GEOMETRY OF FACIES PACKAGES AND E5 EROSION SURFACE
IN THE CARDIUM FORMATION, FERRIER FIELD

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IN THE

CARDIUM FORMATION,

FERRIER FIELD, ALBERTA

By

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ABSTRACT

The Upper Cretaceous (Turonian) Cardium Formation was deposited along the western margin of the Western Interior Seaway, within the Alberta Foreland Basin of the Canadian Cordillera. Like other Cretaceous formations within the Western Interior Seaway, it is characterized by a series of linear sandstone and conglomerate bodies encased in marine shales. Ferrier oil field is one of the western-most of the Cardium linear sand ridges.

The Raven River Member in Ferrier field consists of two coarsening-upward sequences. The upper sequence contains hummocky cross-stratified sandstones, which suggest deposition below fairweather wave base. Cross sections show that the two sequences are scoured to variable depths by a major erosion surface (termed "E5").

The E5 erosion surface defines an undulating topography of gently and steeply dipping surfaces, termed "terraces" and "bevels," respectively. Ferrier field and neighbouring Willesden Green field are terraces; an erosional bevel coincident with the northeastern margin of Ferrier separates the two terraces. These morphological elements cannot be explained by either totally subaqueous or totally subaerial erosion; erosion at the shoreface during stillstands of sea level is invoked.

The terraces at Ferrier and Willesden Green have gentle southwestward dips relative to horizontal well log markers,

but were probably cut horizontally at fairweather wave base during stillstand. This suggests that the Raven River sediments were dipping to the northeast during shoreface incision. Since the mean dip of the terrace at Willesden Green (0.07 degrees) exceeds that of the terrace at Ferrier (0.03 degrees), a downward flexing of the sediment surface is suggested in addition to an initial basinward tilt.

The conglomerates which immediately overlie the E5 erosion surface at northeastern Ferrier are interpreted to be shoreface gravels.

Based on the morphology of the E5 erosion surface basin-wide, and assuming a constant depth to fairweather wave base of 10 meters, it is possible to separate the horizontal and vertical erosion components of stillstand and steady sea level rise from one another. In total, 132 meters of vertical sea level rise occurred over the 85 kilometers which separates Carrot Creek field from western Ferrier field. Assuming that the rate of erosion effective during incision of the E5 surface to be 1.2 m/year, then it would have taken just over 70,000 years to cut the erosion surface from Carrot Creek to Ferrier. During this time, sea level rose at an average rate of 1.9 mm/year.

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Oleh Wowkodaw of Home Oil Company, Calgary, allowed me access to the computing facilities there, for which I thank him. Liz Barr (McMaster class of 1987) deserves virtually all the credit for photocopying over two thousand well logs, of which only a small percentage are presented in this thesis; I admire her endurance and extend my appreciation. I thank Mark Birchard (McMaster class of 1987) for thoroughly cleaning and photographing many Ferrier cores, and pointing out items of geologic interest along the way. I also appreciate the prompt and friendly service afforded me at the Alberta Energy Resource Conservation Board's Core Research Centre, Calgary.

Jack Whorwood (Dept. of Geology, McMaster University) deserves special thanks for developing the photographs presented and liberally offering his advice on thesis presentation. Shelley Leggitt produced the mesh diagrams in Figures 5.6 and 5.7, and suggested many useful ideas regarding the organization of this thesis. Anne Marie Plint shaded the mesh plots. Kathy Bergman and Steve Zymela assisted in the use of the computer as a word-processor.

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 - INTRODUCTION

1.1 INTRODUCTION

Many formations in the Cretaceous Western Interior Seaway, such as the Shannon, Sussex, Gallup/Tocito, Viking, and Cardium, are characterized by long, linear sandstone and conglomerate bodies. These bodies, which are usually tens of kilometers long and 3-4 kilometers wide, trend parallel or sub-parallel to the regional strandline. They are problematic in origin, having apparently been deposited on the open shelf tens of kilometers away from the time-equivalent paleoshoreline (examples given by Walker, 1984; Tillman and Siemers, 1984; Slatt, 1984). Internally, the linear ridges are rooted in offshore marine muds and have been considered to coarsen gradually upward into sandstones and conglomerates.

If these linear ridges were deposited tens of kilometers from the nearest shoreline, then a number of problems arise. Sand and gravel can be moved across the shelf by various combinations of storm-generated geostrophic flows, density currents, and tidal currents, but there is no convincing explanation for how this coarse material can then be focussed into long, narrow, en echelon ridges. The problem of the formation of coarsening-upward sequences with gravel on top remained unresolved until very recently; this problem is the major focus of this thesis.

The Cardium Formation (Upper Turonian) of the Western Interior Seaway has received considerable attention in recent years because it consists of a series of these linear ridges which are characterized by coarsening-upward sequences capped by conglomerates.

Recent work in the Cardium Formation has suggested that the problems of transporting coarse material across the shelf and moulding it into linear ridges are no longer the most important ones. In the subsurface a series of erosion surfaces have been traced, and numbered E1 through E7 (Plint et al., 1986; updated by Plint et al., 1987). These dissect the Cardium. They have been used to establish an event stratigraphy or "allostratigraphy" (North American Commission on Stratigraphic Nomenclature, 1983) for the Cardium in the subsurface (Plint et al., 1986), and the six allostratigraphic units bounded by these surfaces have a set of allomember names (Plint et al., 1986). Of these seven erosion surfaces, E5 has become the best documented. Bergman (1987) has shown that the conglomerates at Carrot Creek field overlie the E5 erosion surface, and hence the idea of a continuous coarsening-upward sequence which ends in a conglomerate is not correct. The conglomerates are not genetically related to the underlying coarsening-upward sequence. The erosion surfaces are thought to have been created as the result of sea level fluctuation (Plint et al., 1986; Bergman and Walker, 1987).

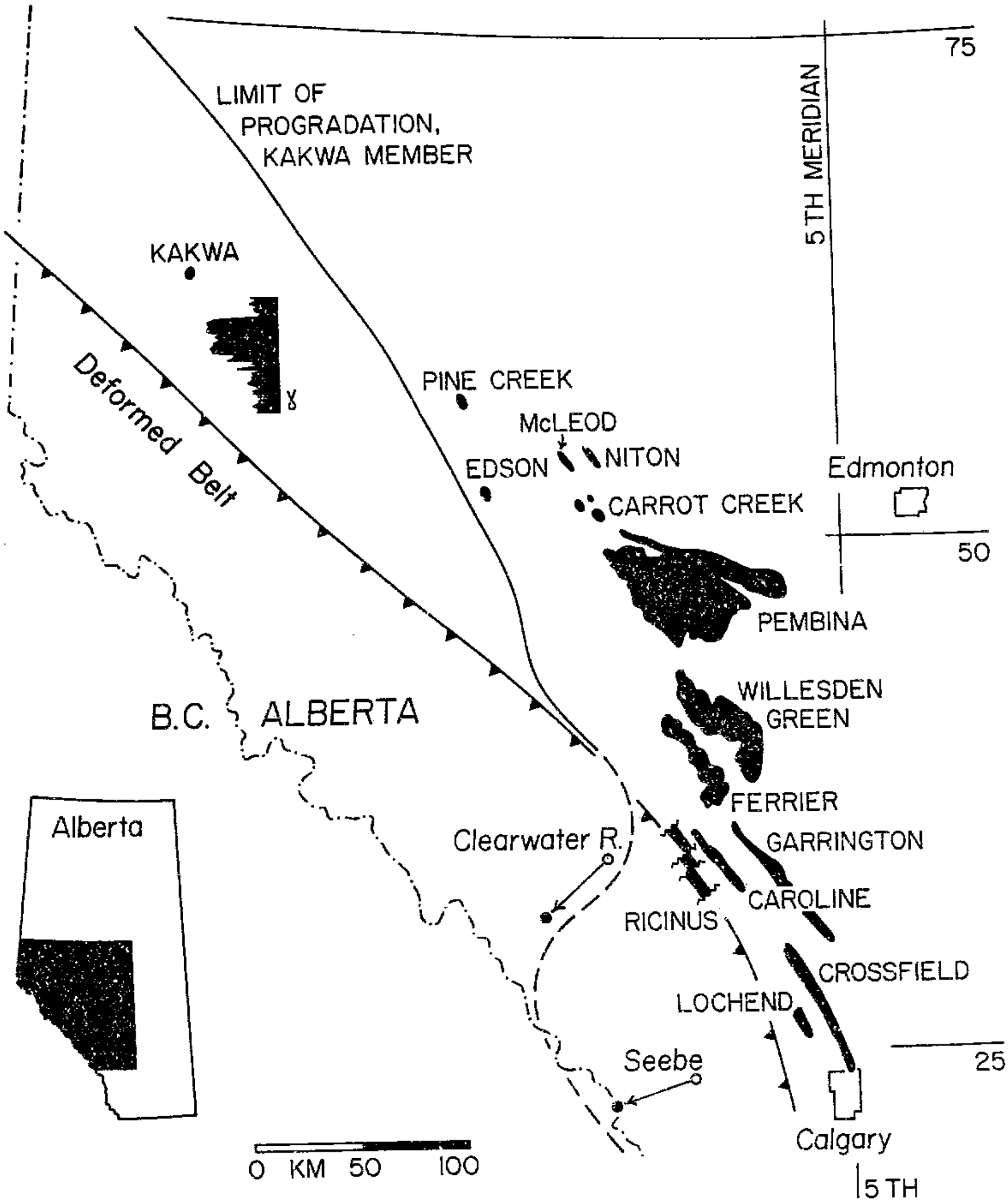
The problems posed earlier regarding the "offshore bar" hypothesis become inapplicable in the context of erosion surfaces and sea level fluctuations.

1.2 FERRIER FIELD AND ITS RELATION TO OTHER CARDIUM OIL FIELDS

Ferrier oil field is one of the western-most long, linear Cardium oil fields producing from the Raven River Member (Plint et al., 1986) and the overlying Carrot Creek conglomerate (Figure 1.1). It is the field geographically closest to the presumed Raven River shoreface in the west, although this shoreface has never been identified, either in subsurface or in outcrop. Ferrier and adjacent Willesden Green field are compared to the more "distal" and well-documented Pembina and Carrot Creek oil fields farther to the northeast (Leggitt, 1987; Bergman, 1987). The morphology of the E5 surface must be documented in detail at Ferrier in order to understand the full regional implications of it.

This thesis emphasizes the role of sea level fluctuation and erosional shoreface incision in determining the erosional morphology of the major E5 surface which dissects both Ferrier and Willesden Green. The distribution of the conglomerate which rests on top of the E5 surface is compared to that found in the Pembina and Carrot Creek fields. Sand body development and geometry of the Raven River Member is documented for Ferrier and part of Willesden

Figure 1.1 Map of south central Alberta showing location of subsurface Cardium oil fields. Open circles indicate outcrop exposure at Seebe and Clearwater River. Black circles indicate their restored location after palinspastic reconstruction (Walker, 1986).


LIMIT OF
PROGRADATION,
KAKWA MEMBER
5TH MERIDIAN
75
KAKWA
Deformed Belt
PINE CREEK
McLEOD
NITON
EDSON
CARROT CREEK
Edmonton
50
PEMBINA
WILLESDEN
GREEN
B.C.
ALBERTA
FERRIER
Alberta
Clearwater R.
GARRINGTON
CAROLINE
RICINUS
CROSSFIELD
LOCHEND
Seebe
25
0 KM 50 100
Calgary
5 TH

Green, and is compared to the "offlapping" sequences of Keith (1985, 1987) for Willesden Green (recently questioned by Walker and Eyles, in preparation), and to the southeastward shingling pattern of Raven River sands in Ferrier hypothesized by Griffith (1981).

CHAPTER 2 - BACKGROUND AND SETTING

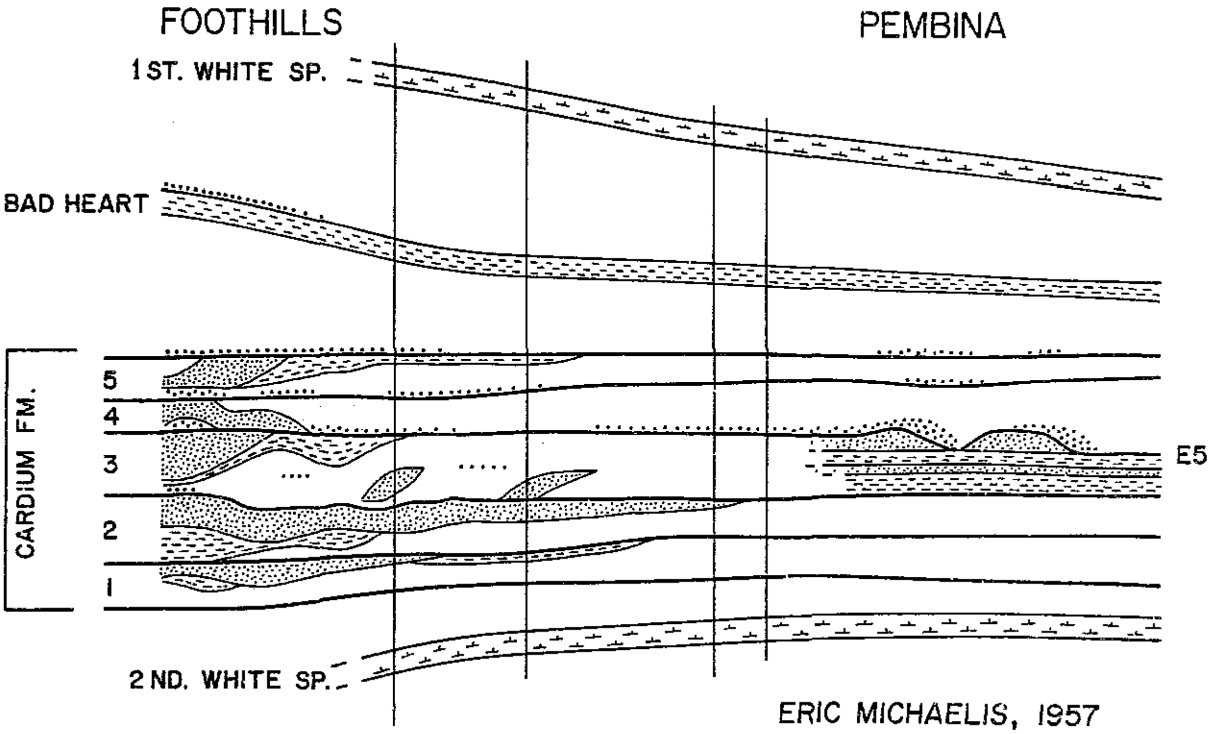
2.1 PREVIOUS WORK

There is a wealth of published information available regarding the Cardium Formation. Only those works which are relevant to this thesis will be mentioned here; the reader is referred to Walker (1983a) and Bergman (1987, pp. 1-67) for additional background.

In 1963, Stott published his classic Cardium outcrop study which had been initiated by the Geological Survey of Canada in 1954, following the discovery of oil in the Cardium Formation at Pembina the previous year. He proposed a six member "layer cake" stratigraphy for the Cardium, which has since been modified by Duke (1985). Stott's work postdated an earlier attempt by Michaelis (1957) to correlate Cardium outcrop with subsurface data (Figure 2.1). Michaelis' stratigraphic packages anticipate what is now called an "event stratigraphy." Later industry studies by Berven (1966) and Swagor et al. (1976) tried to explain the offshore transport of coarse Cardium sediments by storm events. It was later suggested by Wright and Walker (1981) that Cardium gravel emplacement as bedload was unreasonable. However, their assumption of emplacement during only one storm was certainly incorrect (Walker, pers. comm., 1987).

An integrated, detailed study of Cardium stratigraphy and sedimentology was initiated in 1982, and the first

Figure 2.1 Correlation of Cardium outcrop to subsurface as suggested by Michaelis (1957). Note that the five coarsening-upward sequences are separated from the overlying conglomerates. The relative position of the E5 surface (Plint et al., 1986) is indicated (after Michaelis, 1957).

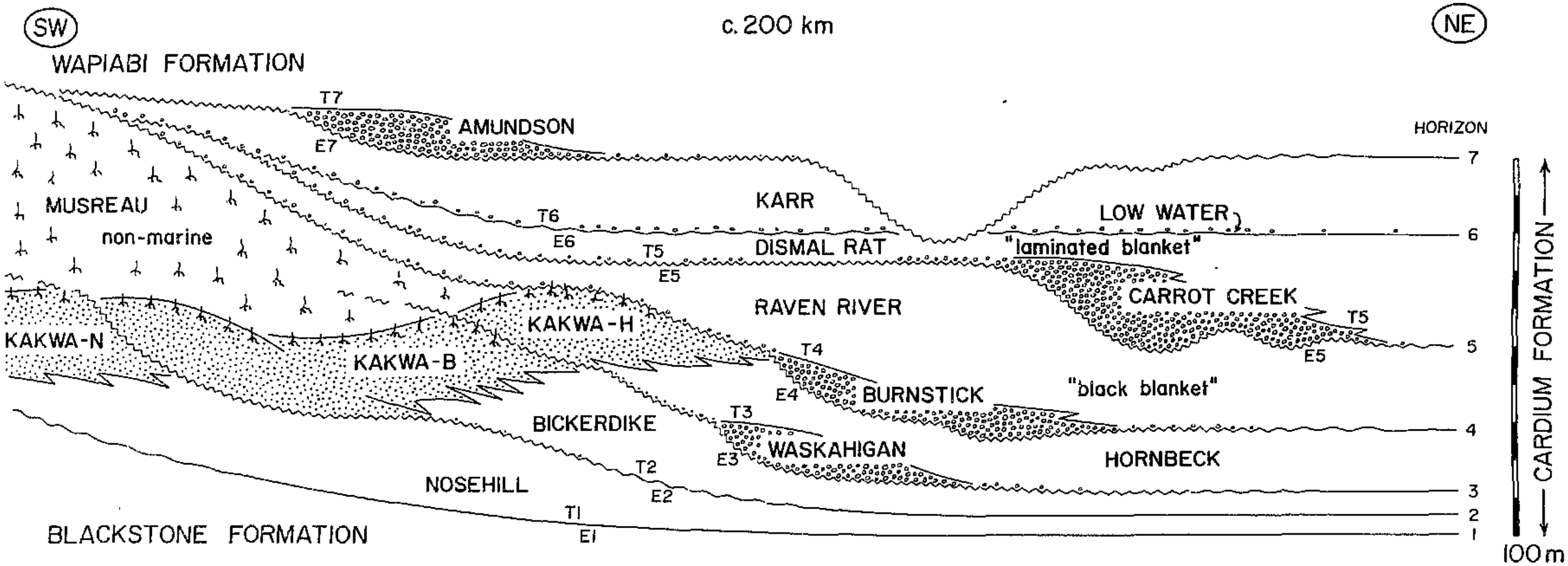

FOOTHILLS
PEMBINA
1 ST. WHITE SP.
BAD HEART
CARDIUM FM.
5
4
3
2
1
E5
2 ND. WHITE SP.
ERIC MICHAELIS, 1957

publications from this study consisted of a series of papers (Walker, 1983a,b,c) focussing on regional correlation between Ricinus, Caroline, and Garrington fields.

More recently, Plint et al. (1986) have divided the Cardium Formation in the subsurface into stratigraphic packages separated by basin-wide erosional unconformities numbered E1 through E7 (Figure 2.2). Bartlett (1987), Bergman (1987), Plint and Walker (1987), and Bergman and Walker (1986, 1987) have documented the geometry of the various sedimentary packages of the Cardium Formation.

This thesis is concerned specifically with Ferrier field. The only previous study of this area has been that of Griffith (1981), who suggested that the Cardium sandstones there were deposited as a series of southeastward shingling sandbodies. Keith (1985, 1987) has suggested a depositional model for the Cardium sandstones and conglomerates at the adjacent Willesden Green field. He documented a series of northeast-dipping, offlapping coarsening-upward sequences, the southwestern edges of which are depositional. This model has recently been modified by Walker and Eyles (in preparation), in which there is no apparent shingling of the sands in Willesden Green; in fact, the thickest sands are stacked vertically, rather than being offset as the term "shingling" implies. Furthermore, Walker and Eyles (in preparation) have suggested that the southwest leading edges

Figure 2.2 Proposed Member terminology for the Cardium Formation. The event stratigraphy shown is based on the recognition and correlation of regionally extensive erosion surfaces numbered E1 through E7. Each erosion surface is followed by a transgression, numbered T1 through T7. Where the conglomerates which overlie the erosion surfaces are limited to thin pebble horizons, the E and T surfaces are essentially coincident. Where the deposits of conglomerate are thick (e.g., 20 m at Carrot Creek), the E surface is traced beneath the conglomerate, and the T surface separates the conglomerate from the overlying mudstones (after Walker and Eyles, in preparation; modified from Plint et al., 1986).


SW
c. 200 km
NE
WAPIABI FORMATION
T7
AMUNDSON
E7
HORIZON
7
MUSREAU
non-marine
KARR
T6
LOW WATER
6
E6
T5
DISMAL RAT
"laminated blanket"
E5
RAVEN RIVER
CARROT CREEK
T5
KAKWA-H
KAKWA-N
KAKWA-B
T4
E5
5
"black blanket"
E4
BURNSTICK
T3
4
BICKERDIKE
E3
WASKAHIGAN
HORNBECK
T2
NOSEHILL
E2
3
T1
2
BLACKSTONE FORMATION
E1
1
CARDIUM FORMATION
100 m

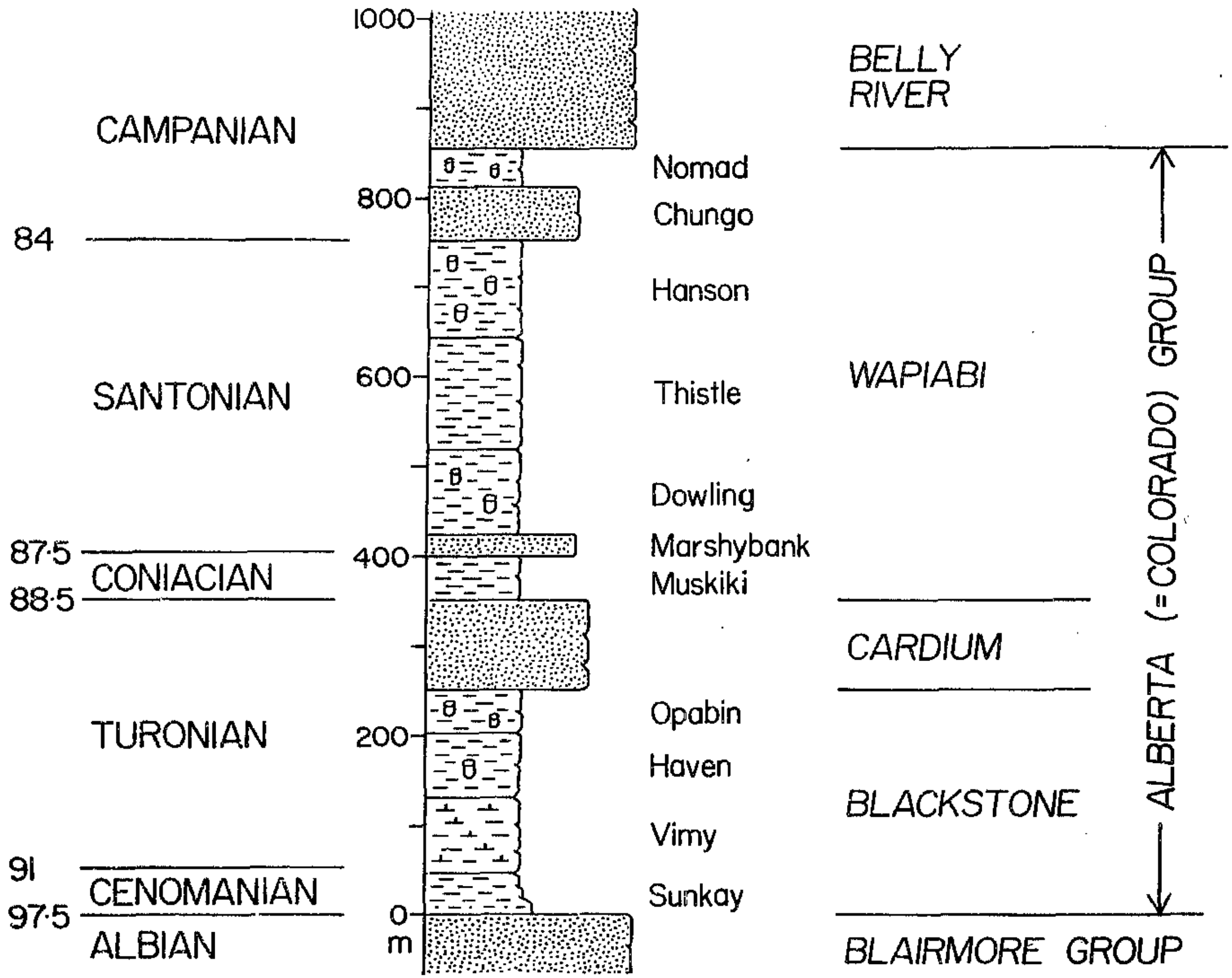
of the Willesden Green sands are erosional, rather than depositional.

