartz selectively replaces portions of echinoderm and brachiopod fragments. Syntaxial overgrowths on some echinoderm fragments. A sutured contact is observed between some echinoderm fragments.

Well Location: 06-32-029-14W4 **Framework:** 00%
Depth (m): 1117.65 **Cement:** 00%
Formation: Detrital **Matrix:** 100%
Rock Classification: QUARTZ BRECCIA

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	00	Clays	63
Fe-calcite	00	Opaques	01

Dolomite	00	**Quartz**	36
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
None observed.

Porosity:
Fracture porosity is 1%.

Comments:
Very fine to very coarse grained (30-1200μm long, typically 130μm) angular to subrounded (larger clasts) quartz grains in a very fine grained clay matrix. Quartz is present both as megaquartz and as chert. Several muddy wisps.

Well Location: 06-32-029-14W4
Depth (m): 1120.50
Formation: Banff
Framework: 45%
Cement: 55%
Matrix: 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	95	**Clays**	05
Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	00
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	09	**Fish Scales**	00
Bryozoans	05	**Ostracods**	06
Corals	00	**Pelecypods**	00
Echinoderms	80	**Pellets**	00

Cement:
2 generations of calcite cement are present. The first generation consists of pyramidal isopachous cement which developed along some skeletal edges and makes up 5% of the total cements. The second generation makes up 95% of the total cements and consists of

coarsely crystalline, equant, well cleaved cement which infills intergranular spaces. Some skeletal fragments have been leached out and infilled with one of or both generations of cement.

Porosity:
Secondary leached porosity is 7%. Pinpoint dissolution of bryozoans. Inhomogeneous distribution of porosity in the section.

Comments:
Syntaxial overgrowths on echinoderm fragments are very common. Second generation cement is moderately to heavily included.

Well Location: 06-32-029-14W4
Depth (m): 1124.55
Formation: Banff
Framework: 20%
Cement: 05%
Matrix: 75%
Rock Classification: CRINOIDAL WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	39	Clays	44
Fe-calcite	00	Opaques	00
Dolomite	12	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	12	Fish Scales	00
Bryozoans	00	Ostracods	08
Corals	00	Pelecypods	00
Echinoderms	80	Pellets	00

Cement:
2 generations of highly included calcite cement are developed where skeletal fragments are concentrated. The first generation consists of pyramidal, isopachous cement (5% of total cements). Equant, coarsely crystalline cement infills intergranular spaces (95% of total cements.

Porosity:
No visible porosity.

Comments:
Heterogeneous section. Distribution of skeletal components is highly variable, from 0-60% over the section. Microcrystalline quartz and chalcedony selectively replace

portions of echinoderm fragments. Syntaxial overgrowths on some echinoderm fragments. Euhedral dolomite rhombs typically 90μm long float in a dense clay matrix Several stylolites cross-cut the section.

Well Location: 06-32-029-14W4 **Framework:** 20%
Depth (m): 1128.80 **Cement:** 08%
Formation: Banff **Matrix:** 72%
Rock Classification: CRINOIDAL WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	57	Clays	22
Fe-calcite	00	Opaques	01
Dolomite	15	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	08	Fish Scales	00
Bryozoans	00	Ostracods	05
Corals	00	Pelecypods	02
Echinoderms	80	Pellets	05

Cement:
Two generations of calcite cement. First generation consists of pyramidal, isopachous cement (2%). Second generation consists of coarsely crystalline, variably included (clean to heavily included), usually well cleaved calcite cement (98% of total cements).

Porosity:
Inhomogeneously distributed secondary leached and fracture porosity is 2%.

Comments:
Fragmented shells are scattered throughout the section but whole shells are concentrated in certain horizons. Microcrystalline quartz selectively replaces parts of some echinoderm and brachiopod fragments. Several black opaque crystals, typically 1.30mm long (pyrite?).

Well Location: 06-14-030-16W4 **Framework:** 55%
Depth (m): 1292.97 **Cement:** 25%
Formation: Banff **Matrix:** 20%
Rock Classification: CRINOIDAL PACKSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	75	Clays	15
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	10
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	03	Fish Scales	00
Bryozoans	00	Ostracods	06
Corals	00	Pelecypods	00
Echinoderms	90	Pellets	01

Cement:
2 generations of calcite cement are present. The first generation consists of pyramidal, isopachous cement which developed along skeletal fragment edges (5% of total cements). The second generation cement consists of coarsely crystalline cement with well developed cleavage. This cement is restricted to intergranular spaces (95% of total cements).

Porosity:
No visible porosity.

Comments:
Extremely inhomogeneous thin section. Microcrystalline quartz and chalcedony both selectively replaces portions of echinoderm fragments. Either can occur in isolation or in combination with the other (i.e. chalcedony replacement with a microcrystalline quartz rim). Quartz replacement takes the form of both rims and patches.

Well Location: 06-14-030-16W4
Depth (m): 1297.89
Formation: Banff
Framework: 60%
Cement: 40%
Matrix: 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	93	Clays	06
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	00
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	10	Fish Scales	00
Bryozoans	03	Ostracods	08

Corals	00	**Pelecypods**	00
Echinoderms	79	**Pellets**	00

Cement:
One generation of coarsely crystalline calcite cement. Cement is variably included ranging from inclusion free to heavily included.

Porosity:
No visible porosity.

Comments:
Syntaxial overgrowths on echinoderm fragments. Coarsely crystalline calcite cement replaces the interior of some skeletal fragments.

Well Location: 16-31-030-16W4
Depth (m): 1292.76
Formation: Detrital
Rock Classification: QUARTZ BRECCIA

Framework: 00%
Cement: 00%
Matrix: 00%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	00	**Clays**	70
Fe-calcite	00	**Opaques**	01
Dolomite	04	**Quartz**	25
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	**Fish Scales**	00
Bryozoans	00	**Ostracods**	00
Corals	00	**Pelecypods**	00
Echinoderms	00	**Pellets**	00

Cement:
None observed.

Porosity:
Fracture porosity is 1%.

Comments:
Poorly sorted paleosol consisting of subangular quartz grains (range 10-270μm long, typically 65μm) in a muddy matrix. Quartz present as mega-quartz only. Discontinuous, subhorizontal fractures are present.

Well Location: 16-31-030-16W4 **Framework:** 70%
Depth (m): 1297.68 **Cement:** 30%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	94	Clays	06
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	00
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	16	Fish Scales	00
Bryozoans	00	Ostracods	10
Corals	00	Pelecypods	04
Echinoderms	70	Pellets	00

Cement:
2 generations of calcite cement are present. The first generation consists of pyramidal, isopachous cement that is poorly developed on only a few skeletal grains. The second generation cement is heavily included and consists of coarsely crystalline calcite in intergranular spaces. The first and second generation calcite cements make up 5% and 95% of the total cements present respectively.

Porosity:
Fracture porosity is 1%.

Comments:
Syntaxial overgrowths on some skeletal fragments. Several obliquely oriented bifurcating fractures cross-cut the section.

Well Location: 16-31-030-16W4 **Framework:** 65%
Depth (m): 1301.60 **Cement:** 35%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	70	Clays	05

Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	25
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	07	**Fish Scales**	01
Bryozoans	05	**Ostracods**	04
Corals	00	**Pelecypods**	03
Echinoderms	80	**Pellets**	00

Cement:
2 generations of calcite cement are present. The first generation is well developed on skeletal grain surfaces and consists of heavily included, pyramidal, isopachous cement. The second generation consists of coarsely crystalline, blocky calcite which fills in intergranular spaces. The pyramidal and equant calcite cements account for 15% and 85% of the total cements respectively. Microcrystalline and megaquartz cement up shell interiors as well as in between grains.

Porosity:
None observed.