2.2 STRATIGRAPHY OF THE ALBERTA GROUP

The Upper Cretaceous (Turonian) Cardium Formation is composed of mudstones, sandstones, and conglomerates. It overlies about 250 meters of marine shales assigned to the Blackstone Formation, and is overlain by about 500 meters of marine shales of the Wapiabi Formation. The three formations together compose the Alberta Group (Figure 2.3), which is equivalent to the Colorado Group in the United States (Stott, 1963). The Cardium is roughly time equivalent to the Ferron, Frontier, and Gallup Sandstones of the southern part of the Western Interior Seaway.

Portions of the Alberta Group crop out in the Foothills of the Canadian Rocky Mountains. Here, the Cardium Formation is approximately 100 meters thick, and can be divided into a series of coarsening-upward sequences (Duke, 1985). The Cardium in the subsurface beneath the Alberta Plains can also be divided into coarsening-upward sequences (Plint et al., 1986), but there is, as yet, no well-established correlation between the sequences of the subsurface and outcrop. A preliminary, possible correlation has been suggested by Walker (1986), based on the work of Duke (1985), Plint et al. (1986), and others.

Figure 2.3 Stratigraphy of the Alberta Group (Colorado Group) in the Alberta Foothills. Absolute ages (Palmer, 1983) are given on the left (after Walker, 1985a)


CAMPANIAN
84
SANTONIAN
87·5
CONIACIAN
88·5
TURONIAN
91
CENOMANIAN
97·5
ALBIAN
1000
800
600
400
200
0
m
Nomad
Chungo
Hanson
Thistle
Dowling
Marshybank
Muskiki
Opabin
Haven
Vimy
Sunkay
BELLY RIVER
WAPIABI
CARDIUM
BLACKSTONE
BLAIRMORE GROUP
ALBERTA (=COLORADO) GROUP

The stratigraphy of the Cardium Formation is based on the recognition and correlation of sharply bounded coarsening-upward sequences, separated by basin-wide unconformities numbered E1 through E7 (Plint et al., 1986). This thesis focusses on the E5 surface at Ferrier field, which erosively truncates the coarsening-upward Raven River Member (Walker, 1986; Plint et al., 1986). The E5 erosion surface is commonly a knife-sharp contact between Raven River sediments and the overlying Carrot Creek Member, which includes the thick conglomerates at Carrot Creek field (Bergman, 1987) and all the other conglomerates and pebble veneers which rest unconformably on the E5 surface. This thesis also briefly examines the two overlying members, the Dismal Rat and Karr Members. The Dismal Rat Member (Plint et al., 1986) includes the dark mudstones ("laminated blanket") which overlie the Carrot Creek Member up to the log marker labelled "E6" on the cross sections in this thesis. The last stratigraphic unit to be considered is the Karr Member (Plint et al., 1986), which is bounded below by the E6/T6 surface and above by the E7/T7 surface.

2.3 BIOSTRATIGRAPHY AND CHRONOSTRATIGRAPHY

The Cardium Formation is of Upper Turonian age (Stott, 1963). It lies within the Scaphites preventricosus Cobban ammonite zone (Jeletzky, 1976) and the Inoceramus deformis Meek bivalve zone (Jeletzky, 1976). The Cardium is bounded below by the _Pseudoclavulina sp._ foraminiferal zone and above by the _Trochammina sp._ foraminiferal zone (Wall, 1967), but the Cardium Formation itself cannot be subdivided using forams.

If the Turonian encompasses 88.5 to 91 Ma, as suggested by Palmer (1983), then it is possible that the entire Cardium Formation was deposited in approximately one million years, given that the uppermost Blackstone is also Upper Turonian.

2.4 STRUCTURAL SETTING

The Cardium Formation at Ferrier field maintains a regional dip of approximately 0.5 degrees to the southwest. No folds or major faults have been observed, although localized faulting in northern Ferrier is evident in repeated sections of the Raven River Member (well 10-17-42-9W5 and others).

Jones (1980) suggested regional isostatic adjustment faulting in the Alberta Basin as a structural control on the hydrocarbon entrapment within oil fields, including Cardium reservoirs. The hypothesis of long, vertical faults throughout Caroline and Garrington fields, and along northeastern Willesden Green may easily be extended to Ferrier. However, this thesis suggests that the Cardium sands in Ferrier are largely structurally unaffected. It seems likely that Jones' proposed vertical displacement of the Cardium "zone" log marker and the Cardium reservoir sand in cross sections may be, and probably is, an artifact of erosional irregularity, rather than postdepositional structural displacement.

2.5 FERRIER FIELD

Ferrier field is approximately 175 kilometers northwest of downtown Calgary (Figure 1.1). It is located between townships 38 and 42, ranges 7W5 to 9W5. Discovered in 1963, it postdates the discovery of vast reserves of oil in the Cardium sandstones at Pembina in 1953. Over 700 wells penetrate the Cardium at Ferrier; within the confines of the thesis map area, 1267 wells penetrate the reservoir or the off-field stratigraphically equivalent horizon. The elongate shape of the field is a function of both the preservation of the Raven River reservoir sandstone and the deposition of patches of conglomerate on top of the E5 unconformity. Erosion along the E5 surface has removed most of the Raven River sand in the off-field areas.

The estimated in-place gas reserves are 12,171 x 10^6 cubic meters, with an average net pay zone of 6.5 meters. The average porosity of the gas-bearing net pay is 15.9% (G.S.C., 1981). In-place oil reserves are estimated at 30,700 x 10^6 cubic meters for the E-pool, 18,000 x 10^6 cubic meters for the D-pool, and 15,400 x 10^6 cubic meters for the

G-pool (G.S.C., 1981). Oil net pay zones average 3.4 - 4.0 meters, porosity ranges between 13 and 14.8%.

Ferrier is located to the west of Willesden Green field, and to the north of Caroline field. It lies on strike with Garrington field to the south (Figure 1.1).

2.6 DATA COLLECTION

This study is based on the examination and correlation of 144 cores and over 1200 shallow-focus resistivity well logs. Standard three-inch diameter core was logged from stratigraphic bottom to top, paying special attention to the thickness of individual facies and the nature of the contacts between them. Lithology, grain size, sedimentary structures, and trace fossil assemblages were noted for each facies. Cored sections which were logged but not included in the drafted core cross sections presented in the foldouts at the back of this thesis are available for viewing at the Department of Geology, McMaster University. Colour and black and white photographs were taken of continuous sections of boxed core, while individual facies, contacts, or particularly noteworthy features were photographed as close-ups.

Cores were provided by the Alberta Energy Resource Conservation Board (ERCB), Calgary. Well logs were collected at Home Oil Company Ltd., Calgary.

CHAPTER 3 - FACIES DESCRIPTIONS

3.1 INTRODUCTION

The Raven River, Carrot Creek, and the Dismal Rat Members of the Cardium Formation at Ferrier and Willesden Green fields can be described in terms of the original eight facies described in detail by Walker (1983b). Facies numbered 9 through 14 (Walker, 1985b) and 15 through 22 (Plint and Walker, 1987) are not found anywhere within the field area, despite Ferrier's western location and presumed proximity to the final position of the Raven River shoreline. A brief description of the eight facies is presented; facies 7, 7A, and three types of facies 8 are elaborated on. Facies 2P is introduced, and an ideal vertical facies sequence is illustrated (Figure 3.8) based on the mean thickness of individual facies measured in Ferrier and Willesden Green cores.

3.2 FACIES DESCRIPTIONS

Facies 1, Massive Dark Mudstone

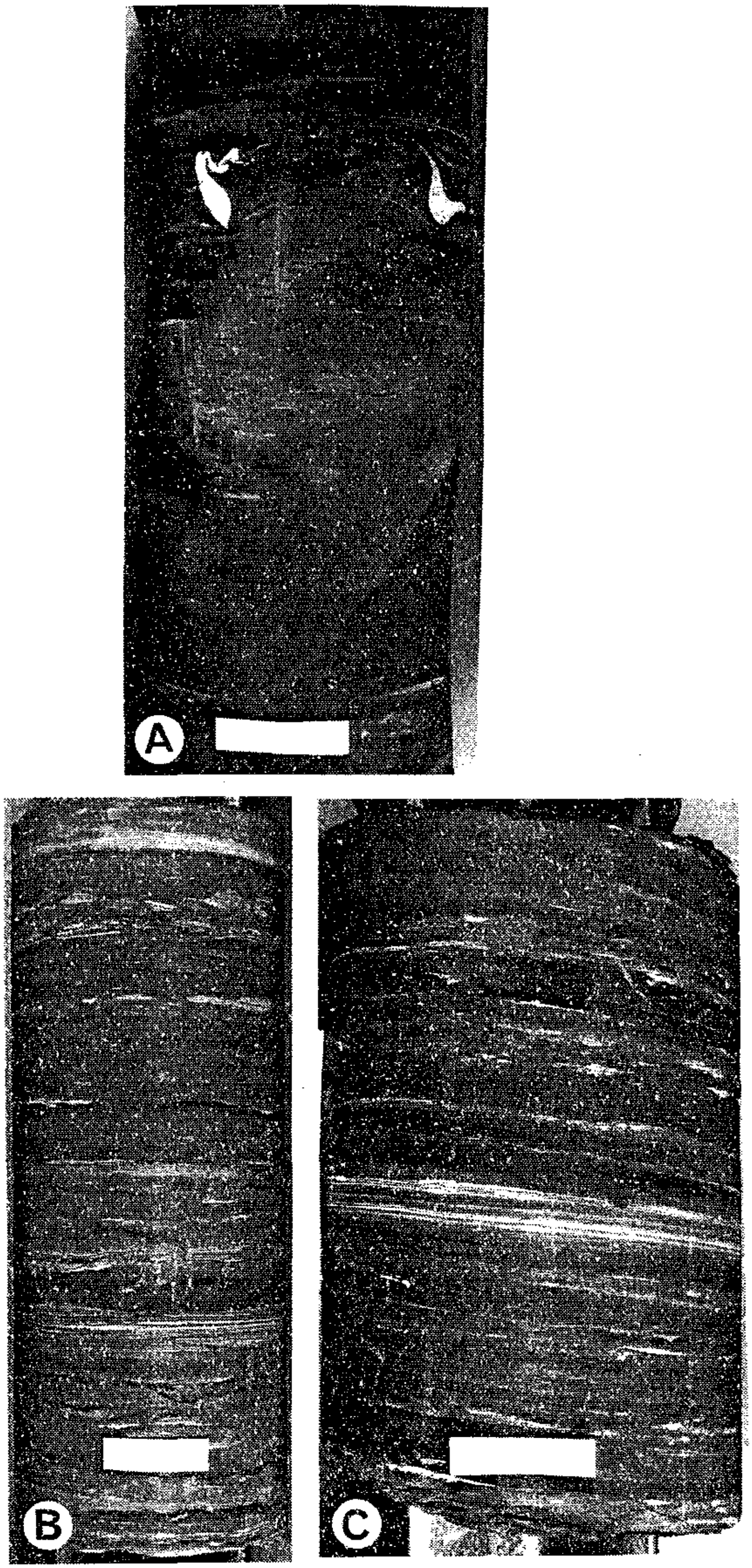
Facies 1 (Figure 3.1a) is a very dark grey to black structureless mudstone found at the base of the Raven River Member, and at the base of the Karr Member. It contains no recognizable burrow forms, but exhibits a faint mottling presumably made by the pinworm Gordia (Walker, 1983b).

Figure 3.1

A. Facies 1, Massive Dark Mudstone. Note fragments of *Inoceramus* shell. 10-19-41-8W5, 6831 ft. Scale is 3 cm.

B. Facies 2, Laminated Dark Mudstone. 10-8-41-8W5, 6850 ft. Scale is 3 cm.

C. Facies 2, Laminated Dark Mudstone. 4-28-41-8W5, 6820 ft. Scale is 3 cm.


A
B
C

Massive sideritic nodules, pyrite clusters, and Inoceramus shell fragments are found in a few cores.

Facies 2, Laminated Dark Mudstone

Facies 2 (Figure 3.1b,c) mudstones are similar to those of facies 1, but are distinct in that they contain thin (1-4 mm), silty laminations, hence the informal designation "laminated blanket" mentioned earlier. Laminations are sharp-based with diffuse tops and may be either continuous across the width of the core or discontinuous, having been disturbed by burrowing organisms. Layers may contain fine internal parallel lamination and may be broadly undulose. The facies occupies almost all of the thickness of the Dismal Rat Member.

Facies 2P, Laminated Dark Mudstone Containing Pebbles

Facies 2P (Figure 3.2a,b,c) mudstones are thinly laminated facies 2 shales which contain sparse rounded chert pebbles rarely exceeding 1 cm clast size. Facies 2P differs from facies 3P, 4P, and 5P of Bergman and Walker (1986) and Bergman (1987) in that the delicate laminae of facies 2 are preserved and have not been pervasively bioturbated. Facies 2P always overlies the main clast-supported conglomerates (facies 8) of the Carrot Creek Member.

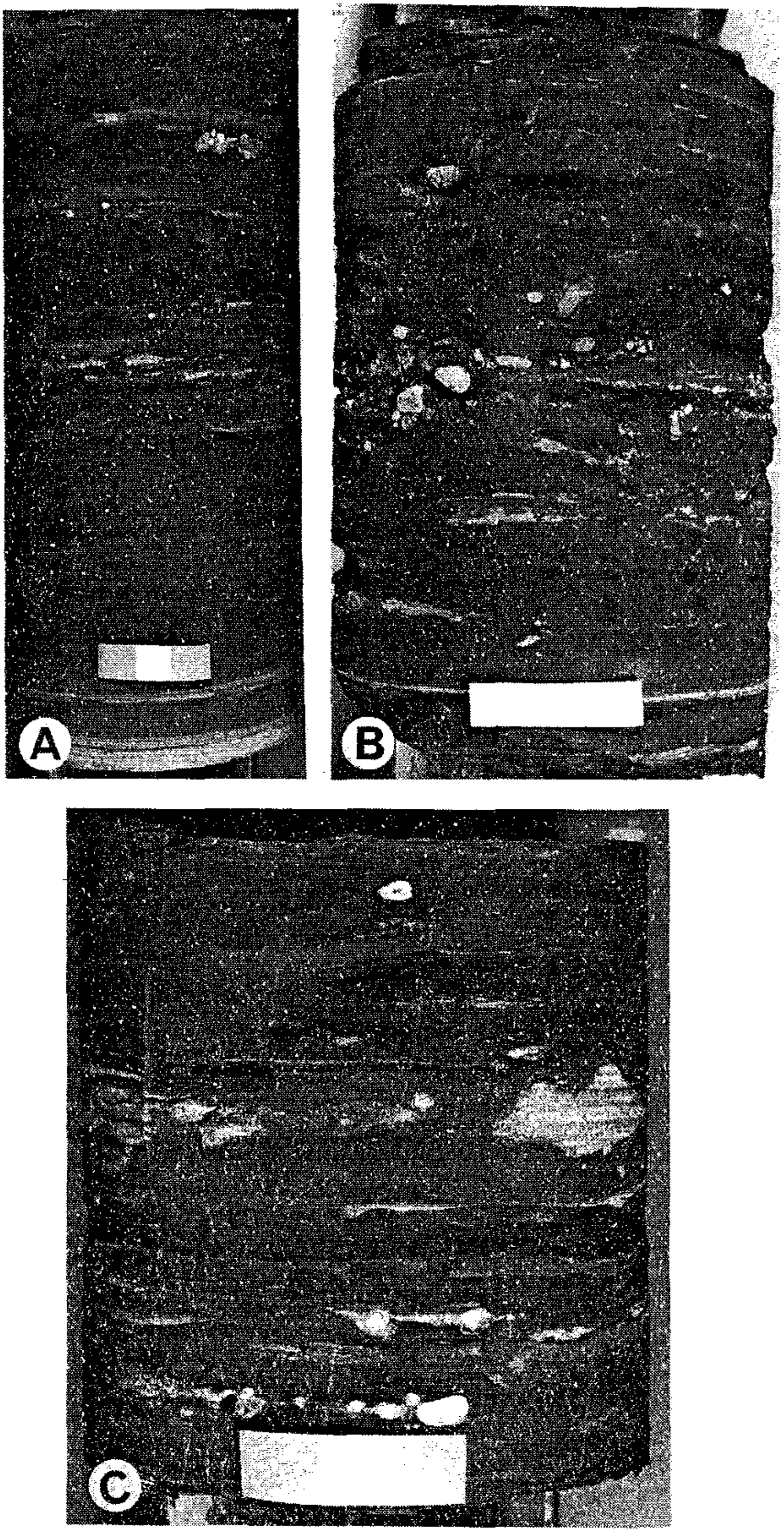
Facies 3, Dark Bioturbated Muddy Siltstone

Figure 3.2

A. Facies 2P, Laminated Dark Mudstone Containing Pebbles. 10-8-41-8W5, 6860 ft. Scale is 3 cm.

B. Facies 2P, Laminated Dark Mudstone Containing Pebbles. 10-13-41-9W5, 7111 ft. Scale is 3 cm.

C. Facies 2P, Laminated Dark Mudstone Containing Pebbles. 14-22-39-8W5, 7260 ft. Scale is 3 cm.


A
B
C

Facies 3 (Figure 3.3a) overlies the massive dark mudstones of facies 1. It contains discontinuous silty laminae and occasional patches of very fine sand, having been thoroughly "stirred" by mud-dwelling organisms. The silt and very fine sand impart an overall lighter colour to facies 3 in contrast to the dark grey to black underlying facies 1.

Facies 4, Pervasively Bioturbated Muddy Siltstone

Facies 4 (Figure 3.3b,c) is gradational from facies 3 to facies 5. Silt and very fine sand compose up to 50% of this pervasively bioturbated facies. Some sharp-based, wave-rippled, graded beds (1-5 cm thick) are preserved, but the thorough mixing of the substrate by burrowing and scavenging organisms is the dominant characteristic. Trace forms include _Teichicnus_, _Terebellina_, _Rhizocorallium_, _Skolithos_, _Helminthopsis_, _Zoophycos_, and occasional _Chondrites_.

Facies 5, Bioturbated Sandstone

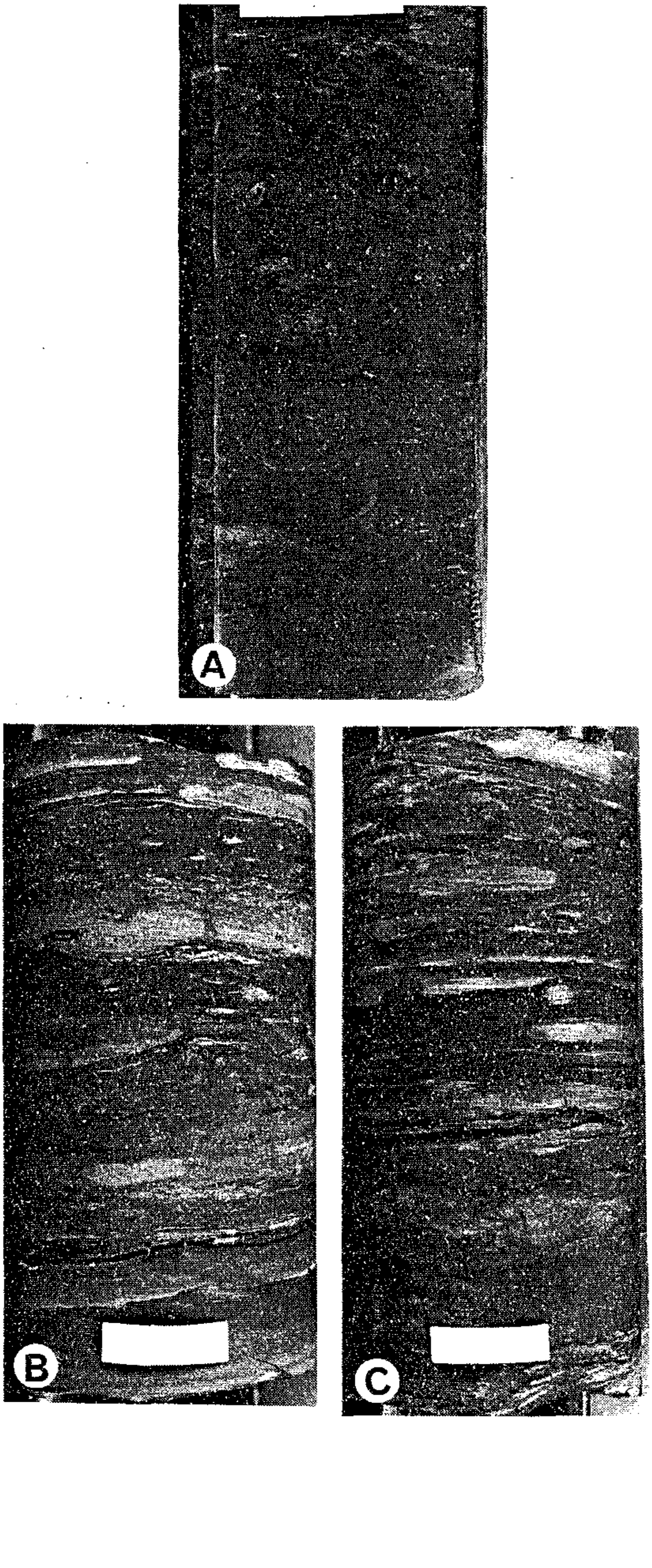
Facies 5 (Figure 3.4a,b) is a pervasively bioturbated, sandy (> 50% silt/very fine sand) version of facies 4. Graded and non-graded wave-rippled beds up to several centimeters thick may be preserved, although intensive bioturbation rarely leaves bedding intact. Trace forms include _Teichicnus_, _Terebellina_, _Ophiomorpha_, _Planolites_,

Figure 3.3

A. Facies 3, Dark Bioturbated Muddy Siltstone. 4-28-41-8W5, 6891 ft. Scale is 3 cm.

B. Facies 4, Pervasively Bioturbated Muddy Siltstone. 1-19-41-6W5, 6390 ft. Scale is 3 cm. Facies 4 is sandier and more thoroughly bioturbated than Facies 3.

C. Facies 4, Pervasively Bioturbated Muddy Siltstone. 10-20-41-6W5, 6345 ft. Scale is 3 cm.


A
B
C

Skolithos, Zoophycos, Helminthopsis, Rhizocorallium, Conichnus, Rosselia, and abundant Chondrites.

Facies 6, Speckled Gritty Mudstone

Facies 6 (Walker, 1983b) is not found within the Raven River, Carrot Creek, or Dismal Rat Members of the Cardium Formation at Ferrier or Willesden Green field.

Facies 7, Non-bioturbated Sandstone

The very fine and fine-grained sandstones of facies 7 (Figures 3.4c,d and 3.5a,b,c,d) make up the Raven River reservoir sands within Ferrier and Willesden Green fields. Individual beds, which vary in thickness from a few centimeters to tens of centimeters, may be massive (Figure 3.4c) or may contain parallel lamination (Figure 3.4d), low-angle inclined stratification (Figure 3.5a,b), or wave ripple cross-lamination (Figure 3.5c). No angle of repose cross-bedding or current ripples have been observed in core. Rip-up mud clasts, both sideritized and non-sideritized (Figure 3.5d), are usually well-rounded and lie with their long axes parallel to bedding planes. Bioturbation is exceedingly rare and is largely limited to occurrences of large Conichnus burrows.