Comments:
Micritic envelopes are present on 10% of the skeletal fragments. Silica is present in both replacement and cementation phases. Microcrystalline quartz replacement of entire grains is observed in 65% of the echinoderm fragments. Very fine grained quartz cements around grains and in interstitial spaces. Shell, dissolution, and silicification rims are all present. Syntaxial overgrowths on some skeletal fragments.

Well Location: 16-31-030-16W4 **Framework:** 70%
Depth (m): 1303.10 **Cement:** 30%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	**%**	**Terrigenous & Other Minerals:**	**%**
Calcite	93	**Clays**	05
Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	02
Fe-dolomite	00		

Framework Components:	**%**		**%**
Brachiopods	05	**Fish Scales**	00

Bryozoans	06	**Ostracods**	05
Corals	00	**Pelecypods**	04
Echinoderms	80	**Pellets**	00

Cement:
2 generations of inclusion rich calcite cement are developed. The first generation consists of bladed isopachous cements which developed along skeletal margins. The second generation consists of coarsely crystalline equant grains that fill intergranular spaces. The first and second generation cements account for 2% and 98% of the total cements respectively.

Porosity:
Bifurcating fracture porosity and rare secondary leaching in patches yields a porosity of 1%.

Comments:
Syntaxial overgrowths on echinoderm fragments. Microcrystalline quartz selectively replaces parts of echinoderm fragments. No quartz cementation as there was at a depth of 1301.6m. Some shells are broken due to compaction.

Well Location: 16-31-030-16W4 **Framework:** 52%
Depth (m): 1309.10 **Cement:** 48%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	92	**Clays**	05
Fe-calcite	00	**Opaques**	00
Dolomite	00	**Quartz**	03
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	10	**Fish Scales**	00
Bryozoans	06	**Ostracods**	08
Corals	00	**Pelecypods**	05
Echinoderms	71	**Pellets**	00

Cement:
2 generations of calcite cement are developed. First generation consists of heavily included, pyramidal, isopachous cement which is present along skeletal grain boundaries. The second generation of cement consists of slightly included, coarsely crystalline equant

calcite which crystallizes in intergranular spaces. First and second generation cements account for 4% and 96% of the total cement content respectively.

Porosity:
Fracture porosity is 1%.

Comments:
Syntaxial overgrowths on echinoderm fragments. Several skeletal grains have had their interiors dissolved and subsequently infilled with the two cements; isopachous, pyramidal calcite cement lines the grain cavity and the interior is filled with coarsely crystalline cement. Microcrystalline quartz selectively replaces parts of some echinoderm fragments.

Well Location: 16-31-030-16W4 **Framework:** 55%
Depth (m): 1315.12 **Cement:** 45%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	90	Clays	05
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	10	Fish Scales	00
Bryozoans	04	Ostracods	03
Corals	00	Pelecypods	03
Echinoderms	80	Pellets	00

Cement:
2 generations of calcite cement are developed. The first generation consists of inclusion rich bladed isopachous cement. The second generation consists of coarsely crystalline equant cement with well developed cleavage. The first generation cement accounts for 10% of the total cements and it developed along skeletal fragment edges. 90% of the total cements is accounted for by the second generation cement which infills intergranular spaces. Second generation cement ranges from inclusion free to heavily included. Inclusion density decreases with distance from skeletal fragment.

Porosity:
No visible porosity.

Comments:
Microcrystalline quartz selectively replaces parts of echinoderm fragments. Ghost fabrics are generated by the replacement of echinoderm fragments by second generation blocky cements. Syntaxial overgrowths on skeletal fragments. Several shells are filled with micritic muds. Several wackestone/packstone patches.

Well Location: 16-04-031-11W4
Depth (m): 1097.20
Formation: Banff
Rock Classification: SILTY DOLOMITE

Framework: 00%
Cement: 60%
Matrix: 40%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	02	Clays	00
Fe-calcite	00	Opaques	02
Dolomite	54	Quartz	42
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	00	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	00	Pellets	00

Cement:
Euhedral dolomite rhombs cement up a quartzose matrix.