The abrupt-based beds dominated by low-angle (< 15 degrees), inclined stratification are interpreted as hummocky cross-stratified.

Figure 3.4

A. Facies 5, Bioturbated Sandstone. Note occurrence of *Helminthopsis* and *Terebellina*. 9-7-40-8W5, 2208 m. Scale is 3 cm.

B. Facies 5, Bioturbated Sandstone. 10-13-41-9W5, 7124 ft. Scale is 3 cm.

C. Facies 7, Non-bioturbated Sandstone. Massive. 4-20-41-8W5, 6857 ft. Scale is 3 cm.

D. Facies 7, Non-bioturbated Sandstone. Parallel lamination. 10-13-41-9W5, 7115 ft. Scale is 3 cm.

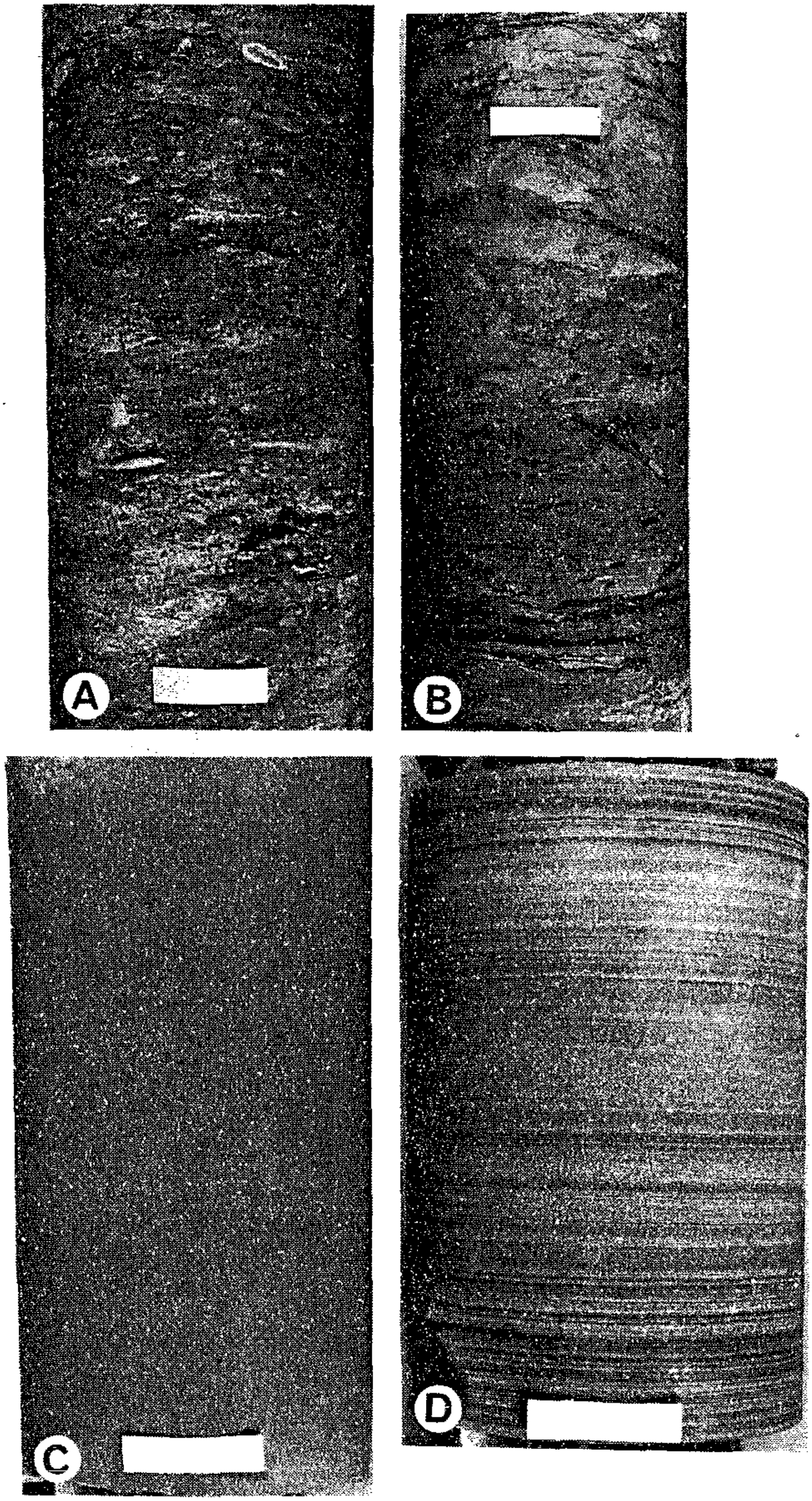

A
B
C
D

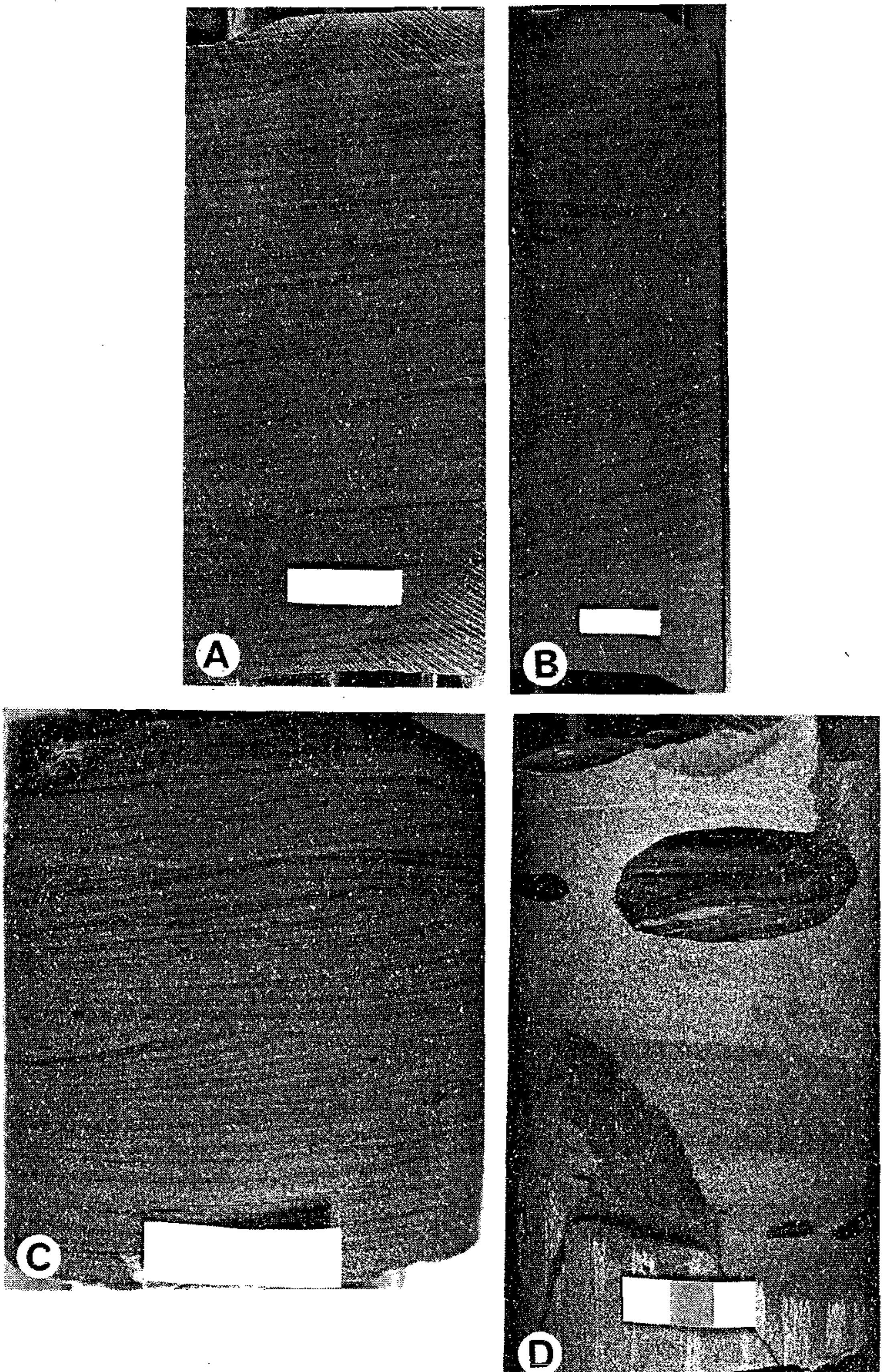
Figure 3.5

A. Facies 7, Non-bioturbated Sandstone. Low-angle inclined stratification (<15 degrees) interpreted to be hummocky cross-stratification. 6-2-42-7W5, 6527 ft. Scale is 3 cm.

B. Facies 7, Non-bioturbated Sandstone. Low-angle inclined stratification (<15 degrees) interpreted to be hummocky cross-stratification. 9-11-41-10W5, 7600 ft. Scale is 3 cm.

C. Facies 7, Non-bioturbated Sandstone. Wave-ripple cross-lamination. 10-26-40-8W5, 6754 ft. Scale is 3 cm.

D. Facies 7, Non-bioturbated Sandstone. Rounded mud-clasts parallel to stratification. 11-13-40-9W5, 7497 ft. Scale is 3 cm.


A
B
C
D

Facies 7A, Interbedded Sandstone and Mudstone

Facies 7A (Figure 3.6a) is very fine to fine-grained sandstone interbedded with black, featureless mudstone. Sharp-based sandstone beds range from 1 cm to 5 cm in thickness and are usually wave rippled or wave cross-laminated. Mudstone intercalations occur as drapes between 5 mm and 2 cm thick. Bioturbation is rare, and is restricted to occurrences of sandy Planolites within the mudstone.

Facies 8, Conglomerates

The conglomerates can be divided into numerous types (Bergman, 1987); three types will be presented here. Thicknesses vary from a thin pebble horizon to a maximum of 12 meters at northern Ferrier field.

Clast-supported conglomerates

The clast-supported conglomerates of the Carrot Creek Member (Figure 3.6b,c) can be divided into stratified and massive. Startification is rare in the Carrot Creek area (Bergman and Walker, 1986; Bergman, 1987), and is virtually non-existent in the Ferrier/Willesden Green area. Textural variations such as changes in grain size, sorting, and the presence or absence of matrix exist, and even some vague imbrication (Figure 3.6b) of clasts has been observed, but no definite stratification has been detected. Massive clast-supported conglomerates (Figure 3.6c) form the bulk of the

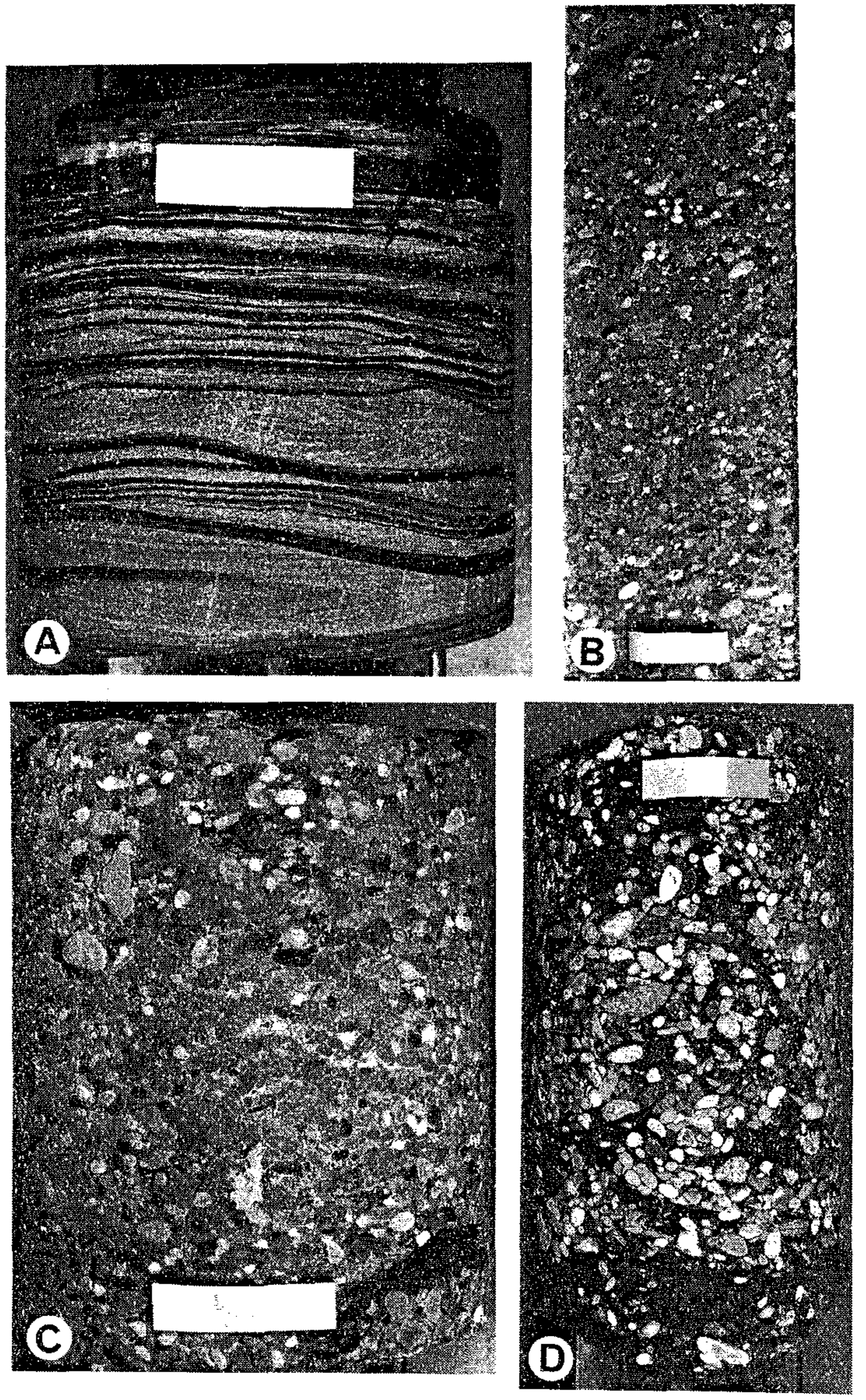
Figure 3.6

A. Facies 7A, Interbedded Sandstone and Mudstone. Note wave-ripple cross-lamination and absence of bioturbation. 16-26-41-7W5, 6590 ft. Scale is 3 cm.

B. Facies 8, Conglomerate. Clast-supported, with vague imbrication. 10-10-41-8W5, 6678 ft. Scale is 3 cm.

C. Facies 8, Conglomerate. Clast-supported, no stratification. 4-20-41-8W5, 6848 ft. Scale is 3 cm.

D. Facies 8, Conglomerate. Mud-supported. 10-20-41-8W5, 6789 ft. Scale is 3 cm.


A
B
C
D

clast-supported conglomerates at Ferrier and Willesden Green.

Clast size varies over the field area, ranging from 2 mm to 6.5 cm; average size is 5 mm.

Matrix-supported conglomerates

Matrix-supported conglomerates (Figures 3.6d and 3.7a) are referred to as "mudstones with conglomerate stringers" by Bergman and Walker (1986) and are designated facies 3P, 4P, and 5P, suggesting that these are pebbly versions of facies 3,4, and 5. However, the matrix in the matrix-supported conglomerates at Ferrier and Willesden Green fields is almost always black mudstone which bears little resemblance to the silty, pervasively bioturbated facies described earlier. This mud-supported conglomerate differs from facies 2P in that the mud does not contain continuous silty laminations (1-4 mm thick) within it. Also, the pebbles in facies 2P are not confined to continuous pebble stringers but are sparse and seemingly randomly distributed, occurring singly or in small, discontinuous lenses. Pebbles in the matrix-supported conglomerates often occur in "stringers" which are continuous across the width of the core. The pebbles rarely exceed 1 cm in size.

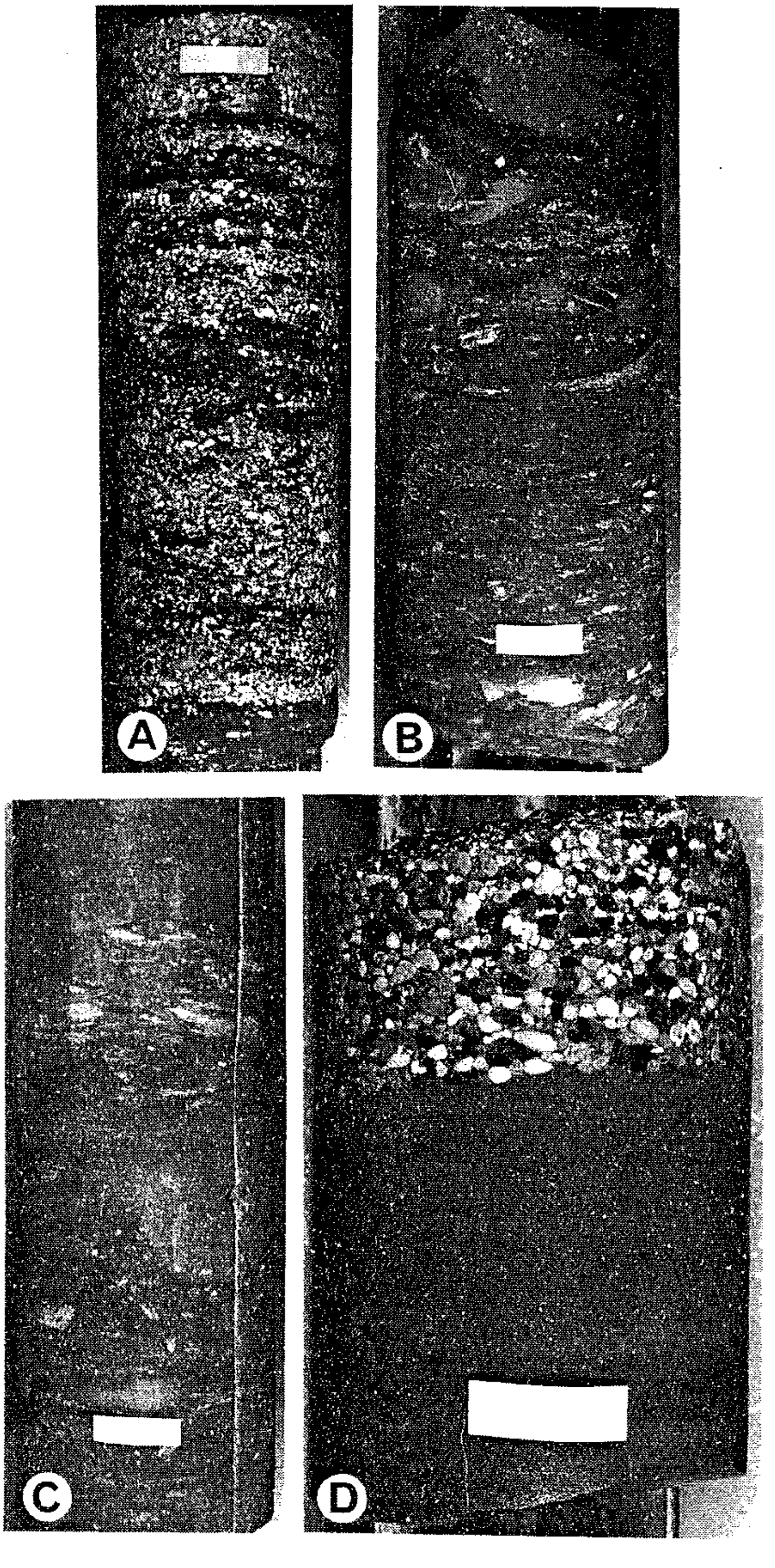
Figure 3.7

A. Facies 8, Conglomerate. Mud-supported. 4-2-39-7W5, 2080 m. Scale is 3 cm.

B. Gritty Siderite. Angular to sub-angular chert grains up to 3 mm in partially sideritized bioturbated muddy siltstone. 2-31-38-6W5, 2076 m. Scale is 3 cm.

C. Gritty Siderite. Angular to sub-angular chert grains up to 2 mm in partially sideritized bioturbated muddy siltstone. 6-10-38-6W5, 6758 ft. Scale is 3 cm.

D. E5 Erosion Surface. A knife-sharp contact between Facies 7 horizontally-stratified sandstone and a clast-supported chert pebble conglomerate. 11-13-40-9W5, 7489 ft. Scale is 3 cm.


A
B
C
D

Gritty siderite

The gritty siderite facies (Figure 3.7b,c) consists of coarse subangular to angular chert grains set in a background of bioturbated silt and mud which is usually partially sideritized. In Ferrier and Willesden Green fields, the gritty horizon varies in thickness from 5 to 30 cm and contains grains which range in size from medium-grained sand to 4 mm clasts. It is included in Bergman (1987) and Leggitt (1987) as part of facies 8 (conglomerates).

3.3 VERTICAL FACIES SEQUENCE

The Raven River Member consists of two coarsening-upward sequences (Figures 3.8 and 3.9) over a large area of the field, but they become one large sequence in central Ferrier field. The lower "b" sequence is invariably rooted in facies 1 and gradually coarsens upward through facies 3 and 4, often grading into the bioturbated sandstones of facies 5.

The "b" sequence is abruptly overlain by either facies 3 or 4 of the "a" sequence, and it is at the base of these units that the gritty siderite horizon is often found. However, it should be noted that the gritty siderite is not restricted to the base of the muddy facies directly overlying the bioturbated sandstones of the "b" sequence, as it is in the Carrot Creek area (Bergman, 1986, 1987; Bergman

Figure 3.8 An idealized vertical facies sequence showing facies relationships. Facies numbers, each preceeded by the letter "F", are shown to the immediate right of the stratigraphic section beside each facies ("F8" is shown to the left of the section). The coarsening-upward sequences "a" and "b" of the Raven River Member are indicated. Gritty siderite may occur at various horizons within the "a" sequence as indicated by the bracketed interval. A resistivity well log signature which shows the "a" and "b" sequences is provided for comparison.