Porosity:
Homogeneously distributed secondary leached porosity is 25%.

Comments:
Moderately well sorted rock consists of euhedral dolomite rhombs (typically 40μm long), subrounded quartz grains (typically 50μm long) and rare anhedral calcite crystals. Porosity is lower where the percentage of calcite is higher.

Well Location: 16-04-031-11W4
Depth (m): 1099.75
Formation: Banff
Rock Classification: MUDSTONE

Framework: 03%
Cement: 00%
Matrix: 97%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	70	Clays	25
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	04
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	15	Fish Scales	00
Bryozoans	00	Ostracods	00
Corals	00	Pelecypods	00
Echinoderms	85	Pellets	00

Cement:
None observed.

Porosity:
No visible porosity.

Comments:
Floating broken skeletal fragments and subangular quartz grains in a micritic mud matrix. Highly bioturbated section.

Well Location: 06-15-031-16W4
Depth (m): 1236.22
Formation: Banff
Rock Classification: QUARTZ BRECCIA

Framework: 10%
Cement: 90%
Matrix: 00%

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	45	Clays	00
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	55
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	20	Fish Scales	00
Bryozoans	10	Ostracods	25
Corals	00	Pelecypods	05
Echinoderms	40	Pellets	00

Cement:

Dominant cementation is by quartz. Microcrystalline and megaquartz both replace portions of skeletal fragments and cement up the space in between them. Finely crystalline calcite cement is also present in a minor capacity.

Porosity:
Fracture porosity is 1%.

Comments:
Heterogeneous section. Hard to distinguish individual skeletal fragments from each other because they are partially or wholly replaced by calcite and quartz cements. There are several generations of quartz replacement and cementation.

Well Location: 06-15-031-16W4
Depth (m): 1237.40
Formation: Banff
Framework: 18%
Cement: 01%
Matrix: 81%
Rock Classification: SKELETAL WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	78	Clays	20
Fe-calcite	00	Opaques	01
Dolomite	00	Quartz	01
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	10	Fish Scales	00
Bryozoans	08	Ostracods	07
Corals	00	Pelecypods	00
Echinoderms	75	Pellets	00

Cement:
Coarsely crystalline calcite cements up the interior of predominantly ostracod shells as well as other skeletal fragments. Hard to determine mineral composition percentages because slide is not stained.

Porosity:
No visible porosity.

Comments:
Microcrystalline quartz replacement of portions of skeletal fragments. Broken and whole shells are present, some echinoderm plates up to 3mm long. Broken skeletal fragments are aligned.

Well Location: 06-15-031-16W4 **Framework:** 12%
Depth (m): 1251.30 **Cement:** 02%
Formation: Banff **Matrix:** 86%
Rock Classification: SKELETAL WACKESTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	75	Clays	20
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	05
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	11	Fish Scales	00
Bryozoans	08	Ostracods	15
Corals	00	Pelecypods	00
Echinoderms	62	Pellets	04

Cement:
One generation of coarsely crystalline calcite cement is present.

Porosity:
No visible porosity.

Comments:
Inhomogeneous section consists of scattered skeletal fragments and subangular quartz grains (typically 40μm long) in a micritic mud matrix. Micritic muddy pods contain scattered calcite and quartz grains.

Well Location: 16-31-31-16W4 **Framework:** 55%
Depth (m): 1306.25 **Cement:** 45%
Formation: Banff **Matrix:** 00%
Rock Classification: CRINOIDAL GRAINSTONE

Mineralogy

Carbonate Minerals:	%	Terrigenous & Other Minerals:	%
Calcite	93	Clays	05
Fe-calcite	00	Opaques	00
Dolomite	00	Quartz	02
Fe-dolomite	00		

Framework Components:	%		%
Brachiopods	15	**Fish Scales**	00
Bryozoans	10	**Ostracods**	05
Corals	00	**Pelecypods**	00
Echinoderms	70	**Pellets**	00

Cement:
Two generations of calcite cement are present. The first generation consists of pyramidal, isopachous cement along grain edges (5%). The second generation consists of coarsely crystalline, well cleaved, heavily included calcite cement (95% of total cements).