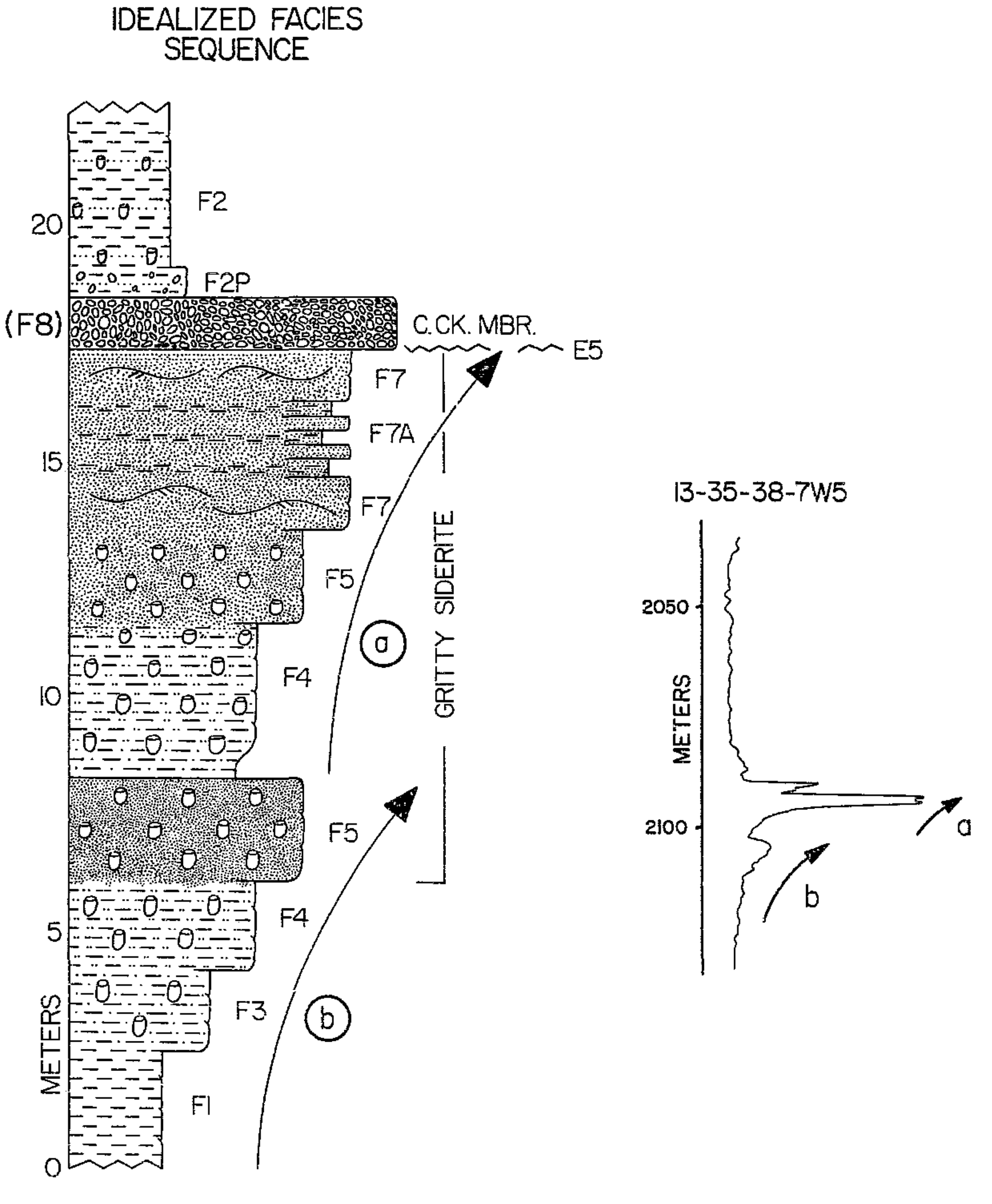
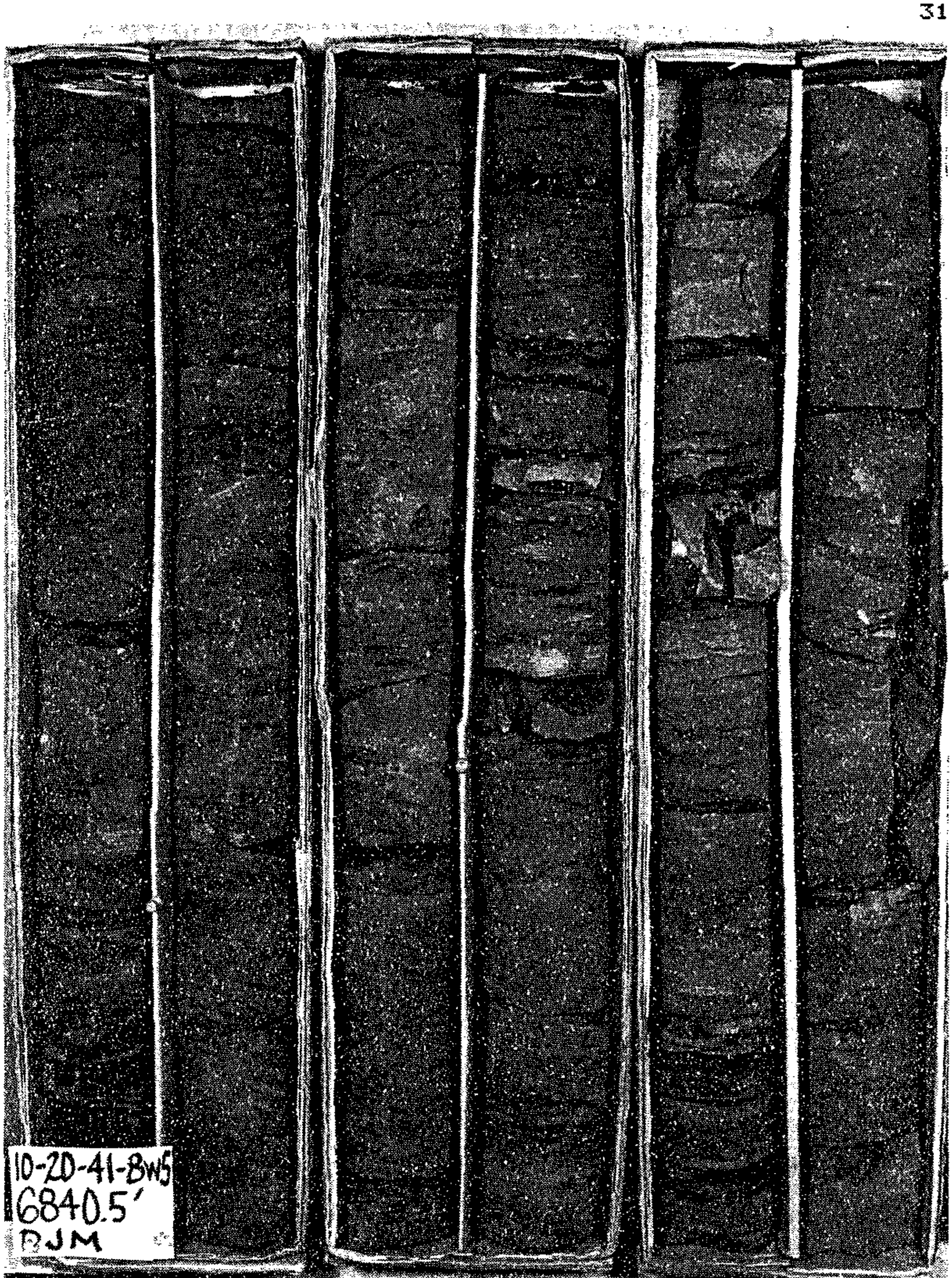
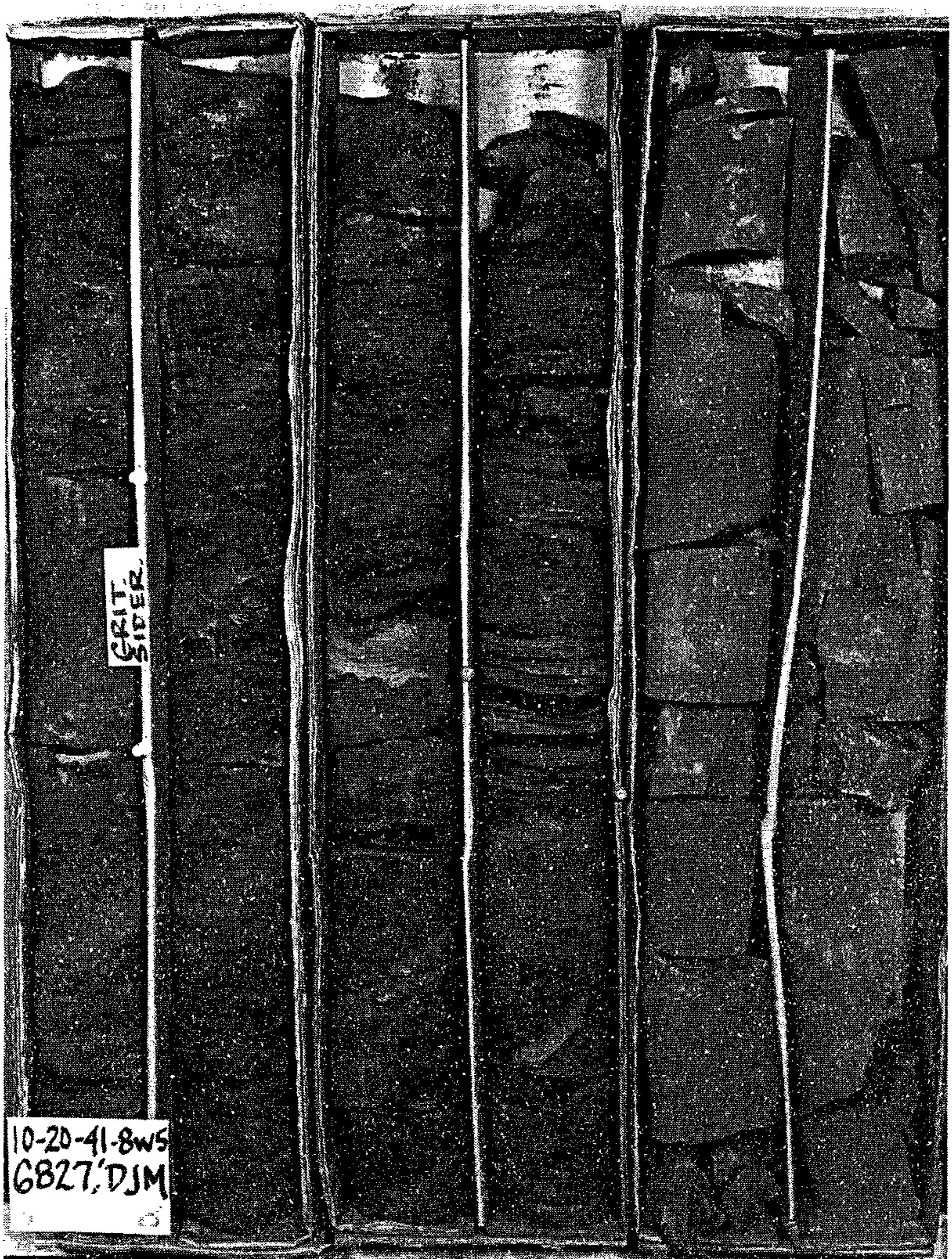

IDEALIZED FACIES
SEQUENCE
F2
F2P
(F8)
C.CK. MBR.
E5
F7
F7A
F7
F5
F4
F5
F4
F3
F1
GRITTY SIDERITE
a
b
METERS
0
5
10
15
20
13-35-38-7W5
METERS
2050
2100
a
b

Figure 3.9 The following three pages show core photographs of well 10-20-41-8W5. Core depths are given in feet; the bottom of the core in each photograph is in the lower left, and the top is in the upper right. All three photographs in succession show a stratigraphically continuous core. Both the "a" and "b" coarsening-upward sequences are shown. The core begins in Facies 4 muddy siltstone and coarsens-upward into Facies 5. Gritty siderite is located at the top of Facies 5 (the top of the "b" coarsening-upward sequence, 6811 ft.). The "a" sequence begins abruptly in Facies 4 and coarsens-upward into hummocky cross-stratified Facies 7 sandstones. These are abruptly overlain by Facies 8 conglomerates.


10-2D-41-8W5
6840.5'
BJM


GRIT.
SIDER.
10-20-41-8W5
6827' DJM


E5
10-20-41-8W5
6813.5'
MCLEAN

and Walker, 1986, 1987). Also, gritty siderite may be found at various horizons within the "a" sequence and, as is evident from the core cross sections (Chapter 4), there are up to three distinct and stratigraphically separate gritty siderite horizons.

The "a" sequence begins with facies 3 or 4 and coarsens upward into the hummocky cross-stratified (HCS) reservoir sandstones of facies 7.

The facies 8 conglomerates of the overlying Carrot Creek Member (Plint et al., 1986) rest unconformably on top of various parts of the "a" and "b" sequences depending on the depth of erosional scour along the E5 surface which separates the Carrot Creek from the Raven River Member. The conglomerate contact is either sharp (Figure 3.7d) or bioturbated.

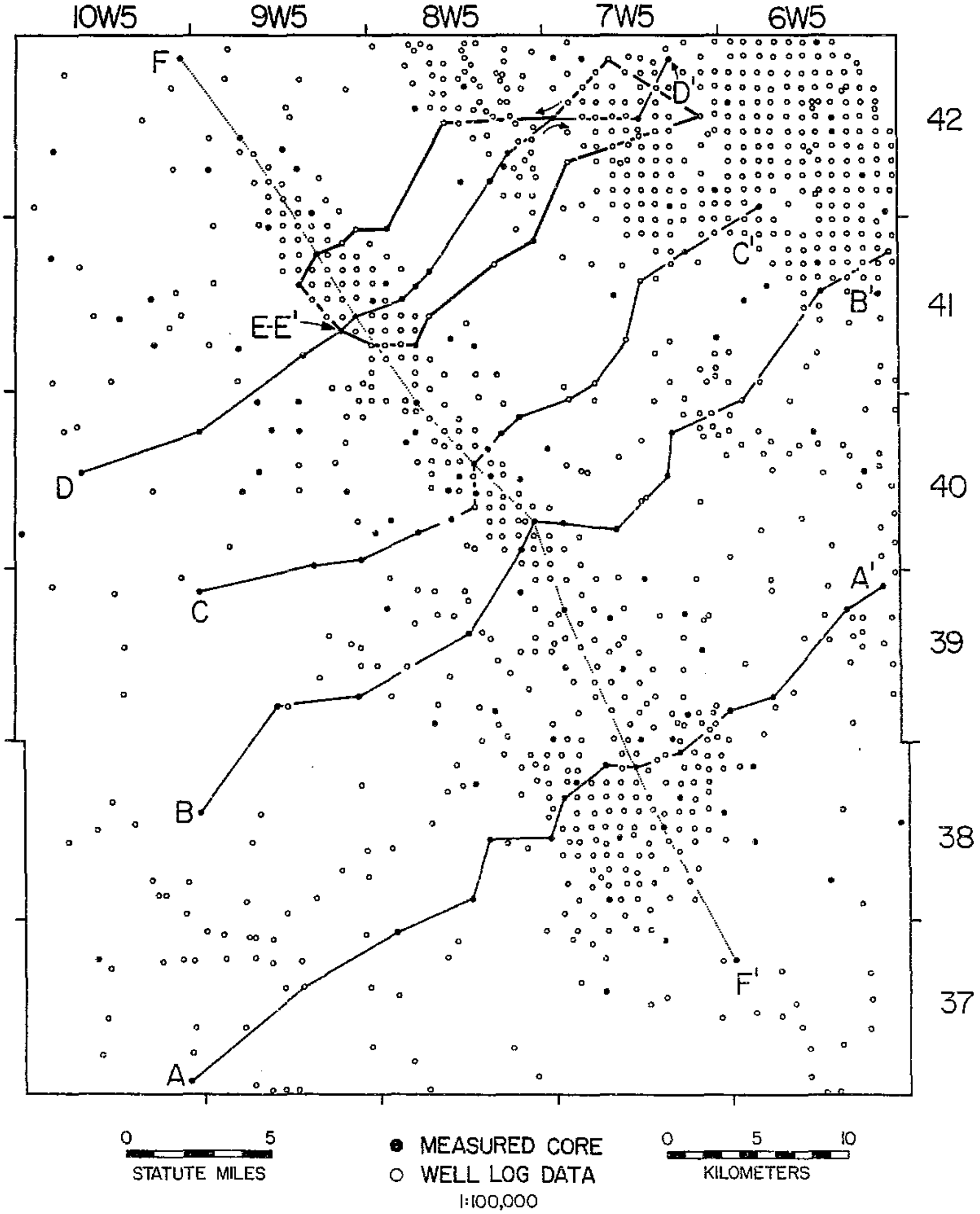
Facies 2P or 2 overlies the conglomerate. Facies 2 is a basin-wide unit which mantles the Carrot Creek Member and is informally termed the "laminated blanket." Facies 2 grades upward into facies 1, but is not separated from it by a "gritty layer" as is the case in the Carrot Creek area (Bergman and Walker, 1986).

CHAPTER 4 - CROSS SECTIONS

4.1 CONSTRUCTION

The morphology of the E5 erosion surface and the two-dimensional facies geometry within the Cardium Formation are summarized in well log and core cross sections. Thirty-two detailed correlation lines based on all 144 cores and over 1000 well logs were constructed over the entire map area. For this thesis, five cross sections and one "closed" loop were "distilled" from the wealth of longer lines and loops originally constructed. Of the five sections, four are perpendicular to the trend of Ferrier and one section is parallel to it (Figure 4.1). Their construction is based on correlation of the shape of shallow-focus resistivity well log signatures. Individual well log signatures were traced onto tracing paper and then overlain on adjacent well log signatures in the cross section in order to achieve a "best fit" correlation between their general shapes, as well as between individual well-defined peaks. Once this had been done over the entire map area (Figure 4.1), a datum common to all log signatures was chosen based on its prominence and proximity to the E5 surface. This datum lies below the main reservoir Raven River sand in both Ferrier and Willesden Green fields and has been informally designated the "yellow spike" by Walker and Eyles (in preparation). A datum below, rather than above, the E5 surface was chosen so that erosion

Figure 4.1 Map showing the location of cross sections A-A' through F-F'. Loop E-E' is shown with a slightly bolder line than that of cross section D-D'. All examined cores within the field area are shown.


10W5
9W5
8W5
7W5
6W5
42
41
40
39
38
37
F
F'
D
D'
E-E'
C
C'
B
B'
A
A'
0
5
STATUTE MILES
MEASURED CORE
WELL LOG DATA
1:100,000
0
5
10
KILOMETERS

along the E5 may be recognized and documented. An upper datum might easily drape the E5 surface or some other erosive horizon between it and the E5 surface; flattening the upper datum might therefore either "flatten out" the irregular morphology of the E5 in cross section or distort it. By extensive loop-tying, that is, the construction of circular or rectangular log cross sections that begin and end at the same well log, datum consistency was insured over the entire map area (see cross section E-E' at the back of this thesis for one example of this). The cross sections are hung on this lower "yellow spike" datum. Three upper markers (labelled "UD-1" and "markers") are correlated across the lines of section; they serve as an additional control on the geometry of the E5 surface. Where they parallel the "yellow spike" datum, the undulose morphology of the E5 surface is "sandwiched" between horizontal markers, which lends additional support to the erosive nature of the E5 surface .

4.2.1 WELL LOG CROSS SECTION A-A'

Well log cross section A-A' (Foldout A-A' in pocket at back of thesis) is the most southerly transect of the four log cross sections perpendicular to the trend of Ferrier field presented (Figure 4.1). In some respects it is the most complete well log cross section presented as most of the wells used in its construction are long ones which penetrate the entire Cardium Formation. The cores which accompany the well logs used in this cross section (indicated by vertical black bars alongside the well log signatures) aid in log correlation; neither a well log section nor a core cross section can be constructed independently of the other.

The "yellow spike" datum below the E5 surface was selected for the reasons given in section 4.1. The datum (labelled "datum") is a prominent positive resistivity deflection over much of A-A', but loses its distinctiveness in 13-3-38-8W5, 16-15-38-8W5, and 16-13-38-8W5, Careful loop-tying over this area, linking the loops with other areas with more prominent "yellow spike" deflections, and use of other lower markers, have insured that these are consistent log picks.

There is significant northeastward change in the two-dimensional morphology of the E5 erosion surface. It is undulose, attaining regional lows at 11-22-37-9W5 and 10-8-39-6W5, the former occupying an off-field position to the west of Ferrier, and the latter occupying the off-field gap between Ferrier and Willesden Green field. Relative topographic highs on the E5 surface occur at Ferrier field (16-15-38-8W5 to 4-7-39-6W5) and at Willesden Green field (6-36-39-6W5). As much as 11 meters of topographic relief exists between 16-15-38-8W5 and 10-8-39-6W5. The development of the Raven River reservoir sandstone, which appears as both a blocky and a spiky positive resistivity deflection, is best observed in those wells which define Ferrier field. The E5 surface rises over these prominent log responses and descends into the gap between Ferrier and Willesden Green before climbing up back on to Willesden Green.

It is difficult to pinpoint where the E5 surface intersects the log signature of 7-1-37-10W5, the southwestern-most well featured on this section. 7-1-37-10W5 is part of the Ricinus oil field which consists of a channelled reservoir sandstone which has been cut into older Raven River sediments (Walker, 1985b). Walker (pers. comm., following a suggestion of A.G. Plint) suggests that perhaps the E5 surface is the erosion surface at the base of the Ricinus channel. However, the other erosion surface log responses of 7-1-37-10W5 correlate reasonably well with those of neighbouring 11-22-37-9W5. The E6 surface roughly parallels E5 and appears to drape it; this is particularly well-illustrated between 4-7-39-6W5 and 12-26-39-6W5, the region of greatest relief along the E5 surface. The E7 surface shows considerable relief, stepping down approximately 10 meters between 16-13-38-8W5 and 7-32-38-7W5. The E4 surface below the "yellow spike" datum "steps down" between 16-15-38-8W5 and 16-13-38-8W5; three such steps have been documented along the E4 surface by Pattison (1987).

4.2.2 CORE CROSS SECTION A-A'

The "yellow spike" datum upon which the A-A' sections are hung is the top of the "b" coarsening-up cycle (Foldout A-A'). It is the contact between facies 5 and an overlying facies 4. Only in 13-3-38-8W5 is the datum indistinguishable from the surrounding lithologies; this is also reflected in the resistivity well log for that well. The gritty siderite in 13-35-38-7W5 is found within the facies 5 horizon which caps the "b" coarsening-up sequence. In 6-36-39-6W5, it is found two meters above the top of the "b" sequence and defines the contact between facies 4 and facies 3. Since it is found at different horizons relative to the datum, the gritty siderite has not been used as the marker horizon along line A-A'. The "yellow spike" datum marks the top of the "b" coarsening-upward sequence, which is laterally traceable over the entire map area.

The E5 surface is undulose over Ferrier, dips down between Ferrier and Willesden Green (10-8-39-6W5), and rises back up onto Willesden Green to the northeast. The "a" sequence is largely absent from 10-8-39-6W5; only 3.5 meters of facies 4 defining the base of sequence "a" are present, the overlying coarser units having been removed by erosion along the E5 surface. The Carrot Creek conglomerate is present as a pebble veneer over much of southern Ferrier, but attains a thickness of three meters at the eastern edge of the field (13-35-38-7W5, a relative topographic high). Facies 5 in sequence "a" decreases in thickness towards the northeast, changing laterally into the more muddy facies 4 and 3.

The E6 surface, at times virtually unrecognizable in core (16-13-38-8W5, for example), is easily detected in 10-8-39-6W5 by the presence of approximately one meter of sideritized conglomerate which rests upon it. This is not the Carrot Creek conglomerate (which always rests unconformably upon the E5 surface) because this gravelly unit is underlain by facies 2P, which, along with facies 2, always overlies the E5 surface. E5 is marked by a subtle but distinctive contact between facies 4 and facies 2P in 10-8-39-6W5. The coarse unit which rests on the E6 surface in this well has changed character in nearby 12-26-39-6W5, there present only as approximately three meters of silty mud. The facies 7 reservoir sand which is not found in the gap between Ferrier and Willesden Green re-appears at Willesden Green (6-36-39-6W5).

4.3.1 WELL LOG CROSS SECTION B-B'

Well log cross section B-B' (Foldout B-B' in pocket at back of thesis) lies several kilometers to the north of, and roughly parallel to, cross section A-A' (Figure 4.1). It closely resembles section A-A'; the primary difference between the two sections is the greater topographic relief along the E5 surface of section B-B'. Like A-A', B-B' is a relatively complete well log cross section in that most of the wells used in its construction are long ones which penetrate the entire Cardium Formation.

The "yellow spike" datum (labelled "datum") below the E5 surface is a prominent positive resistivity deflection over much of B-B′, but loses its prominence in 12-1-40-8W5, 10-12-40-8W5, and 10-7-40-7W5. In these wells, the "yellow spike" datum occurs as a small resistivity peak within an overall coarsening-upward sequence which culminates in the Raven River sandstone blocky/spiky log response. Extensive loop-tying over this area has insured datum consistency. Also, correlation of cored intervals (some of which include the datum lithology) of some of the wells used in the construction of core cross section B-B′ (Section 4.3.2) has shown that the "yellow spike" well log pick is consistent over line B-B′.

The E5 erosion surface undulates over the line of section in much the same way that it does over A-A′. Regional topographic lows along the E5 surface are found at 9-24-38-10W5, 6-15-40-7W5, and 4-23-40-7W5. The first of these three wells occupies an off-field position to the west of Ferrier field, while the latter two occupy the off-field gap between Ferrier and Willesden Green field. Relative topographic highs on the E5 surface occur at the eastern edge of Ferrier (10-7-40-7W5) and at Willesden Green field (6-22-41-6W5). There is approximately 10 meters of topographic relief between 6-15-40-7W5 and 6-22-41-6W5. The topographic highs always correspond to wells in which the Raven River sand is particularly well-developed (i.e. - the reservoir sand in Ferrier and Willesden Green fields), hence the raised topography which defines the oil fields. Regional lows along the E5 always correspond to little or no development of Raven River sand.

The E6 erosion surface roughly parallels the E5 surface over most of B-B', but deviates from this trend at 6-15-40-7W5. Here it continues northeastward at a relatively constant horizon while the E5 below it dips into the gap between Ferrier and Willesden Green. The undulose E7 surface maintains as much as 13 meters of topographic relief between 10-12-39-9W5 and 12-1-40-8W5. The E7 log response is indistinguishable between Ferrier and Willesden Green fields (4-23-40-7W5 to 3-31-40-6W5); it is conceivable that it coincides with or cuts out the E6 surface here. To the west of Ferrier the E7 surface is present as a relative high (8-9-39-9W5 and 10-12-39-9W5).

4.3.2 CORE CROSS SECTION B-B'

The datum upon which the B-B' sections are hung is the "yellow spike" datum, which is the top of the "b" coarsening-upward sequence (Foldout B-B'). It is the contact between either facies 7 or 5 and an overlying facies 5,4, or 3. Only in 10-12-40-8W5, directly underneath Ferrier field, is the datum ambiguous and not easily distinguished as a major facies change.

Lateral facies change is evident along the "yellow spike" horizon. From the southwest to the northeast, the facies and facies contacts become progressively muddier, beginning with facies 5 underlain by facies 7 in 8-9-39-9W5, a facies 4/5 contact in 10-12-39-9W5 and 6-9-40-7W5, and ending in a facies 3/5 contact in 11-26-40-7W5. The facies 5/5 "contact" in 10-12-40-8W5 is characteristic of the single coarsening-upward sequence immediately below the Ferrier field Raven River sandstone. This sandy "contact" interrupts the northeastward lateral fining trend.

The E5 surface rises relatively steadily from 10-12-39-9W5 to the eastern edge of Ferrier field (10-12-40-8W5 and 10-7-40-7W5, core not shown for the latter). It dips down between Ferrier and Willesden Green (4-23-40-7W5) and then rises back up onto Willesden Green to the northeast. The "a" sequence is largely absent from 4-23-40-7W5; only about 3.5 meters of facies 3 and 4 defining the base of sequence "a" are present, the overlying coarser units having been removed by erosion along the E5 surface. The Carrot Creek conglomerate is present as a thin horizon of pebbles over much of B-B′, but attains a thickness of approximately 3 meters at 10-12-40-8W5.

The E6 surface is sometimes recognized in core by the presence of exceptionally silty horizons in otherwise monotonous laminated dark mudstones (facies 2). E6 is easily detected in 14-22-39-8W5 and in 6-9-40-7W5 by this criterion. In 4-23-40-7W5, where the E6 surface may be coincident with, or cut out by the E7 surface, it is detected by a pebble horizon abruptly overlain by a gritty siderite. The E6 erosion surface may be distinguished by the massive siderite approximately 6 meters above the Carrot Creek pebble veneer in 11-26-40-7W5, although the distinction is tenuous at best. The E7 surface is detected in 6-9-40-7W5 by the presence of an overlying silty unit.

4.4.1 WELL LOG CROSS SECTION C-C'

Well log cross section C-C' (Foldout C-C' in pocket at back of thesis) lies a few kilometers to the north of section B-B' and trends approximately parallel to it (Figure 4.1). Six of the wells used in the construction of C-C' do not penetrate the entire Cardium Formation; 2-15-40-8W5 through 4-36-40-8W5, and 16-26-41-7W5 and 6-5-42-6W5 have been drilled through the Raven River sandstone and 20-30 meters into the underlying muddier sediments. 2-15-40-8W5 through 4-36-40-8W5 are Ferrier field wells, 16-26-41-7W5 and 6-5-42-6W5 are Willesden Green field wells. The longer wells which penetrate the entire Cardium Formation are those which occupy off-field positions.

The "yellow spike" datum below the E5 surface is a prominent resistivity deflection over all of C-C'. The difficulty in picking the "yellow spike" datum given the choice of two equally attractive prominent resistivity deflections in 6-31-39-9W5 and 4-2-40-9W5 was resolved by careful tracing of well logs and subsequent superimposition of signatures, and by loop-tying with other well logs in which the "yellow spike" datum was easily recognized. The prominent log response not selected as "yellow spike" is marked by an asterisk (*) in 4-2-40-9W5.

The E5 erosion surface rises steadily from the southwest to the northeast, reaching a topographic high at the eastern edge of Ferrier (4-36-40-8W5). It then dips into the gap between Ferrier and Willesden Green (regional low at 16-31-40-7W5), gradually rising to the northeast up onto the back of Willesden Green. Between the highest topography (6-5-42-6W5) along the E5 surface on this cross section and the lowest topographic depression (16-31-40-7W5), there is approximately 12.5 meters of relief. As might be expected, the relative highs coincide with blocky and spiky reservoir sandstone log responses immediately below the E5 surface. However, the prominent log responses which characterize the Raven River sand are found off-field to the southwest of Ferrier as well as on-field. These distinctive off-field log signatures gradually become less blocky to the southwest as the E5 surface erodes down into them.

The E6 erosion surface is roughly sub-parallel to the "yellow spike" datum. It may be either coincident with or cut out by the E7 erosion surface between 7-8-40-8W5 and 10-

22-40-8W5, inclusive, since a distinct E7 log response above the typical E6 log response is not apparent. The E6 surface does not appear to drape the E5 morphology between Ferrier and Willesden Green fields along this line of cross section. It is difficult to determine the morphology of the E7 surface between Ferrier and Willesden Green due to the difficulty in picking the E7 well log response from the signatures of 16-31-40-7W5, 7-5-41-7W5, and 16-9-41-7W5.

4.4.2 CORE CROSS SECTION C-C'

The datum upon which the C-C' sections are hung is the "yellow spike" datum which is the top of the "b" coarsening-upward sequence (Foldout C-C'). It is the contact between an underlying sandy facies relative to an overlying muddier facies; in this core section, facies 5/7 and facies 4/5 contacts are documented (6-31-39-9W5, 4-2-40-9W5, and 7-8-40-8W5). A facies 5/5 "contact" defines the "yellow spike" datum lithology in 10-26-40-8W5, where a more sandy facies 5 underlies a less sandy facies 5. Lateral facies change is best observed along the datum horizon, where facies 7 in 6-31-39-9W5 and 4-2-40-9W5 passes into facies 5 in 7-8-40-8W5 and 10-26-40-8W5. This lateral northeastward gradation of sandy to muddy facies is evident in the previous two lines of section as well. Facies 5 and 7 are thickest directly underneath Ferrier field, occupying much of the "a" coarsening-upward sequence in 10-26-40-8W5 and 4-36-40-8W5.

The E5 surface rises steadily from the southwest to the northeast until the eastern edge of Ferrier field is reached (4-36-40-8W5). The E5 surface then dips into the off-field gap between Ferrier and Willesden Green (16-31-40-7W5, not shown in core section). Erosion along the E5 unconformity has removed approximately 11 meters of vertical section between 4-36-40-8W5 and 16-31-40-7W5. Immediately to the northeast the erosion surface steps back up onto Willesden Green (see well log section), allowing the preservation of a topographic high at 16-26-41-7W5.

The Carrot Creek conglomerate which rests unconformably on the E5 surface attains a maximum thickness of 2.3 meters at 4-36-40-8W5, the eastern edge of Ferrier field. Of the cores shown, it is only present as a pebble veneer in 6-31-39-9W5 to the southwest. It is interesting to note that the Carrot Creek Member rests on top of facies 4 in 6-31-39-9W5, despite the occurrence of approximately 3 meters of hummocky cross-stratified Raven River sandstone immediately below this "anomalous" occurrence of facies 4. The conglomerate is relatively thick throughout the rest of the cross section, including a one meter thickness of it at the southwestern edge of Willesden Green field (16-26-41-7W5).

The E6 and E7 surfaces were not recognized in any of the C-C′ cores, owing to the subtle nature of the relatively nondescript erosive mud-on-mud contacts.

4.5.1 WELL LOG CROSS SECTION D-D′

Well log cross section D-D′ (Foldout D-D′ in pocket at back of thesis) is the northern-most transect of the four log cross sections perpendicular to the trend of Ferrier field presented (Figure 4.1). It shows among the thickest accumulations of conglomerates found anywhere within the field area, and illustrates the extreme degree to which erosion along the E5 surface has taken place (4-28-41-8W5).

The "yellow spike" datum is easily recognized along D-D′, becoming more prominent towards the northeast. To the southwest of 10-13-41-9W5, however, the datum becomes less pronounced as a resistivity log response. Extensive loop-tying has insured that this is a consistent "yellow spike" log pick. Loop E-E′, described in section 4.6, shows the "yellow spike" datum consistency between northern Ferrier field and Willesden Green field in the vicinity of cross section D-D′.

The E5 erosion surface maintains the same general morphology along D-D′ as it does along the other cross sections described previously. Of particular interest is the thick accumulation of Carrot Creek conglomerate on the eastern edge of Ferrier field (10-20-41-8W5), and the paucity of it only 1.5 kilometers to the northeast (4-28-41-8W5). The blocky log response present in 10-20-41-8W5 is reduced to a minor resistivity peak in 4-28-41-8W5. Approximately 15 meters of vertical relief along the E5 surface occurs between 10-20-41-8W5 and 4-28-41-8W5. The E5 climbs back up onto Willesden Green field to the northeast of 4-28-41-8W5.

The E6 erosion surface follows much the same pattern along line D-D' as it does along the cross sections described previously. It does not appear to drape the E5 surface at 4-28-41-8W5, but rather planes across the gap between Ferrier and Willesden Green fields as it does in cross sections B-B' and C-C'. This contrasts with some recent observations by Walker and Eyles (in preparation) in which the E6 surface roughly drapes the E5 topography at the western margin of Willesden Green. The E7 surface is relatively easy to correlate across Willesden Green field, but is not traceable across the between-field gap or across the top of Ferrier field. It is conceivable that the E7 log response is coincident with or erodes out the E6 log response across those areas where correlation of these surfaces is difficult.

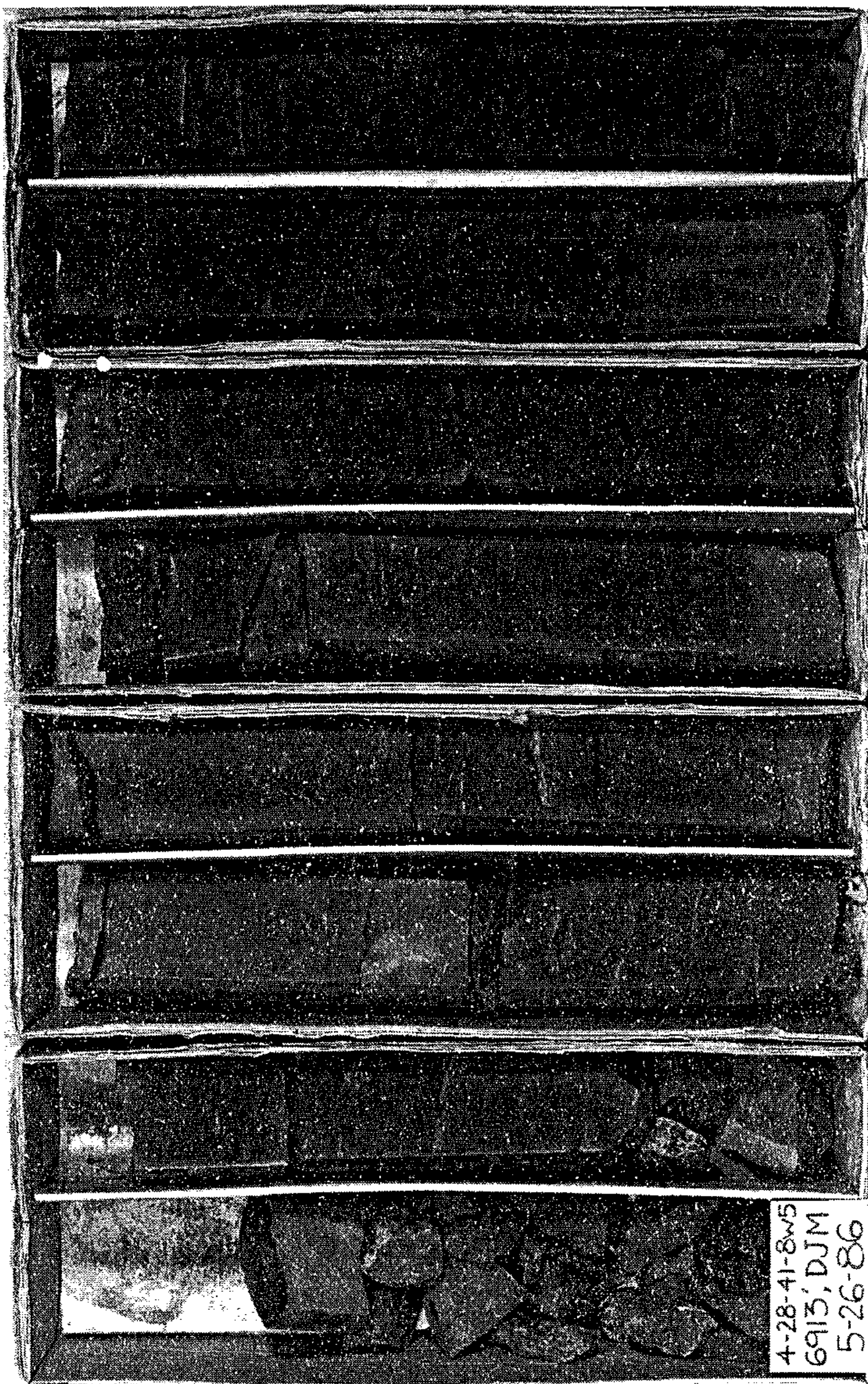
4.5.2 CORE CROSS SECTION D-D'

The datum upon which the D-D' sections are hung is the "yellow spike" datum, which is the top of the "b" coarsening-upward sequence (Foldout D-D'). As with other cross sections, it is the contact between an overlying muddier facies and an underlying sandier one. The lateral facies change along the datum horizon tends to progress from sandier to muddier facies to the northeast, particularly evident between 4-20-41-8W5 and 10-20-41-8W5, where facies 7A and 7 of the "a" and "b" sequences, respectively (4-20-41-8W5), become facies 4 and facies 5 of the "a" and "b" sequences of 10-20-41-8W5. The "a" sequence corresponds to the "red" sequence in Willesden Green (Walker and Eyles, in preparation), and the "b" sequence corresponds to the "yellow" sequence in Willesden Green (Walker and Eyles, in preparation).

There are three distinct gritty siderite horizons shown in core section D-D'. There is one in 4-13-41-9W5 (which caps either the "green" or the "gray" coarsening-upward sequence of Walker and Eyles, in preparation), a stratigraphically higher one which is correlatable between 10-20-41-8W5 and 4-11-42-8W5 (which caps the "yellow" coarsening-upward sequence of Walker and Eyles, in preparation), and a third one, even higher, in 1-14-42-8W5 (which caps the "red" sequence of Walker and Eyles, in preparation). The presence of these three separate horizons shows that a single gritty siderite horizon cannot be used as a basin-wide marker or datum.

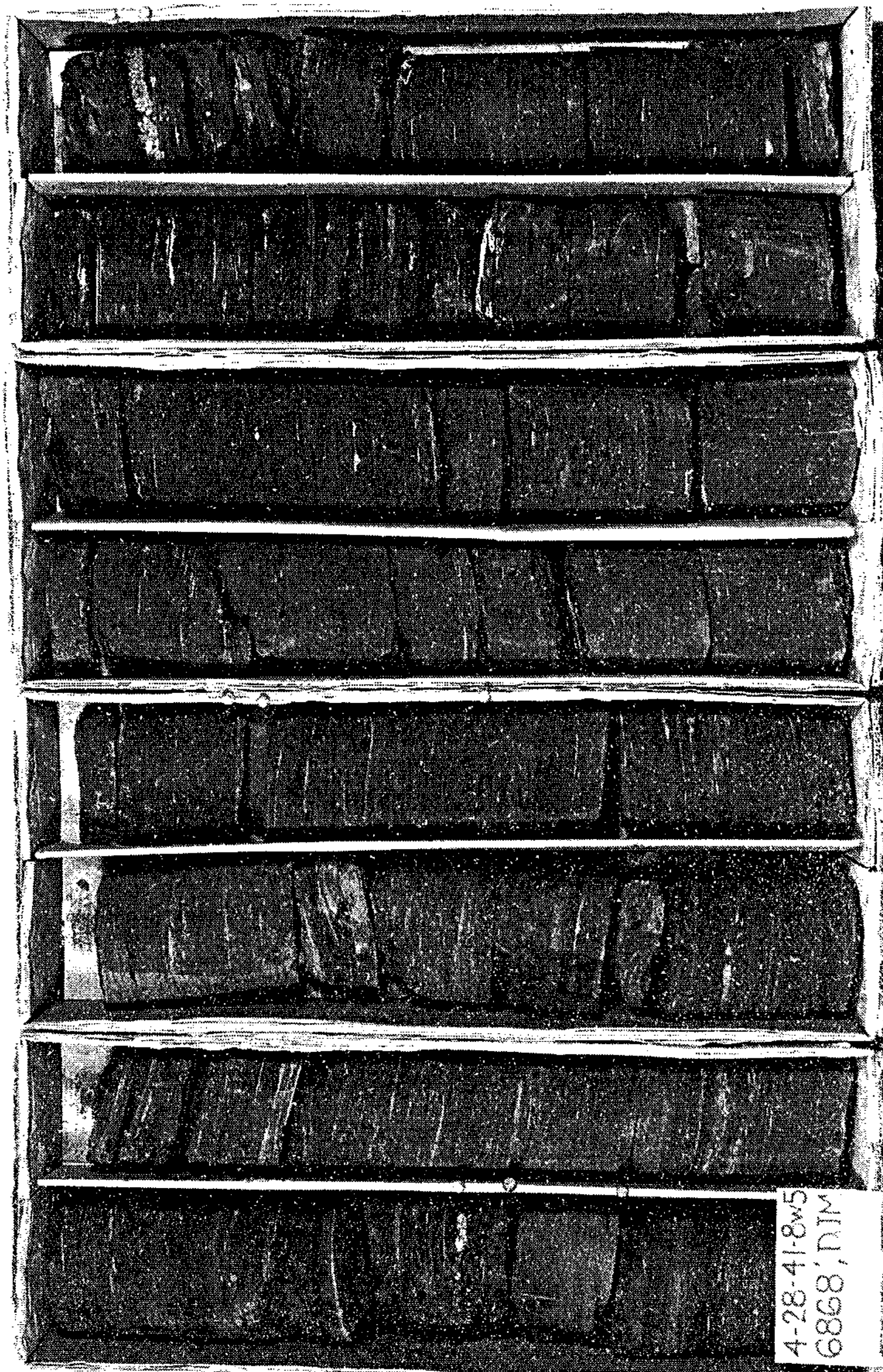
Approximately 7 meters of Carrot Creek conglomerate rests on a relative topographic high along the E5 surface (10-20-41-8W5), as is the norm along the eastern edge of Ferrier field. This thickness correlates with a thin pebble veneer in 4-28-41-8W5, only 1.5 kilometers to the northeast.

Figure 4.2 The following four pages show core photographs of well 4-28-41-8W5, which is featured in both well log and core cross section D-D′ (Foldout at back of thesis). Core depths are given in feet; the bottom of the core in each photograph is in the lower left, and the top is in the upper right. All four photographs in succession show a stratigraphically continuous core. This is an off-field well and hence lacks reservoir-quality facies. It begins in Facies 3 bioturbated muddy siltstone and coarsens-upward gradually into Facies 4 pervasively bioturbated muddy siltstone. At 6878 feet, the sequence is erosively truncated by the E5 surface which is mantled by a thin pebble veneer. This in turn is abruptly overlain by Facies 2P and 2 laminated dark mudstones.


4-28-41-8W5
6913', DJM
5-26-86


4-28-41-8w5
6898', DJM


E5
4-28-41-8w5
6883',DJM


4-28-41-8w5
6868', DJM

The conglomerate is piled up against and on top of the eastern edge of Ferrier field, but does not maintain its substantial thickness to the northeast, into the between-field gap. The correlation of the thick Carrot Creek conglomerate in 10-20-41-8W5 with the lowermost pebble horizon in 4-28-41-8W5 is justified by the comparison of vertical facies successions. Facies 3 and 4 below the Carrot Creek pebble horizon in 4-28-41-8W5 are only found below the E5 surface. Facies 2P and 2 which overlie the Carrot Creek pebble veneer in 4-28-41-8W5 are only found above the E5 surface. Thus, the lowermost pebble horizon in this predominantly muddy core was correctly chosen as the Carrot Creek Member (see Figure 4.2).

4.6 LOOP E-E'

Well log loop E-E' (Foldout E-E'/F-F' in pocket at back of thesis) is one example of "loop-tying," that is, insuring datum consistency by construction of roughly circular or rectangular cross sections which begin and end at the same well. In this example, the "yellow spike" datum below the E5 surface has been successfully tested for closure between northern Ferrier and Willesden Green fields. The loop begins along the western edge of Ferrier field (4-13-41-9W5), traverses the gap between Ferrier and Willesden Green fields (12-16-41-8W5 to 6-26-41-8W5), and continues into Willesden Green. The section reverses the direction of traverse there (switch from southwest-northeast to northeast-southwest) and continues back across the between-field gap, ending at 4-13-41-9W5.

The salient features of loop E-E′ have already been discussed in the previous sections in terms of cross sections A-A′ through D-D′; E-E′ most closely resembles cross section D-D′, as both traverse the same general vicinity (Figure 4.1). E-E′ shares 4-13-41-9W5 and 6-19-42-7W5 with D-D′. However, there are two items which deserve explanation. First, the dip of the E5 surface between 12-16-41-8W5 and 6-26-41-8W5 is assumed. There is no core or well log data in this immediate area, but nearby wells indicate that the deep scouring along the E5 surface to the immediate east of Ferrier field is almost certainly present between 12-16-41-8W5 and 6-26-41-8W5. Second, the abrupt end of two marker correlation lines below the "yellow spike" (one slightly above the other), between 10-31-41-8W5 and 10-36-41-9W5, is drawn so that there can be no doubt regarding their separate identities. The upper one is correlative with the first marker below the "yellow spike" datum between 4-13-41-9W5 and 16-7-42-7W5, inclusive.

4.7 WELL LOG CROSS SECTION F-F′

Well log cross section F-F′ (Foldout E-E′/F-F′ in pocket at back of thesis) is a northwest-southeast longitudinal section along the elongate trend of Ferrier field. A core cross section has not been constructed along F–F′ because a number of wells used in the construction of well log section F–F′ are already featured, with cored sections, in the four cross sections perpendicular to the elongate trend of Ferrier field.

The "yellow spike" datum, upon which this cross section is hung, is presumably eroded away by the E5 surface at the northwestern end of the cross section (7–36–42–10W5). This well has been placed relative to 10–17–42–9W5 by correlating the next lower marker (a prominent positive resistivity deflection in the northwestern portion of the field area) between the two wells on a flat horizon parallel with the "yellow spike" datum above. The well log signature for 10–17–42–9W5 has been "restored" back to its original pre-fault shape; the fault-repeated section of Raven River Member, evident in cored section and on the original well log, has been removed for the purposes of smooth correlation.

It is surprising that the E5 erosion surface does not erode down through the Raven River reservoir sandstone (prominent positive resistivity deflection) to the southeast. 12–30–37–6W5, an off-field well, is a relative topographic high with respect to the morphology of the E5 surface. One would expect a topographic low along the E5 surface in an off-field position (i.e. 7–36–42–10W5). The thin, spiky resistivity well log response which represents the Raven River reservoir sand in 12–30–37–6W5 is probably not worthy of economic exploitation, and hence is an "off-field" well (also, other factors such as diagenesis and reservoir water content may differentiate between economic "on-field" wells and uneconomic "off-field" wells). Thus, it is important to note that while the northwestern end of Ferrier field is defined by the degree of erosion along the E5 surface, the southeastern end is defined by the development of the reservoir sand along topographic highs, where the degree of erosion may have been less intense.