Porosity:
Secondary leaching of skeletal fragments and fracturing yield 2-5% porosity. Pinpoint dissolution of bryozoans.

Comments:
Syntaxial overgrowths, micritic envelopes and microcrystalline quartz replacement of skeletal fragments.

APPENDIX F
X-RAY DIFFRACTION DATA

WELL	DEPTH (M)	MINERALOGY (%) CALCITE	DOLOMITE	ILLITE	KAOLINITE	PLAG	QUARTZ	TS
02/16-14-025-12W4	1045.20	100	0	0	0	0	0	Y
	1045.47	82*	0	18	0	0	0	N
	1047.50	99	0	0	0	0	1	Y
	1049.52	23	34	12	0	0	31	Y
	1051.50	10	38	16	0	0	36	Y
02/16-22-025-12W4	1041.50	52	0	7	0	0	41	Y
	1044.75	33	14	28	1	0	24	Y
	1047.12	54	0	16	0	0	30	N
	1048.46	38*	0	19	0	0	43	N
	1049.50	28	0	47	0	0	25	N
	1051.70	32	0	45	0	0	23	N
14-35-025-15W4	1121.47	72	0	28	0	0	0	Y
	1126.00	85	0	15	0	0	0	Y
	1128.00	21	31	0	0	0	48	Y
	1134.00	25	35	0	0	0	40	Y
06-22-026-16W4	1168.63	3	0	0	0	0	97	Y
	1171.65	95	0	0	0	0	5	Y
	1174.85	88	0	0	0	0	12	Y
	1178.78	42	29	0	0	0	29	Y
	1183.30	10	61	0	0	3	26	Y
	1188.00	60	18	0	0	0	22	Y
	1191.90	72	5	0	0	0	23	Y
02/10-29-026-16W4	1221.45	0	60	0	0	1	39	Y
	1225.80	24	33	0	0	0	43	Y
16-35-026-18W4	1328.00	1	53	0	0	0	46	Y
	1330.44	0	61	0	0	2	37	Y
	1332.08	1	38	0	0	0	61	Y
	1333.48	20	39	0	0	0	41	Y
16-06-027-17W4	1284.50	6	59	0	0	0	35	Y
06-32-029-14W4	1124.55	71	23	0	0	0	6	Y
	1128.80	85	11	0	0	0	4	Y
16-31-030-16W4	1297.68	79	0	21	0	0	0	Y
	1301.60	69	0	4	0	0	27	Y
	1303.10	90	0	8	2	0	0	Y
	1309.10	99	0	0	0	0	1	Y

*Mg CALCITE
TS=THIN SECTION

APPENDIX G
SAMPLE DETAILS

WELL LOCATION	YEAR	BNF TOP(M)	EXAMINED INTERVAL(M)	DEPTH (M)	TS	SEM	XRD
00/04-18-021-08W4/0	1952	1010	1011.3-1013.7				
00/13-23-022-12W4/0	1946	973	972.0-985.4				
00/01-06-022-13W4/0	1945	1045	1127.7-1133.5				
00/11-31-023-09W4/0	1959	931	1041.5-1049.7				
00/14-34-023-09W4/0	1987	969	972.0-987.0	974.24	X		
				978.50	X		
				987.00	X		
00/16-05-023-14W4/0	1944	1032	1026.2-1061.0				
00/16-05-023-14W4/0	1944	1032	1108.8-1147.8				
00/16-06-025-08W4/0	1985	991	1076.0-1094.0	1077.10	X		
				1091.50	X		
02/16-14-025-12W4/0	1985	1041	1045.0-1060.0	1045.20	X	X	X
				1045.47			X
				1047.50	X	X	X
				1049.52	X	X	X
				1051.50	X	X	X
02/16-22-025-12W4/0	1985	1039	1040.0-1052.0	1041.50	X	X	X
				1044.75	X	X	X
				1047.12			X
				1048.46			X
				1049.50			X
				1051.70			X
00/14-35-025-15W4/0	1987	1120	1116.5-1139.0	1121.47	X		X
				1126.00	X	X	X
				1128.00	X	X	X
				1134.00	X		X

WELL LOCATION	YEAR	BNF TOP(M)	EXAMINED INTERVAL(M)	DEPTH (M)	TS	SEM	XRD
				1135.95		X	
				1139.00		X	
00/02-31-026-12W4/0	1952	1085	1142.4-1149.4				
00/06-22-026-16W4/0	1980	1165	1155.0-1193.0	1168.63	X		X
				1171.65	X		X
				1174.85	X		X
				1178.78	X		X
				1183.30	X		X
				1188.00	X		X
				1191.90	X		X
02/10-29-026-16W4/0	1984	1208	1215.0-1227.0	1215.75	X		
				1221.45	X		X
				1225.80	X		X
00/16-20-026-17W4/0	1989	1332	1337.0-1355.0				
02/10-31-026-17W4/0	1986	1272	1277.0-1295.3	1277.70	X		
				1280.80	X		
				1288.00	X		
				1293.30	X		
00/06-25-026-18W4/0	1980	1389	1391.0-1409.0	1392.44	X		
				1400.10	X		
				1404.44	X		
00/16-35-026-18W4/0	1981	1313	1327.0-1343.8	1328.00	X		X
				1330.44	X		X
				1332.08	X		X

WELL LOCATION	YEAR	BNF TOP(M)	EXAMINED INTERVAL(M)	DEPTH (M)	TS	SEM	XRD
				1333.48	X		X
00/14-05-027-08W4/0	1952	1032	1029.0-1038.7				
00/06-18-027-15W4/0	1960	1202	1200.2-1218.5				
00/11-35-027-16W4/0	1960	1257	1257.0-1267.6				
00/16-06-027-17W4/0	1981	1267	1269.0-1287.0	1269.30	X		
				1274.30	X		
				1279.40	X		
				1284.50	X		X
00/14-16-027-18W4/0	1988	1288	1304.0-1316.0				
00/07-31-028-11W4/0	1979	1052	1044.0-1056.0				
00/10-32-028-16W4/0	1963	1364	1359.6-1373.7				
02/06-15-029-10W4/0	1987	1076	1086.0-1092.0	1086.22	X		
				1086.59	X		
00/07-33-029-12W4/0	1960	1087	1085.0-1093.0				
00/06-32-029-14W4/0	1990	1119	1116.5-1131.0	1117.65	X		
				1124.55	X		X
				1128.80	X		X
00/14-34-029-15W4/0	1953	1253	1249.6-1261.9				
00/06-02-029-16W4/0	1986	1305	1295.0-1309.5				
00/14-32-029-16W4/0	1988	1380	1381.0-1396.0				
00/05-03-030-09W4/0	1946	997	992.4-1008.8				
00/05-03-030-09W4/0	1946	997	1022.6-1047.9				
00/06-31-030-15W4/0	1985	1220	1228.0-1232.0				

WELL LOCATION	YEAR	BNF TOP(M)	EXAMINED INTERVAL(M)	DEPTH (M)	TS	SEM	XRD
00/12-02-030-16W4/0	1952	1282	1281.4-1296.3				
00/06-14-030-16W4/0	1987	1289	1289.0-1311.0	1292.97	X		
				1297.89	X		
00/05-23-030-16W4/0	1985	1274	1267.0-1284.0				
00/16-28-030-16W4/0	1986	1258	1248-1267.5				
00/16-31-030-16W4/0	1986	1296	1285.0-1317.3	1292.76	X		
				1297.68	X	X	X
				1299.30			
				1301.60	X		X
				1303.10	X	X	X
				1307.20			
				1309.10	X		X
				1315.12	X		
00/16-04-031-11W4/0	1982	1099	1096.0-1103.25	1097.20	X		
				1099.75	X		
00/06-15-031-16W4/0	1986	1236	1235.0-1254.0	1236.22	X		
				1237.40	X		
				1251.30	X		
00/16-31-031-16W4/0	1986	1248	1294.0-1312.55	1306.25	X		
TOTAL:					59	12	35