4.8 SUMMARY

1. The "yellow spike" datum upon which these cross sections are hung is a consistent positive resistivity deflection. In core, it is the top of the "b" coarsening-upward sequence, defined by a facies contact between an underlying sandy facies relative to an overlying muddier one.

2. The elongate depression defined by the erosive morphology of the E5 erosion surface extends the entire length of Ferrier and defines the eastern margin of the field. As much as 15 meters of erosional relief along the E5 surface is documented along the northeastern margin of Ferrier field (D-D').

3. The Carrot Creek conglomerate is concentrated along the eastern edge of Ferrier field on a relative topographic high. The greatest thickness occurs along the northeastern

margin of the field, adjacent to the area of deepest erosional "scour."

4. Laterally, Raven River facies become muddier to the northeast. Facies 7 and 5 to the southwest become facies 5 and 4/3, respectively.

5. There are three distinct gritty siderite horizons within the Raven River Member at Ferrier and Willesden Green fields. None of them is laterally traceable for more than a few kilometers. They are not facies dependent.

6. The E6 erosion surface does not drape the E5 morphology between Ferrier and Willesden Green fields, except along section A-A'. This contrasts with recent observations by Walker and Eyles (in preparation).

7. The E7 erosion surface shows considerable relief; it rises stratigraphically to the southwest and northeast, and descends over Ferrier, western Willesden Green, and the gap which separates them. It is conceivable that the E7 surface is either coincident with or cuts out the E6 surface in places where a distinct E7 log response is unrecognizable, the most likely being within the gap which separates Ferrier and Willesden Green.

CHAPTER 5 - MAPS

5.1 INTRODUCTION

The cross sections in chapter 4 demonstrate the presence of a major erosion surface, E5 of Plint et al. (1986), within the Ferrier/Willesden Green area. This chapter focuses on the morphology of the E5 surface within the field area, and seeks to determine the relationship of the overlying Carrot Creek conglomerate and upper markers UD-1 and UD-2 to the E5 surface. This is best accomplished by the construction of isopach maps which contour the shape of the E5 surface and reveal the changes in morphology along upper "datums," as well as determining regional trends in the thickness of the Carrot Creek conglomerates.

Four isopach maps and two computer-generated three-dimensional mesh diagrams are presented. The first of these maps, UD-1 to UD-2, is an isopach of the interval between two upper "datums" and has been constructed to test the validity of using upper markers as relatively flat basin-wide datums. The second map, UD-2 to E5, contours the morphology of the E5 surface assuming a flat upper datum (UD-2). A conglomerate thickness map follows which, when superimposed on the contoured E5 surface, illustrates the distribution of the Carrot Creek conglomerate relative to an eroded topography. The three-dimensional mesh diagrams are computer plots of the same data used to construct the "UD-2 to E5" isopach map; these diagrams are visual aids for showing the topography of erosion surface E5.

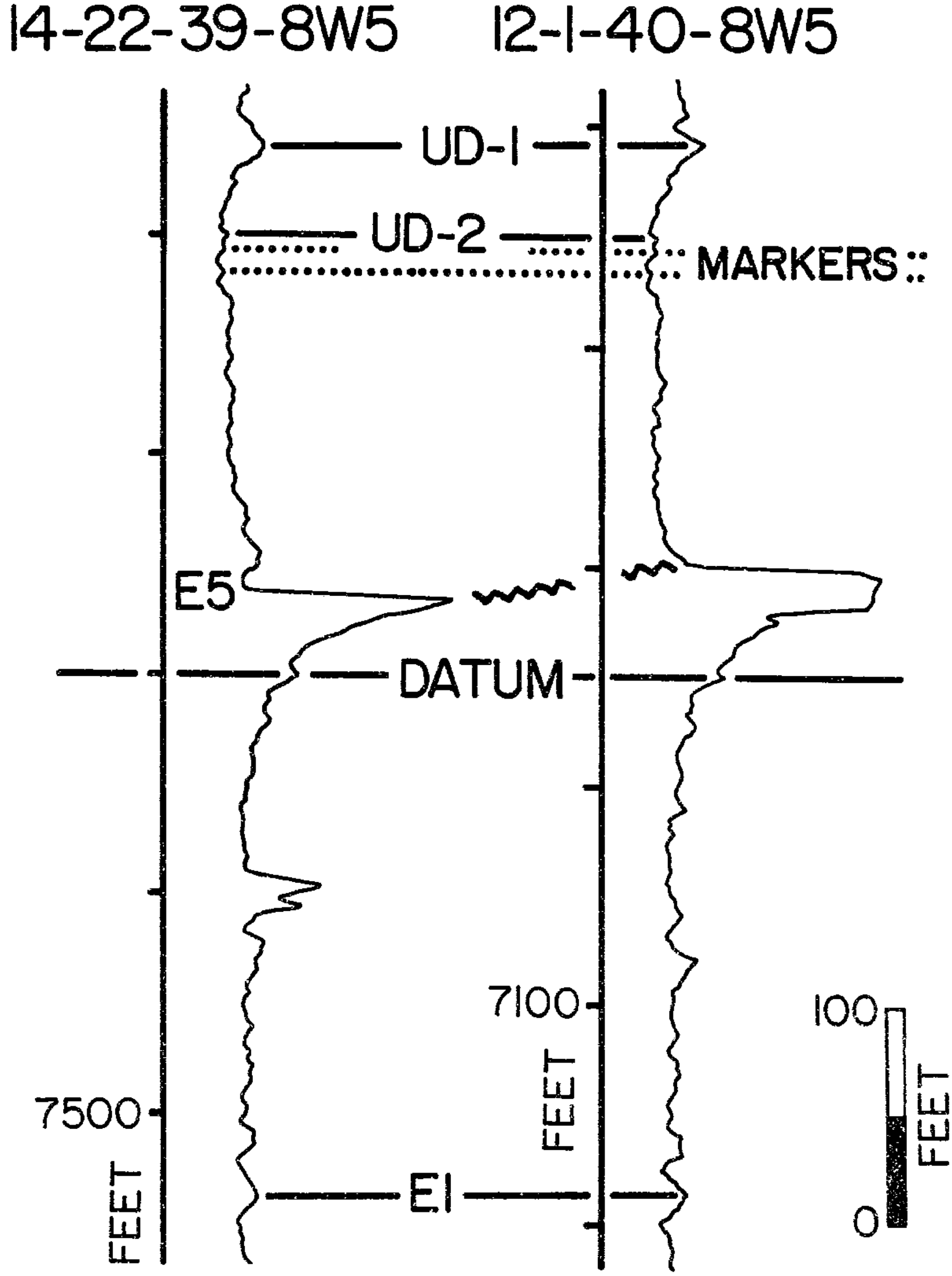
5.2 CONSTRUCTION

Isopached intervals are bounded by distinct resistivity well log deflections. The determination of the E5 horizon (Carrot Creek conglomerate lower contact) and the top of the Carrot Creek Member were facilitated by matching cored intervals with well log signatures; only where conglomerate thicknesses were less than 2.5 meters did it become difficult to differentiate between the coarsening-upward log response and the response of the overlying pebble veneer.

The markers UD-1, UD-2, and E5 are labelled on all the cross sections presented in chapter 4 (foldouts at the back of this thesis) and are shown in Figure 5.1. The associated numerical values, given in either meters or feet of subsurface depth, were entered into a Lotus 1.2.3 computer file which converted all imperial unit values to meters and made the necessary subtractions for subsequent isopaching. Appendix 1 contains the raw numerical data.

The interval UD-2 to E5 was printed as two three-dimensional mesh diagrams by Zycor graphics at Home Oil Company, Ltd.. The method by which these diagrams were constructed is explained by Bergman (1987, see her appendix).

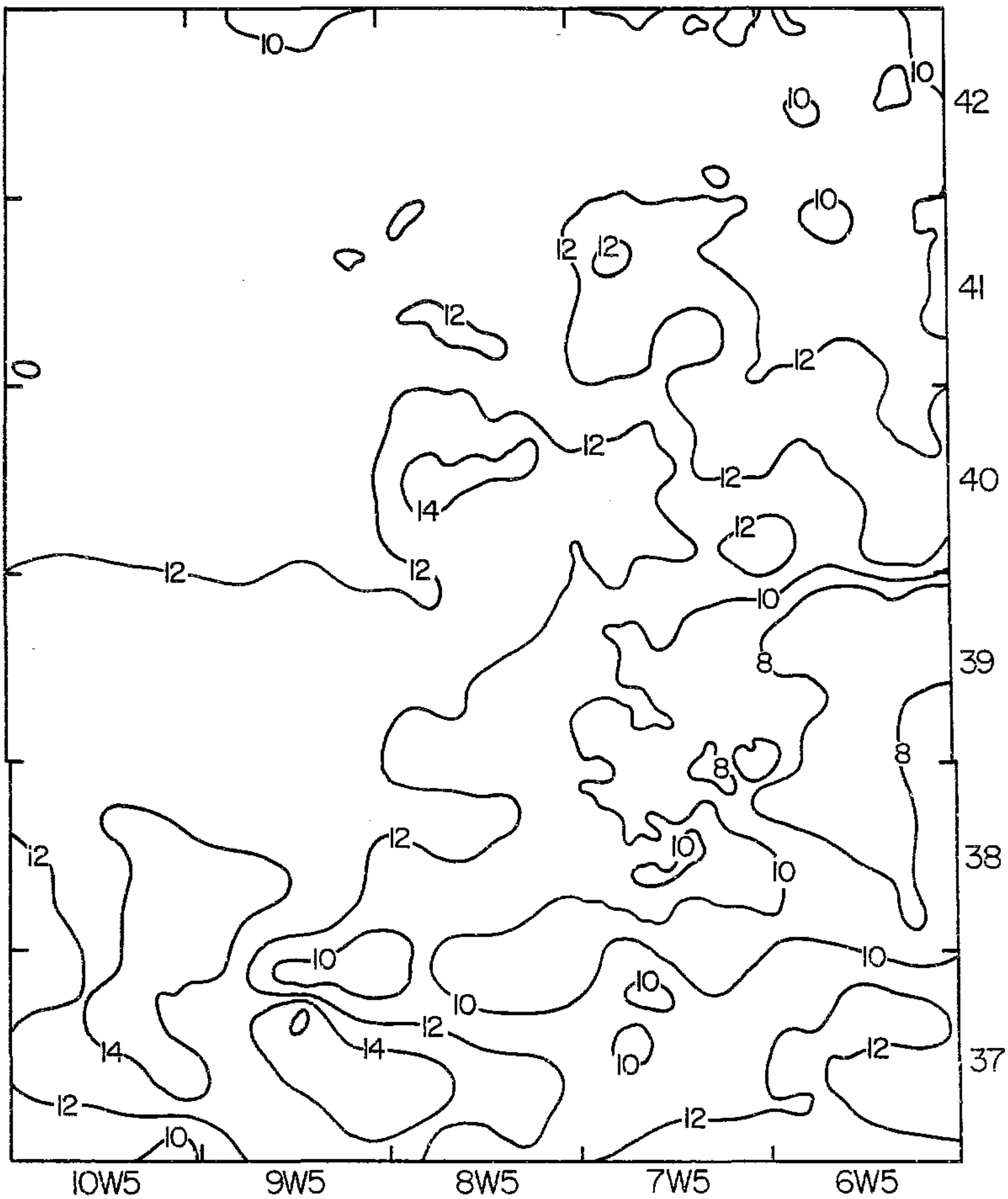
Figure 5.1 Resistivity well log markers used in the construction of Figures 5.2, 5.3, 5.6, and 5.7. The "datum" is the "yellow spike" datum indicated on the cross sections and in the text. "E1" is the E1 erosion surface (Plint et al., 1986) and denotes the base of the Cardium Formation.


14-22-39-8W5
12-1-40-8W5
UD-1
UD-2
MARKERS
E5
DATUM
7100
FEET
100
FEET
0
7500
FEET
E1

5.3 UD-1 TO UD-2

The interval between UD-1 and UD-2 has been isopached to study the morphology of these markers. The purpose of constructing this map (Figure 5.2) was to see if the UD-2 surface (upon which the "UD-2 to E5" isopach map is "hung") is relatively flat with respect to the stratigraphically higher marker UD-1, thereby lending support to what one hopes is a realistic E5 morphology (Figures 5.3, 5.6, and 5.7). The map also shows whether there is significant variation in sediment thickness between upper markers. If there is an appreciable amount of relief between UD-1 and UD-2, then one is left doubting the reliability of an upper marker as an originally flat surface.

There is up to 6 meters of relief between UD-1 and UD-2 (Figure 5.2). The isopached interval is thickest in T37-38, R8-10, and is thinnest in T38-39, R6 and part of 7; these are the extremes. There appears to be no systematic trend in Figure 5.2; it appears as though UD-1 and UD-2 are largely two different irregular surfaces (however, they do become parallel in T40-42, R9-10 and T42, R8). Hence, UD-2 was probably not an originally flat surface and is probably not a good choice of datum by which to illustrate the erosive morphology of the E5 surface.



UD-1 TO UD-2

0 5 STATUTE MILES

0 KILOMETERS 10

1:100,000

5.4 UD-2 TO E5

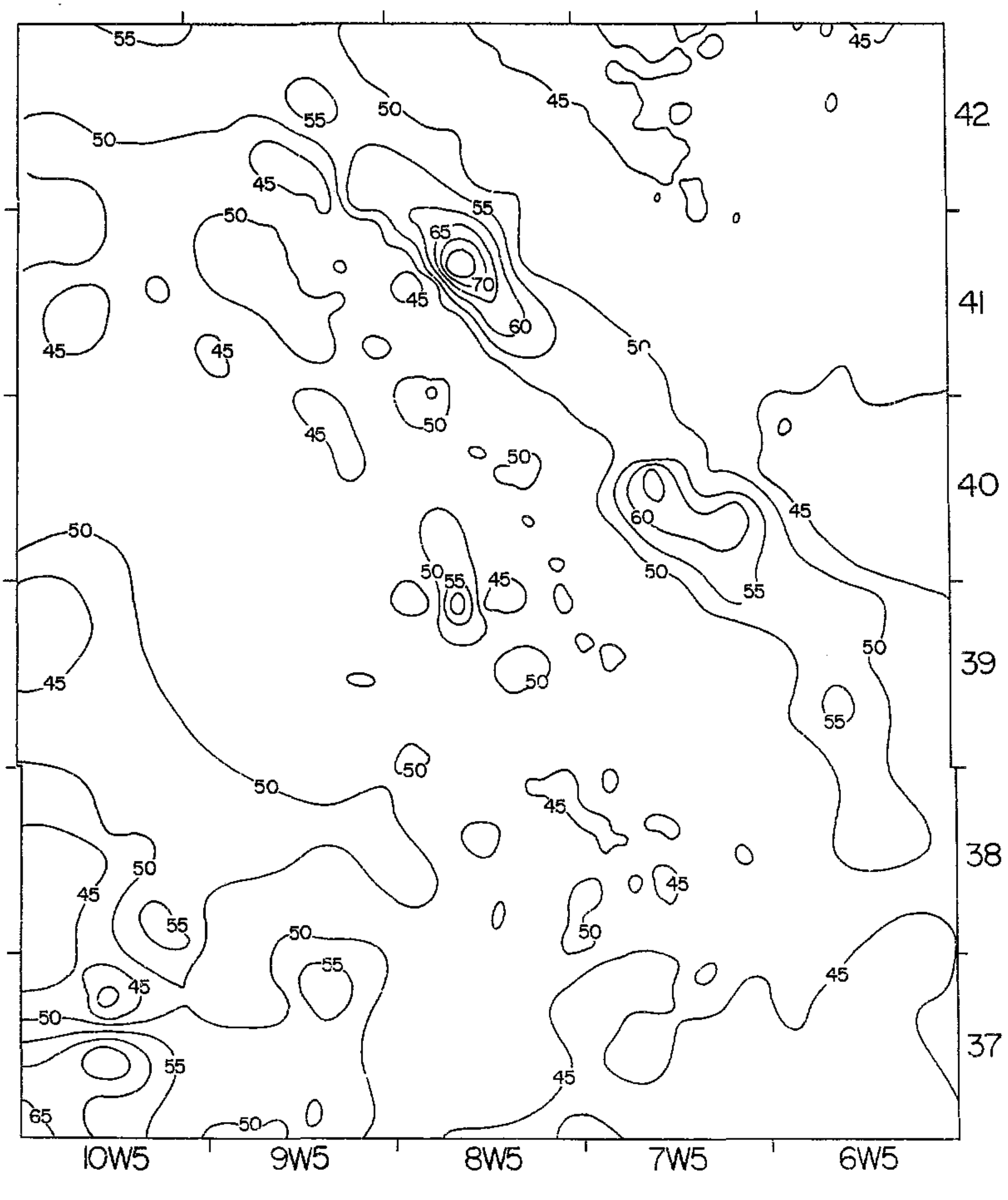
The interval between UD-2 and the E5 erosion surface has been isopached (Figure 5.3) to determine the morphology of the E5 surface.

This is a map of the thickness of sediment, largely mudstone, which rests between two markers. Therefore, larger numerical values indicated on the map (in meters) suggest topographic lows along the E5 surface. These correspond to erosional scours, portions of which are shown in profile along lines of cross section in chapter 4. Smaller values indicate relative topographic highs, or areas where erosion along the E5 surface is not so deep, and, the underlying coarsening-upward sequences are more completely preserved.

There is an elongate topographic low which is situated parallel to the eastern margin of Ferrier field. This is the area of maximum erosion along the E5 surface and marks the inter-field area between eastern Ferrier and western Willesden Green fields. Drilling density is considerably lower in this area because most of the "a" coarsening-upward sequence, which culminates in the reservoir facies 7 sandstones, has been eroded away; most of the wells that do exist within the inter-field gap were drilled to deeper exploration targets.

Immediately to the west of the elongate scour is a relative topographic high which runs the length of Ferrier field and continues both to the south and to the west of the

Figure 5.3 UD-2 to E5 isopach map showing the morphology of the E5 erosion surface assuming a flat UD-2. Larger numerical values indicated on the map (in meters) suggest topographic lows along the E5 surface, while smaller values indicate topographic highs. Contour interval is 5 m.



UD-2 TO E5

0 5
STATUTE MILES

1:100,000

0 KILOMETERS 10

field, with minor variation. To the northwest, the scour along the E5 surface persists and defines the northwestern boundary of the field. With the exception of 10 meters of localized scour in T39, R8, the E5 surface does not undulate more than about 5 meters in total topographic relief to the immediate west and south of Ferrier field. Only toward Ricinus field in T37, R10 do the isopach values become quite large, indicating E5 (?) scour there (see previous discussion of Ricinus in section 4.2.1).

The fact that the whole of Ferrier field is not defined by a single **prominent** linear ridge (topographic high) in Figure 5.3 is also indicated on the well log and core cross sections in chapter 4. There, the E5 surface was undulatory over most of the western portion of the field area, including some development of the "a" coarsening-upward sequence well to the west of Ferrier field itself. It is not until the eastern margin of Ferrier field is reached that the E5 surface is consistently situated on a linear, northwest-trending topographic high, and even then, the relief is only pronounced along the northeastern edge of Ferrier field (T41, R8 and T42, R9) where the 45 meter contour is present.

Toward Willesden Green field, the E5 surface rises from the elongate trough onto the western side of Willesden Green, exhibiting a maximum relief of approximately 30 meters, although the average relief is closer to 5-10 meters.

5.5 CONGLOMERATE THICKNESS

There is an obvious trend to the distribution of the Carrot Creek conglomerate (Figure 5.4). It is thickest at the northeastern margin of Ferrier field and rests along its erosive bevelled edge and along the northeastern topographic high indicated on Figure 5.5. It is plastered on the southwestern flank of the erosive scour in T41, R8-9 and T42, R9 and rises up onto northeastern Ferrier. The thickest occurrence of conglomerates lies along the eastern margin of Ferrier, and the areal distribution of the Carrot Creek Member appears to be strongly controlled by the shape of the E5 surface upon which it rests.

It should be noted that these maps (Figures 5.4 and 5.5) only show the > 2.5 m thickness of the Carrot Creek conglomerate within the field area. In almost every core examined, and probably within almost every well which penetrates the Raven River Member, there is at least a pebble veneer overlying the E5 surface.

5.6 MESH DIAGRAMS

Figures 5.6 and 5.7 are computer-generated mesh diagrams which show the relief along the E5 surface based on the data used to construct the "UD-2 to E5" isopach map

Figure 5.4 Isopach map of the Carrot Creek conglomerate. Contour interval is 2.5 m. Only >2.5 m thicknesses of conglomerate are shown.