LEGEND:
TS=THIN SECTION XRD=X-RAY DIFFRACTION
SEM=SCANNING ELECTRON MICROSCOPE

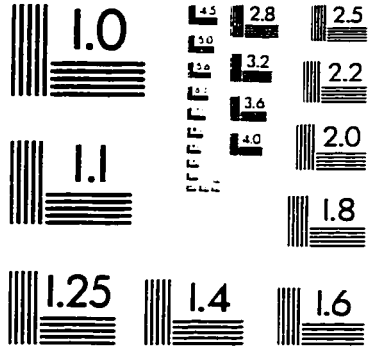
APPENDIX H
CORES EXAMINED - CYCLIC BREAKDOWN

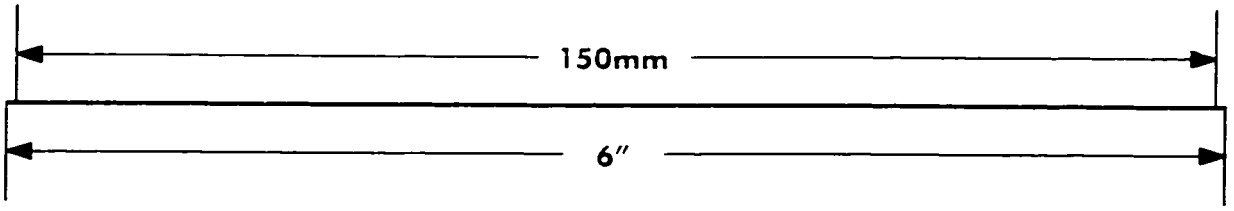
CORES EXAMINED-CYCLIC BREAKDOWN

CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4
00/16-05-023-14W4/00	00/11-31-023-09W4/00	00/16-05-023-14W4/00	00/01-06-022-13W4/00
00/16-04-031-11W4/00	00/16-05-023-14W4/00	00/16-16-025-08W4/00	00/16-05-023-14W4/00
	00/16-16-025-08W4/00	00/02-31-026-12W4/00	00/07-31-028-11W4/00
		00/16-31-031-16W4/00	00/07-33-029-12W4/00
			00/16-31-031-16W4/00

CYCLE 5	CYCLE 6	CYCLE 6 (CONTINUED)
00/14-05-027-08W4/00	00/04-18-021-08W4/00	00/14-34-029-15W4/00
02/06-15-029-10W4/00	00/13-23-022-12W4/00	00/06-02-029-16W4/00
00/05-03-030-09W4/00	00/14-34-023-09W4/00	00/14-32-029-16W4/00
	00/16-05-023-14W4/00	00/06-31-030-15W4/00
	02/16-14-025-12W4/00	00/12-02-030-16W4/00
	02/16-22-025-12W4/00	00/06-14-030-16W4/00
	00/14-35-025-15W4/00	00/05-23-030-16W4/00
	00/06-22-026-16W4/00	00/16-28-030-16W4/00
	02/10-29-026-16W4/00	00/16-31-030-16W4/00
	00/16-20-026-17W4/00	00/06-15-031-16W4/00
	02/10-31-026-17W4/00	
	00/06-25-026-18W4/00	
	00/16-35-026-18W4/00	
	00/06-18-027-15W4/00	
	00/11-35-027-16W4/00	
	00/16-06-027-17W4/00	
	00/14-16-027-18W4/00	
	00/10-32-028-16W4/00	
	00/06-32-029-14W4/00	

TEST TARGET (QA-3)





APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

© 1993, Applied Image, Inc., All Rights Reserved