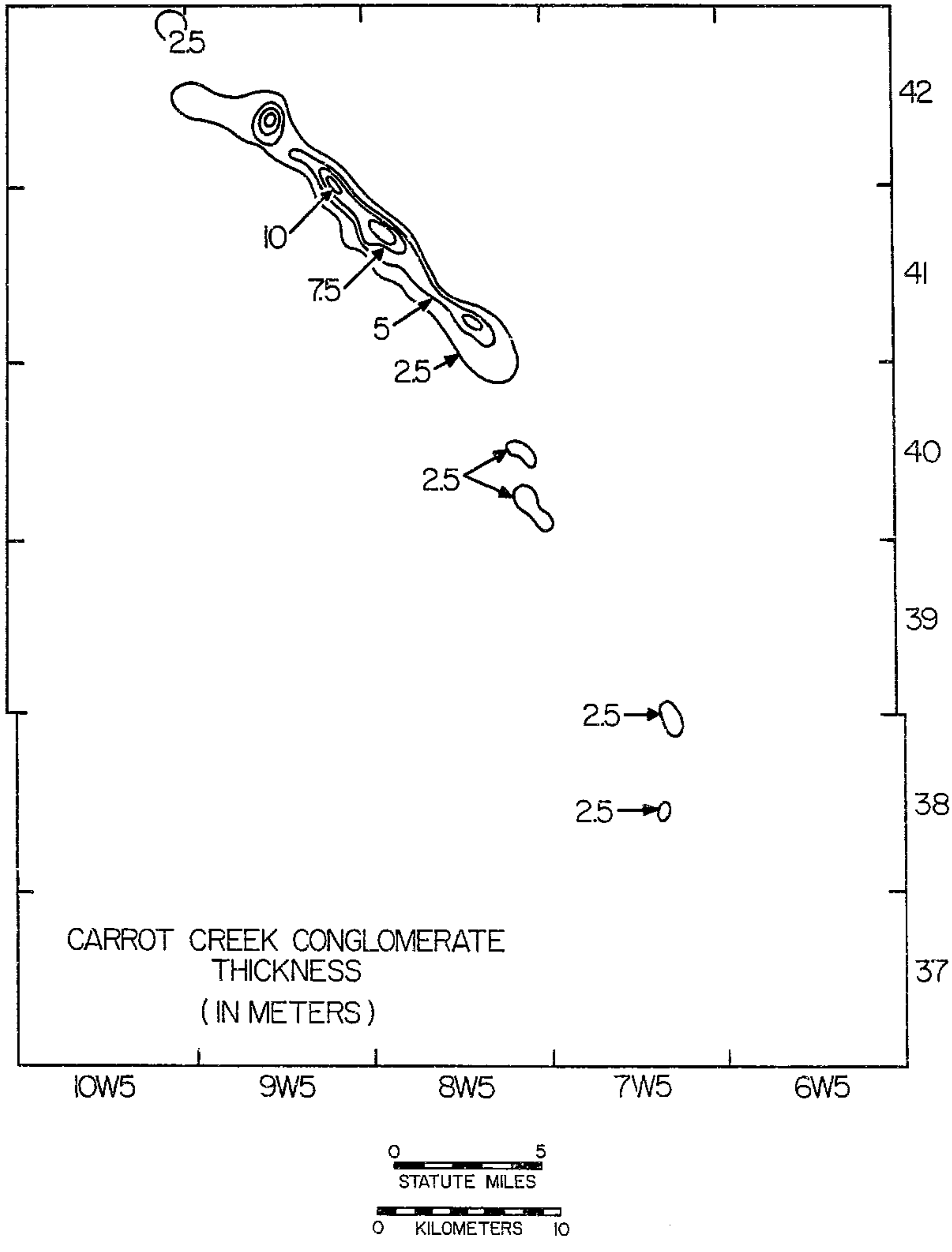
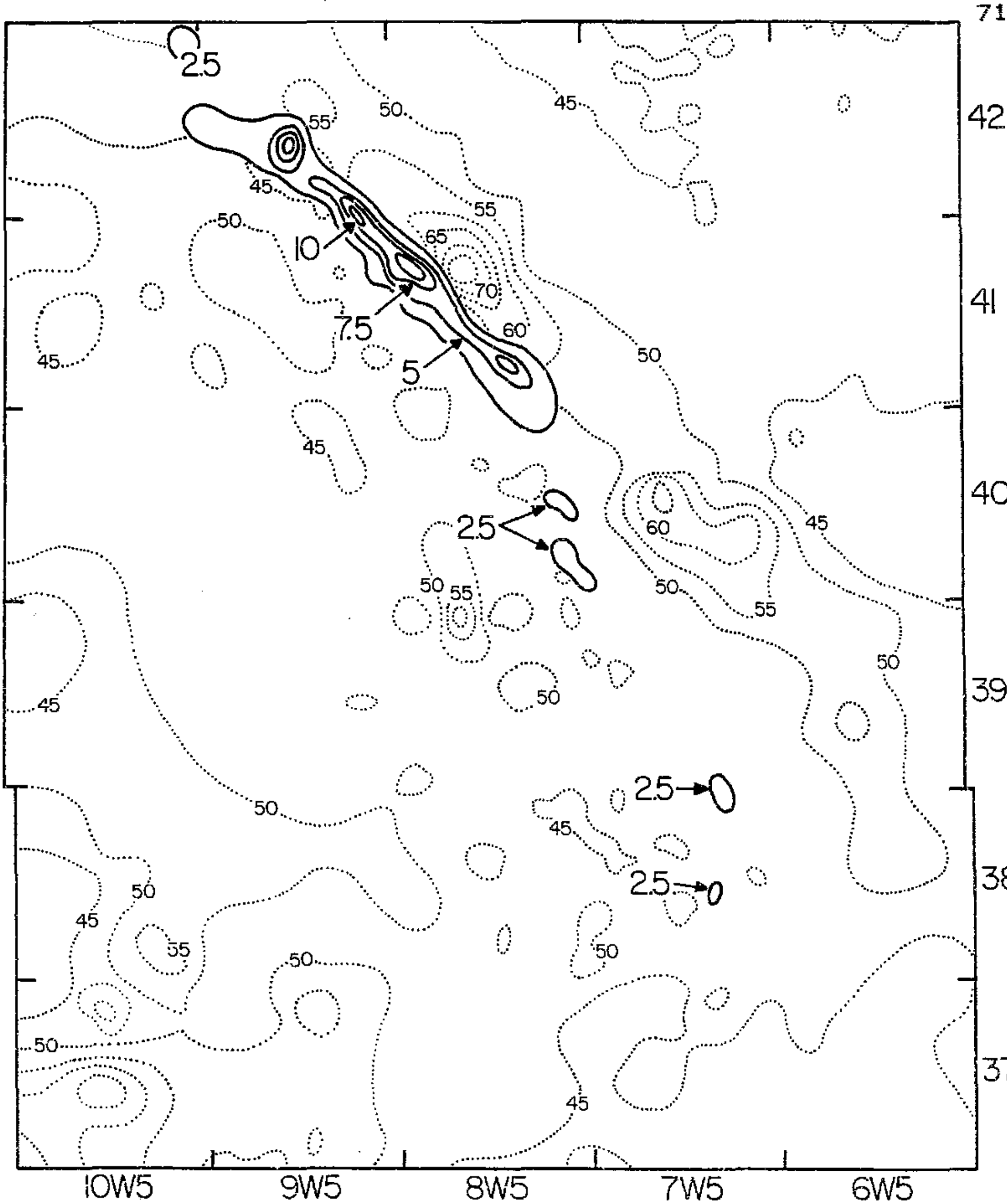

2.5
10
7.5
5
2.5
2.5
2.5
2.5
42
41
40
39
38
37
10W5
9W5
8W5
7W5
6W5
CARROT CREEK CONGLOMERATE
THICKNESS
(IN METERS)
0
5
STATUTE MILES
0
KILOMETERS
10

Figure 5.5 Map showing the areal distribution of Carrot Creek conglomerate upon the E5 erosion surface. Contour intervals are the same as those in Figures 5.3 and 5.4. Note that the thickest deposits of conglomerate are concentrated along the northeastern margin of Ferrier field, resting on the erosive bevelled edge and along the northeastern topographic high (T41, R8-9 and T42, R9).



CARROT CREEK CONGLOMERATE
THICKNESS (METERS)
SUPERIMPOSED ON THE
E5 SURFACE

0 5
STATUTE MILES

0 10
KILOMETERS

100,000

Figure 5.6 Mesh diagram of the E5 surface when viewed from the southwest corner (240 degrees) of the field area. Ferrier field is elongate and trends northwest. The term "terrace" denotes a raised, relatively flat topographic high (see Chapters 7 and 8 for a complete discussion). The term "bevel" denotes a relatively steeply inclined surface (see Chapters 7 and 8 for a complete discussion). The "bevel" is facing away from the viewer and is not visible from the viewing angle.

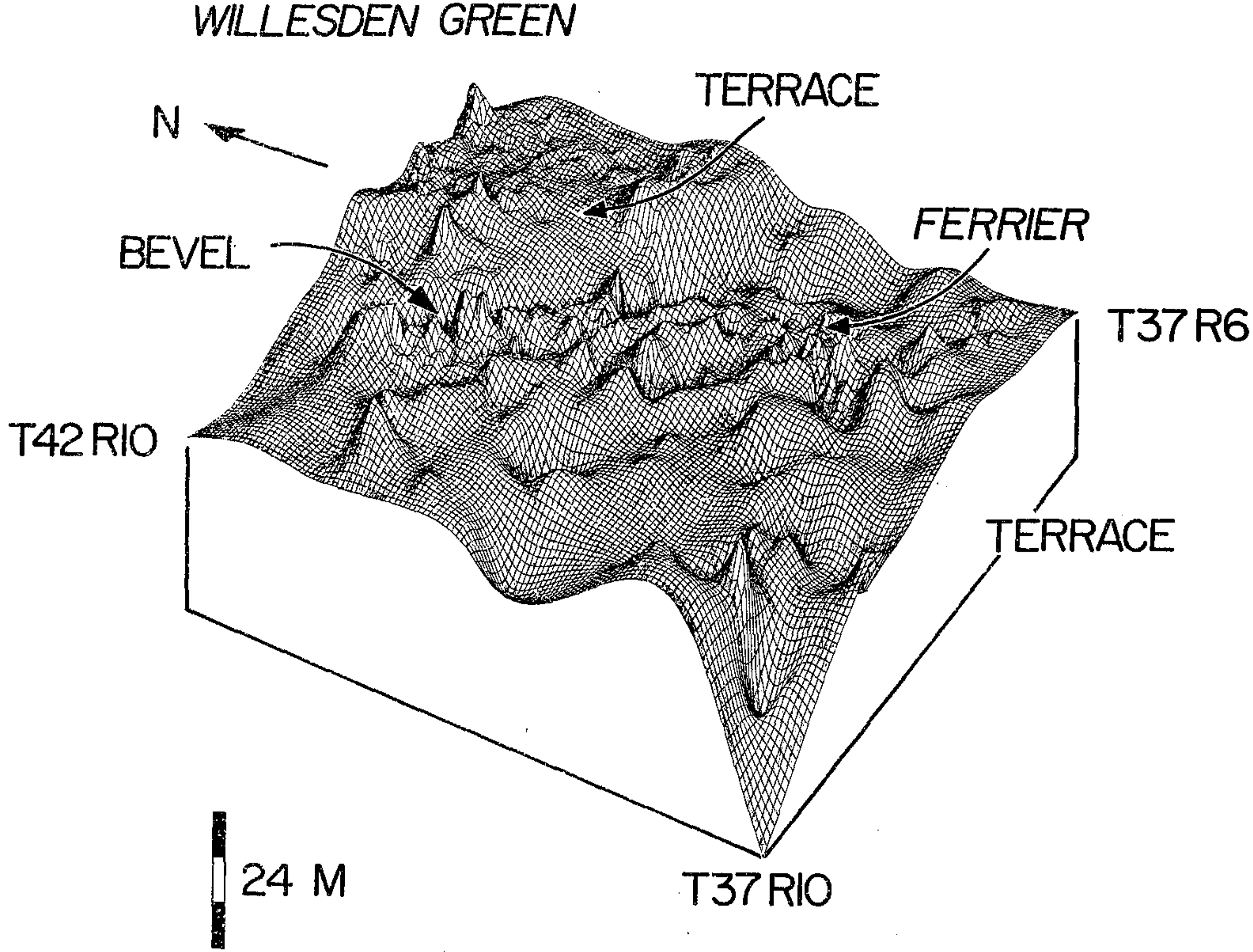
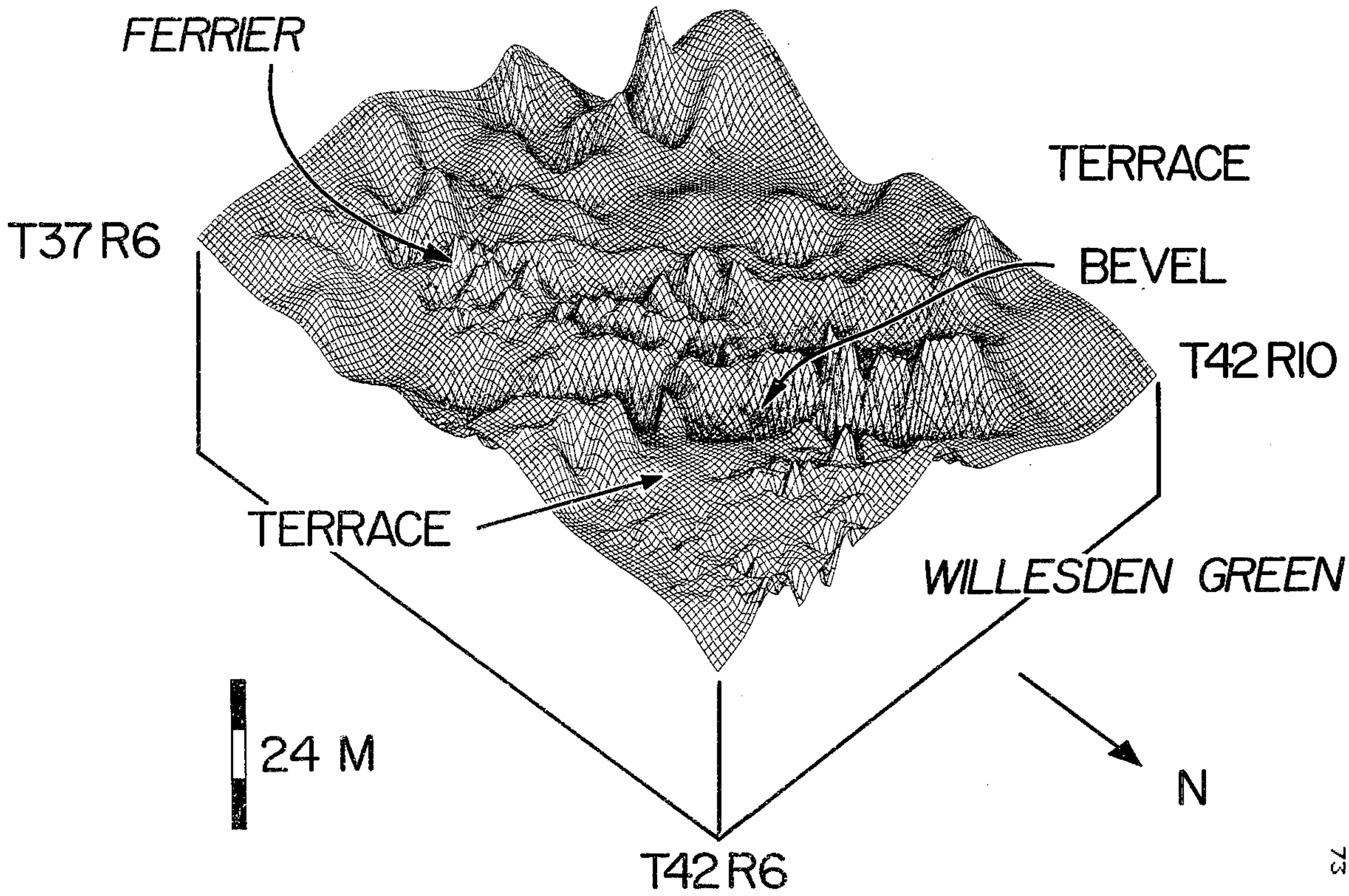

WILLESDEN GREEN
N
TERRACE
BEVEL
FERRIER
T37 R6
T42 RIO
TERRACE
24 M
T37 RIO

Figure 5.7 Mesh diagram of the E5 surface when viewed from the northeast corner (45 degrees) of the field area. Ferrier field is elongate and trends northwest. The northeastern edge of the field (T41, R8-9 and T42, R9) appears as a ridge. The "bevel" faces the viewer. The large peak in the southwest corner of the field area is an artifact of sparse well control and ambiguous well logs.


FERRIER
TERRACE
T37 R6
BEVEL
T42 RIO
TERRACE
WILLESDEN GREEN
24 M
N
T42 R6

(Figure 5.3). While the vertical scale is greatly exaggerated, it emphasizes the deep trough-shaped scour along the eastern edge of Ferrier field and the gentle rise back onto Willesden Green field. The terms "terrace" and "bevel" (Bergman, 1987; Bergman and Walker, 1987) featured on the mesh diagrams are introduced in chapter 7.

5.7 SUMMARY OF MAPS

The isopach maps presented illustrate some important points.

1. The use of upper markers ("datums") is potentially dangerous in the construction of isopach maps (and cross sections) which are intended to show the morphology of Cardium erosion surface E5. It has been shown that the upper marker (UD-2) well above the E5 surface may itself be erosive (and hence not an originally flat surface), therefore not reflecting the E5 morphology as accurately as possible.

2. The E5 surface maintains a trough-shaped scoured depression between Ferrier and Willesden Green fields. It is continuous along the eastern edge of Ferrier field and defines its eastern and northwestern margins.

3. The greatest thickness of Carrot Creek conglomerate banks against the erosional "bevel" along the northeastern edge of Ferrier field and overrides the top of Ferrier there, resting on top of a relative topographic high. Only a

pebble veneer lies within the scoured depression to the immediate northeast of the area of greatest conglomerate thickness.

4. An undulose topography defined by erosion along the E5 surface characterizes the area to the west and south of Ferrier field; there is no distinct, continuous topographic depression directly to the west or south of Ferrier which accounts for the western and southeastern margins of the field, as defined by drilling density. Only along the northeastern margin of the field is there a substantial topographic "ridge" which shows up on Figures 5.6 and 5.7; the rest of the field is not a prominent linear ridge in the subsurface.

CHAPTER 6

THE RAVEN RIVER MEMBER

6.1 DEPOSITION OF THE RAVEN RIVER MEMBER

The character of the Raven River Member varies throughout the field area. It is commonly composed of two coarsening-upward sequences (Fig. 3.8), but may contain only one, or as many as five sequences (Keith, 1985). Individual coarsening-upward sequences rarely exceed a few meters in thickness, although single sequences which underlie Ferrier field itself may be as thick as 10 meters. Complete sequences end in either facies 4 bioturbated mudstones, facies 5 bioturbated sandstones, or facies 7 hummocky cross-stratified sandstones, each of which may be capped by a gritty siderite.

The deposits of the Raven River Member represent aggrading shelf sediments deposited below fairweather wave base and above storm wave base. Individual hummocky beds suggest episodic emplacement by storm currents (Harms et al., 1975). Amalgamated hummocky cross-stratified sandstones interbedded with bioturbated sandstones and mudstones suggests rapid deposition of storm-reworked sands in an ordinarily quiescent environment. Below the hummocky sands are bioturbated sandstones and mudstones; slow background sedimentation allowed burrowing organisms to churn up the substrate and obliterate most of the wave-formed sedimentary structures. Gritty siderite occurs at the top of coarsening-upward sequences; it is suggestive of a pause in sedimentation (Bartlett, 1987), during which time only minor amounts of coarse material ("grit") was transported into the basin. The siderite formed just below the sediment-water interface. Walker and Eyles (in preparation) have demonstrated that ripping up of the substrate is often associated with the deposition of gritty siderite.

6.2 SHINGLING SAND BODIES

Previous interpretations of the sand body geometry at Ferrier and Willesden Green fields suggest that the Raven River sands were deposited as a series of thin, prograding, offlapping units (Griffith, 1981; Keith, 1985; 1987). At Ferrier, Griffith (1981) has suggested a southeast-dipping offlapping pattern; the entire field was thought to have been an offshore "build up" bar. At Willesden Green, Keith (1985) has identified five individual coarsening-upward "units" which shingle to the northeast. A similar prograding arrangement of sand bodies has been documented for the Gallup Sandstone in the San Juan Basin, New Mexico (Campbell, 1971).

Longitudinal cross section F-F′ (foldout at back of thesis) was constructed parallel to the southeast-trending Z-Z′ section of Griffith (1981). Unlike Griffith's (1981) apparent shingling pattern, F-F′ does not suggest a series of thin, southeast prograding sand bodies. A series of planar and continuous lower markers indicate that there is a continuous and predictable stratigraphy which runs the length of Ferrier field; there is no indication that positive resistivity well log deflections which might represent sandy bodies die out into stratigraphically lower muds. Particularly noticeable is the "yellow spike" datum which is continuous the length of F-F'; Griffith (1981) has chosen to pinch out the "yellow sand" (Walker and Eyles, in preparation) at this horizon half way down the field, for which there is no justification.

Keith (1985) has documented a series of northeast-dipping, offlapping Raven River sands in Willesden Green. His choice of datum from which the offlapping geometry was determined was the E6 erosion surface (Plint et al., 1986). The E6 surface has been shown to drape the E5 topography at western Willesden Green (Walker and Eyles, in preparation). Since the E5 surface dips to the southwest along the western margin of Willesden Green field, the E6 surface does so as well. Restoring the southwestward-dipping E6 surface to the horizontal for use as a datum exaggerates the northeast dip of the sequences. Within the context of this thesis, the "yellow spike" datum is correlative with the top of Keith's (1985) Unit 1 sequence (cross sections 1-12; Keith, 1985). If Unit 1 is flattened to the horizontal (mimicking the "yellow spike" datum), then the northeast dip to Keith's overlying units is lessened considerably; in some cases, the dip disappears. In addition, there is some doubt regarding the correlation of some of Keith's (1985) unit boundaries (Walker and Eyles, in preparation).

6.3 CORRELATION BETWEEN FERRIER AND WILLESDEN GREEN

Walker and Eyles (in preparation) have colour-coded individual coarsening-upward sequences in Willesden Green field. These colours have been included for the Willesden Green wells in core cross sections B-B' through D-D' in this thesis. Certain depositional trends exist in these sequences, as seen in a series of isopach maps (Walker and Eyles, in preparation). These trends extend into Ferrier field, and are correlative across the inter-field erosional gap. These trends include:

a) A thin development of the "yellow sand" (Walker and Eyles, in preparation) in northern Willesden Green; likewise in northern Ferrier.

b) The "red" and "blue" sands (Walker and Eyles, in preparation) which overlie the "yellow spike" are well-developed in west-central Willesden Green; they are thick and amalgamated in northeastern and central Ferrier as well.

c) The gritty horizons which separate the yellow, red, and blue sequences in Willesden Green (core cross sections of Walker and Eyles, in preparation) occasionally do so in

Ferrier as well, even though these sequences are amalgamated together (see core cross section C-C', this thesis).

d) The thick "yellow sand" in southern Willesden Green is thick in southern Ferrier too.

6.4 RELATIONSHIP BETWEEN SAND BODY GEOMETRY AND SHAPE OF FERRIER FIELD

The E5 erosion surface and not the depositional geometry of the Raven River sands defines most of the elongate shape of Ferrier field. Previous interpretations suggest that the sands are stacked vertically or offlap in the seaward direction, producing a topographic high (Griffith, 1981; Griffith et al., 1982; Keith, 1985; 1987). This elongate mound has been referred to as a "build up" bar by Griffith (1981). However, the arguments presented in Chapters 4 and 5 suggest that the E5 erosion surface has largely determined the shape of the field. In the north and east, intense scouring of the sandy Raven River substrate has removed any potential reservoir sand. To the west, the undulose nature of the E5 surface has locally eroded away some of the thick sands and has left others preserved. Most of the drilling to the west of the field is directed at either locally exploitable accumulations of Raven River sand, the Burnstick Member (Plint et al., 1986; Pattison, 1987), or deeper targets. To the south, the E5 surface does not erosively truncate the coarsening-upward sequences of the Raven River Member (cross section F-F'). The Raven River reservoir sand is depositionally thin here and is not economically exploitable, hence the relative decrease in drilling density "off-field" to the south.

CHAPTER 7

EROSION OF THE E5 SURFACE

AND

THE DISTRIBUTION OF THE OVERLYING CONGLOMERATE

7.1 GEOMETRY OF THE E5 SURFACE

The morphology of the E5 surface is defined by cross sections, an isopach map, and three-dimensional mesh diagrams. The salient features of the surface include:

a) A pronounced topographic depression (bevel) between Ferrier and Willesden Green fields.

b) An undulose topography along the E5 surface to the west of Ferrier (terrace) with little systematic trend.

c) A maximum relief along E5 of 15 meters (Twn.41,R.8). The terms "terrace" and "bevel" of Bergman and Walker (1987) may be applied to the erosive morphology documented within the Ferrier-Willesden Green field area. The "terrace" refers to the area west of Ferrier field which exhibits little systematic relief. The "bevel" refers to the eastern margin of Ferrier field which is relatively steep and truncates the underlying coarsening-upward sequences of the Raven River Member.

7.2 MECHANISMS OF EROSION

Before the formation of the E5 surface, storm waves were allowing the deposition of fine- and very-fine sand on the bed as hummocky cross-stratified sands in the Raven River Member. Therefore, in order to cut the E5 erosion surface, there must have been erosion on the bed. In order to do this, erosion must be intensified so that waves may effectively scour the substrate. Erosion could have taken place in one or more of three environments (Bergman, 1987; Bergman and Walker, 1987; Bergman and Walker, in preparation). First, it could have occurred fully subaqueously on the shelf. Second, the lowering of sea level could have been so drastic that the erosion could have been entirely subaerial. The third possibility is erosion at the shoreline by shoreface incision. Each of these possibilities is discussed in turn.

1. Submarine erosion on the shelf

Storm waves have the capacity for scouring the substrate at depth below fairweather wave base (5-15 m; D.J.P. Swift, in Walker, 1985c). Scour surfaces produced by storm wave erosion are generally broad, shallow depressions (meters across, tens of centimeters deep; Kreisa, 1981; Aigner, 1985). However, the eastern margin of Ferrier field is long, continuous, and relatively steep, suggesting strong, localized erosion rather than broad, undulose scouring by storm waves on an open shelf. Therefore, the linear erosional relief along the eastern margin of Ferrier (up to 15 meters) makes storm waves an unlikely candidate for seafloor erosion.

2. Subaerial erosion:

The morphology of the E5 surface in the field area is broadly undulose with a pronounced northwest-southeast trending valley between Ferrier and Willesden Green fields that is parallel to the regional tectonic trend. The topographic surface does not resemble one carved by river channels, particularly since the elongate scour between the two fields trends **parallel** to the rising Cordillera; had rivers sculpted these valleys, then presumably they would have been flowing across rather than down regional paleoslope.

There are no "conventional" traces of fluvially-dominated erosion along the E5 surface. No concentrations of coarse material identified as channel lags exist in the bottoms of deep erosive scours. No roots, paleosols, desiccation cracks, or coals have been observed at the E5 horizon, although such evidence could have been removed by subsequent transgression. Perhaps the most compelling evidence against subaerial scour is the presence of marine facies (facies 2P and 2) immediately above the erosion surface in areas where the Carrot Creek conglomerate exists as a thin pebble veneer.

3. Shoreface erosion:

Bergman and Walker (1987) have proposed the shoreface as the most likely environment of erosion for the E5 surface in the Carrot Creek area. A rapid lowering of sea level caused the original shoreface to move many tens of kilometers basinward. At its maximum extent, it appears to have moved just northeastward of the "bumps and hollows" region described by Bergman (1987) and Bergman and Walker (1987) at Carrot Creek (Figure 12 of Bergman and Walker, 1987; Figure 8.1a, this thesis). Wave scour at Carrot Creek during this maximum lowering of sea level incised a lowstand shoreface there.

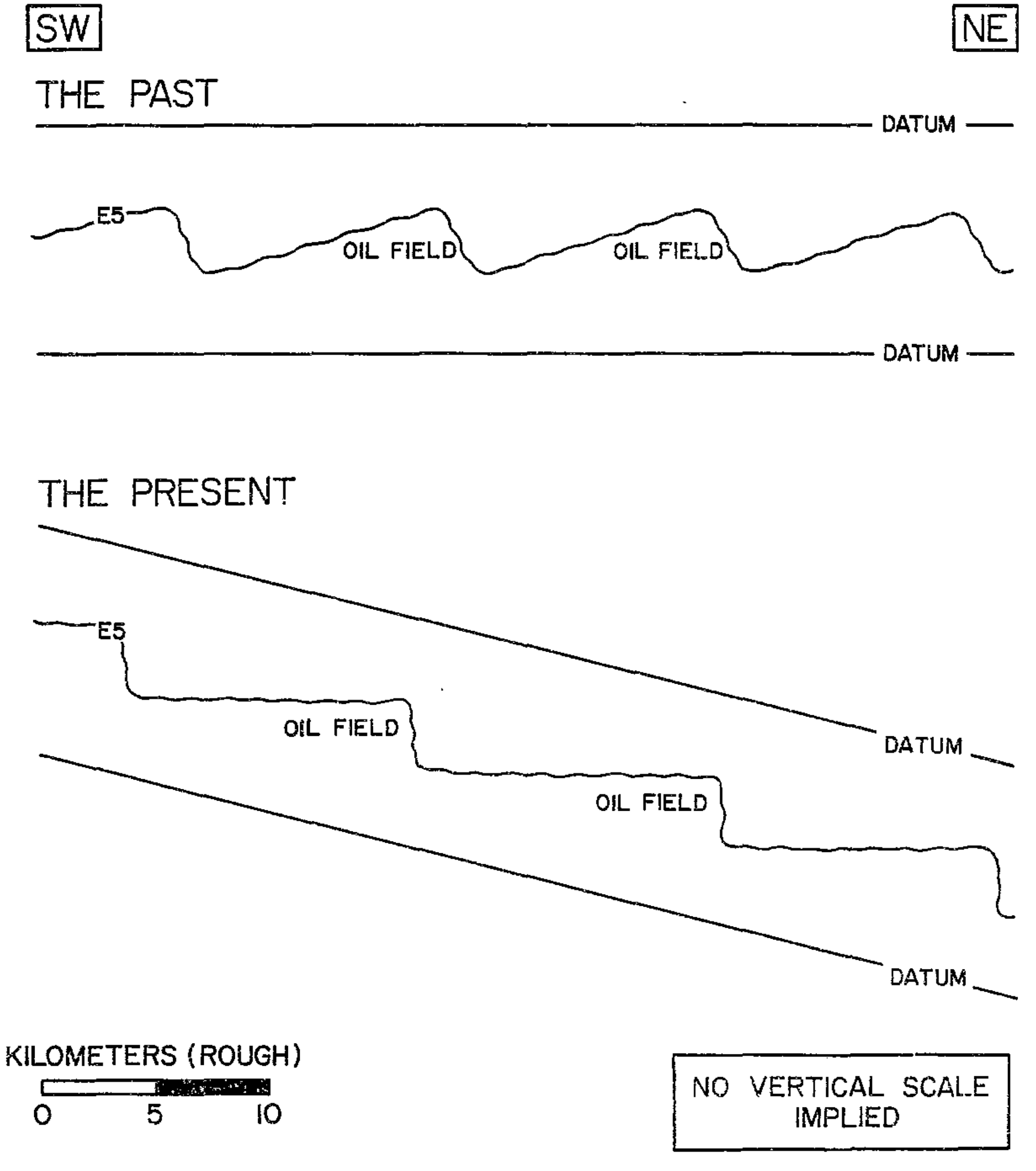
The details of the erosion of the E5 surface at the Carrot Creek and Pembina fields are given in Bergman and Walker (1987), Bergman and Walker (in preparation), and Leggitt (1987). In general, a period of stillstand followed the rapid lowering of sea level, during which time erosional shoreface retreat to the southwest scoured the seafloor (the underlying Raven River sandstones and bioturbated mudstones) up to the "bevel." Gravel was deposited episodically into the newly-formed shoreface, presumably supplied by fluvial processes and reworked alongshore by waves. The gravel might have armored the erosion surface in the region of bumps and hollows at Carrot Creek, and was plastered along the seaward bevelled edge (shoreface) farther to the southwest as the shoreface eroded landward.

The "terrace" area to the southwest of the erosional bevel (Fig. 12 of Bergman and Walker, 1987) must have been emergent during maximum lowstand, but all evidence of subaerial exposure has presumably been removed by subsequent erosion associated with the ensuing transgression.

7.3 MODEL FOR SHOREFACE INCISION

The sculpting of an erosional shoreface profile at Carrot Creek may be extended to the other Cardium oil fields (Leggitt, 1987; Walker and Eyles, in preparation; this thesis). The geometry of the E5 surface, which defines the shoreface profile, has by tradition been documented from correlations hung on markers drawn as horizontal. The Cardium reservoir sands lie within the same stratigraphic horizon (the Raven River Member), and the E5 surface undulates between them, truncating potential reservoirs and preserving others (the oil fields). This geometry is illustrated in the upper half of Figure 7.1, and represents the way geologists have viewed the distribution of the oil fields in the past. However, if each successive reservoir rests at the same horizon, and the mechanism of shoreface erosion that was active at Carrot Creek is valid for the northeastern margins of other Cardium reservoirs, then a problem arises: how does sea level fluctuate such that transgressive shoreface profiles are scoured into Cardium marine sands landward of Carrot Creek while successive ridges seaward of the newly eroded shorefaces are preserved? Given the argument illustrated in the upper half of Figure 7.1, it is apparent that each consecutive seaward ridge

Figure 7.1 The morphology of the E5 erosion surface with respect to horizontal and dipping markers. The upper half of the diagram, entitled "The Past," illustrates the way in which geologists familiar with the basin-wide E5 unconformity have viewed the distribution of Cardium oil fields. Flat markers yield the undulose E5 profile pictured. However, given the arguments in Sections 7.2 and 7.3 which suggest that shoreface incision has carved the E5 morphology into an <u>originally</u> <u>dipping</u> stratigraphy, we now view (at "The Present") the E5 surface with respect to dipping markers.


SW
NE
THE PAST
DATUM
E5
OIL FIELD
OIL FIELD
DATUM
THE PRESENT
E5
OIL FIELD
DATUM
OIL FIELD
DATUM
KILOMETERS (ROUGH)
0
5
10
NO VERTICAL SCALE IMPLIED

would damp out the erosive effects of waves. Therefore, when waves were incising a 15 meter high shoreface at Ferrier, fields such as Willesden Green and Pembina to the northeast (seaward) would have been huge, flat-topped islands that would have damped out the proposed wave action at Ferrier; the "incised shoreface" between Ferrier and Willesden Green would be very difficult to form using this model.

A new approach to Cardium shoreface incision has recently been suggested by Bergman (1987), Leggitt (1987), and Bergman and Walker (in preparation). Re-examination of cross sections hung from horizontal markers suggest that the backs (southwestward sides) of the bumps in the region of bumps and hollows at Carrot Creek might once have been horizontal erosional bites (Bergman and Walker, in preparation). That is to say that the backs of the bumps represent erosion to fairweather wave base. If the datums in the upper half of Figure 7.1 are given an initial dip into the basin (the lower half of Figure 7.1) equal to the present measured values of the inclination of the backs of the bumps in the bump and hollow region at Carrot Creek, then the bump and hollow topography becomes a series of stepped incised shorefaces (Figure 5b of Bergman and Walker, in preparation). A succession of stillstands interrupted by episodes of relatively rapid rises in sea level carved out a "stepwise" shoreface profile in an originally dipping stratigraphy. The lower half of Figure 7.1 (entitled "The

Present" in reference to present thought regarding shoreface incision) illustrates the above principle. Horizontal erosional "bites" between oil fields represent sea level stasis (landward shoreface retreat), while the preserved reservoirs represent relatively rapid sea level rise where the erosive shoreface profile has overstepped what are now the northeastern margins of Cardium oil fields.

The idea of stepwise retreat is not entirely new. Variations of it have been discussed by Kraft (1971), Swift et al. (1972), Swift et al., (1973), Sanders and Kumar (1975), and Rampino and Sanders (1980). However, each of these studies of the formation of the pre-Holocene erosion surface differs from the formation of the E5 surface in the Cardium Formation. The Holocene rise in sea level is a eustatic event directly controlled by the rate of glacial melting. However, in the absence of glaciation, large-scale fall and rise of sea level would presumably have to be controlled by changes in the volumes of spreading centers. There is no evidence, worldwide, for such major and rapid sea level fluctuations in the Upper Turonian (Bergman and Walker, in preparation), particularly when one considers that the Cardium Formation is dissected by seven regionally extensive erosion surfaces (Plint et al., 1986). By contrast, in the Alberta Foreland Basin, sea level rose with respect to a fixed point, or structural hinge, which was probably situated many tens of kilometers to the northeast of Carrot Creek (Bergman and Walker, in preparation). The observed regressions and transgressions occurred as a result of initial upwarping followed by periods of progressive downward flexing (Bergman and Walker, in preparation).

Any eustatic sea level changes in the Turonian (e.g., Vail et al., 1977) would probably be masked by tectonic overprinting in the active Foreland Basin (Jeletzky, 1978). It is important to note that the Cardium was deposited into a tectonically active environment, which differs dramatically from the passive margin setting characteristic of the present Atlantic coast. Modern examples of "stepwise retreat" (Rampino and Sanders, 1980) are influenced by eustatic sea level change on a passive margin rather than by tectonism in a foreland basin. Foreland basins are hinged immediately seaward of the accumulating sediment pile and are subject to periods of upthrust followed by periods of subsidence. Subsidence occurs during loading of the craton by successive thrust slices (Jordan, 1981). Upthrusting causes regression, while subsidence induces transgression. These relative sea level fluctuations appear to be controlled by rapid tectonic movements which are much faster and much more local than those modelled on the scale of foreland basins (Beaumont, 1981; Jordan, 1981; Quinlan and Beaumont, 1984). It has tentatively been suggested (Bergman and Walker, in preparation) that thrusting within the foreland basin during Cardium deposition might account for the relatively rapid, short-lived movements of the basin floor.

7.4 RECONSTRUCTION OF THE ORIGINAL DIP OF THE RAVEN RIVER STRATIGRAPHY

Cross sections A-A' through D-D' (Chapter 4; foldouts at the back of thesis) were constructed approximately normal to the trend of Ferrier field. These cross sections show:

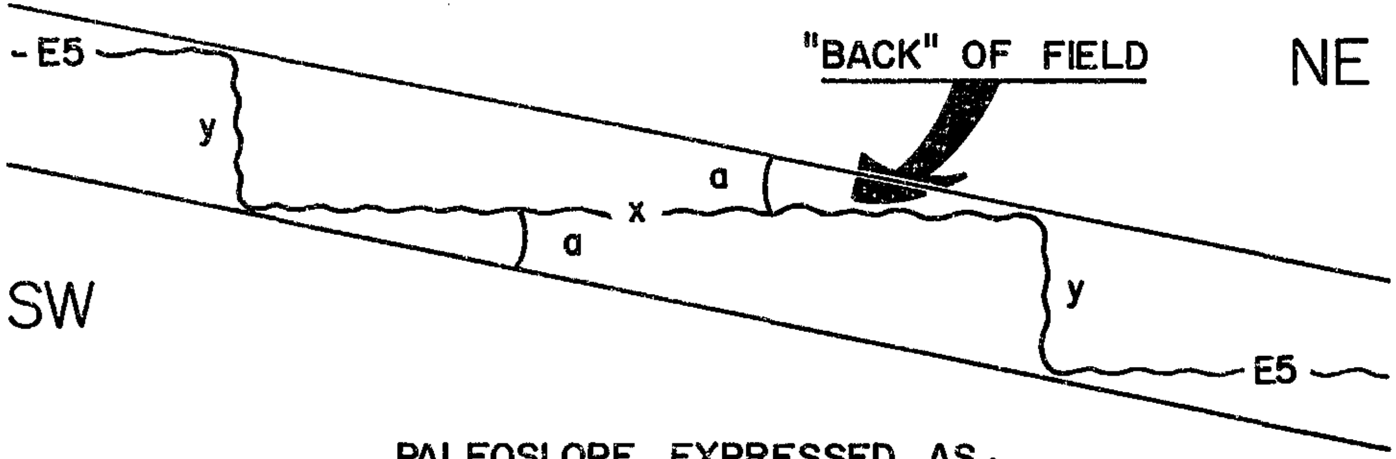
a) An undulating E5 surface which scours down between Ferrier and Willesden Green fields. Along isopach map UD-2 to E5 (Fig. 5.3), in the vicinity of line D-D' (Fig. 4.1), the eastern margin of Ferrier field dips steeply to the northeast. This steepened front is referred to as the "Ferrier bevel."

b) A gentler, southwestward-dipping flank to the northeast of the bevel referred to as the "Willesden Green terrace."

This asymmetrical morphology is also observed on the UD-2 to E5 isopach map (Fig. 5.3).

The dips across the terrace of western Willesden Green field were calculated along sections A-A' through D-D' by the method illustrated in Figure 7.2. They were also calculated for the back of Ferrier field along the same lines of cross section (Fig. 7.3), but there is little appreciable relief to the west of the field from which a shoreface profile can be determined. Hence, the slope values

Figure 7.2 Method for calculating the original dip ("a") of the Raven River stratigraphy. The "back" of the field pictured is synonymous with "terrace."



PALEOSLOPE EXPRESSED AS:

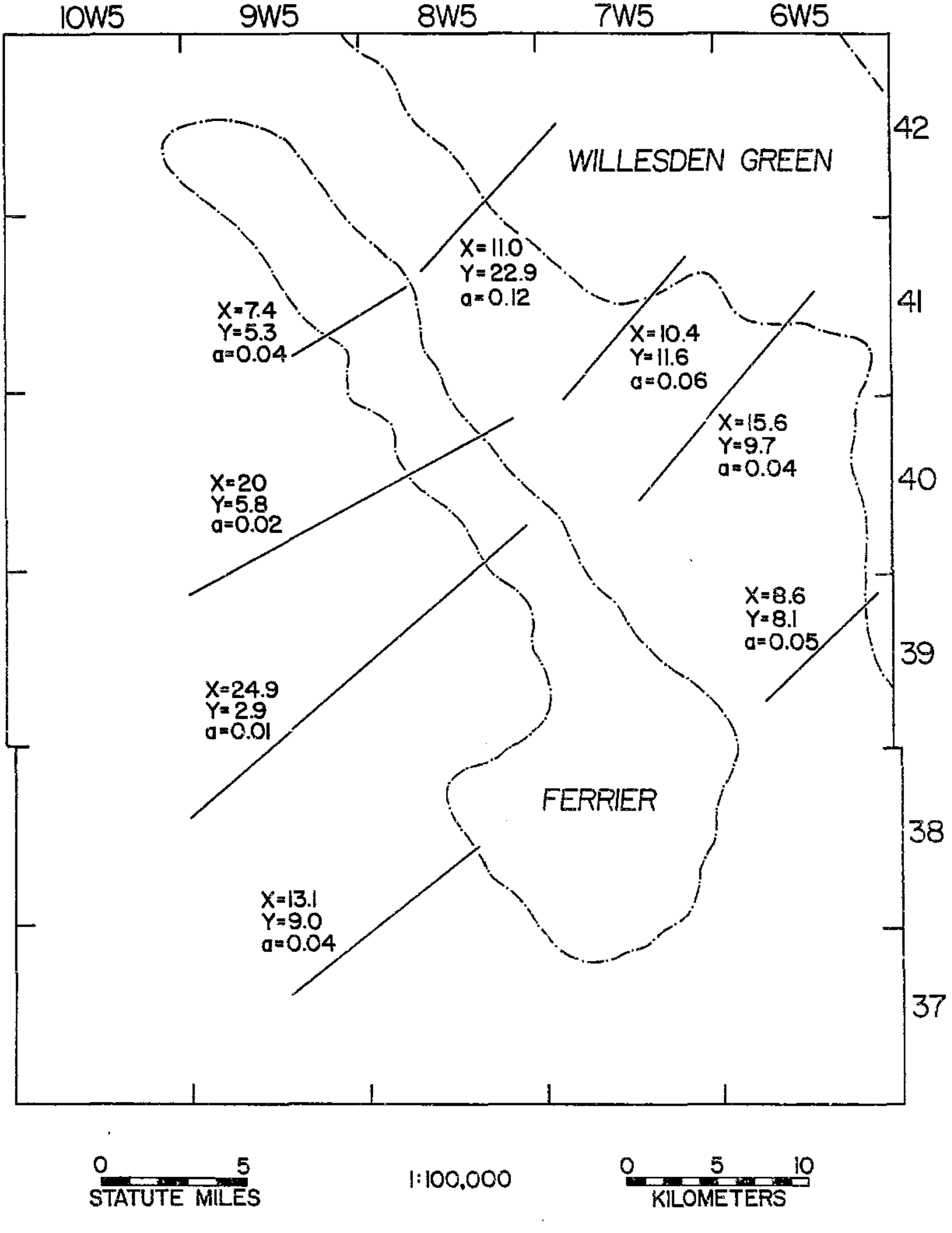
RATIO (GRADIENT) = y/x

OR

ANGLE (DEGREES): $\tan a = y/x$

$\tan^{-1}(y/x) = a$

Figure 7.3 Calculated dip values at western Ferrier and western Willesden Green. The line segments approximate portions of the lines A-A' through D-D' featured in Chapter 4 (Figure 4.1). The southwestern and northeastern endpoints of each line segment are situated in regional lows and highs, respectively, along the E5 surface (lows and highs were determined from lines A-A' through D-D'). The "X" distances are given in kilometers, the "Y" lengths are given in meters.


10W5
9W5
8W5
7W5
6W5
42
41
40
39
38
37
WILLESDEN GREEN
FERRIER
X=11.0
Y=22.9
a=0.12
X=7.4
Y=5.3
a=0.04
X=10.4
Y=11.6
a=0.06
X=15.6
Y=9.7
a=0.04
X=20
Y=5.8
a=0.02
X=8.6
Y=8.1
a=0.05
X=24.9
Y=2.9
a=0.01
X=13.1
Y=9.0
a=0.04
0
5
STATUTE MILES
1:100,000
0
5
10
KILOMETERS

for the back of Ferrier vary considerably in magnitude as there is no systematic regional low to the west from which calculations such as those made for Willesden Green can be made. An average of the Willesden Green and Ferrier dips yields numbers which, according to the model (Section 7.3), approximate the original dip of the Raven River stratigraphy at Willesden Green and Ferrier during "shoreface incision" there.

The paleoslope values calculated by Bergman (1987) for the dip of the Raven River stratigraphy at Carrot Creek have been extensively revised by Bergman and Walker (in preparation). The area of bumps and hollows has been re-evaluated for alongstrike continuity of isopach contours, and where formerly there were areas of bullseye contours around groups of data points, now there are smooth northwest-southeast contours which suggest considerable lateral continuity parallel to regional strike. The slope values decrease from 0.28 to 0.11 degrees from the northeast to the southwest across the field area (average of 0.18). Farther to the southwest, at Pembina, the paleoslope values of Leggitt (1987) have been revised, with a mean value of the slope on the back of the main field of 0.14 degrees (cross section B, Figure 7.42, Leggitt, 1987). At Willesden Green, Walker and Eyles (in preparation) have calculated a mean slope of 0.077 degrees for the area to the immediate northeast of the bevel which defines the northeastern edge of Willesden Green field. The mean slope at western Willesden Green is 0.07 degrees (Figure 7.3), and the mean slope at western Ferrier is 0.03 degrees (Figure 7.3).

The mean paleoslopes given above generally decrease systematically to the southwest, from Carrot Creek to Ferrier (it will be shown in Chapter 8 that given an actual continuous line of cross section across the Alberta Basin, the values do not rigorously adhere to the decrease-to-the-southwest trend, which is to be expected along a single line of section which only shows local slope values and does not show mean values of paleoslopes). This general trend is consistent with the stepwise profile model, which relies on local tectonic upwarping followed by progressive downward flexing. To achieve the initial rapid lowering of sea level which moved the shoreline to the immediate northeast of the region of bumps and hollows, Bergman and Walker (in preparation) have proposed a flexure of the basin floor, with maximum uplift to the west, and flexure gradually dying out basinward. The point of zero movement (a structural hinge) was presumably located many tens of kilometers to the northeast of Carrot Creek (Bergman and Walker, in preparation). With the seafloor now uplifted, shoreface incision began during a relative stillstand of sea level which produced the northeastern-most horizontal erosional bite at Carrot Creek (position #3, Figure 5a,c, Bergman and Walker, in preparation; Figure 8.1a,b, this thesis). Once the incision has been made, the uplifted surface began to flex downward slowly, coming to rest at position #2 (Figure 5a,c, Bergman and Walker, in preparation; Figure 8.1a,b, this thesis). This alternation of stillstand and steady sea level rise (downward flexing of the basin floor) has been documented basin-wide (Figure 8.1a,b). Whereas the mean basinward dip was "quite steep" at Carrot Creek (0.18 degrees, Bergman and Walker, in preparation; 0.15 degrees, this thesis, see Figure 8.1a), by the time the Carrot Creek shoreface had moved to the position of the bevel at Ferrier, the basin had subsided (flexed downward) to 0.07 degrees (the mean of the paleoslopes calculated for western Willesden Green, this thesis).

7.5 DISTRIBUTION OF CONGLOMERATE

The Carrot Creek conglomerate which rests unconformably on the E5 surface is found in localized concentrations throughout the Cardium Formation. There are two main types of conglomerate, the clast-supported conglomerates and the mud-supported conglomerates. The clast-supported conglomerates have been interpreted as shoreface gravels banked up against a major bevel surface (the incised shoreface; Bergman, 1987). At Carrot Creek, the clast-supported gravels rest within the "hollows" and bank up against adjacent "bumps" (Bergman, 1987). At Pembina, the clast-supported conglomerates are confined to the northern edges of the ridges, or what Leggitt (1987) calls the "upper shoreface profile." At Ferrier, the thick concentrations of conglomerates are banked up against the northeastern edge of the field and overlie the eastern topographic high to the immediate southwest, on top of northeastern Ferrier (Figure 5.5).

The mud-supported conglomerates are found above clast-supported ones, or occur by themselves immediately above the E5 surface; matrix-supported gravels are rarely found below clast-supported ones. Mud-supported conglomerates largely occur in the off-field areas and on top of the incised "steps" or "terraces" (the back of Ferrier and Willesden Green).

Bergman and Walker (1987) have suggested that the Carrot Creek conglomerates were deposited during stillstand and hence rest in the position of the shoreface. The gravels were subsequently worked along the shoreface and into the hollows by waves. Ensuing transgression cut off the gravel supply. Some of the thick concentrations of gravel were reworked from the bevel and redistributed across the top of the terrace as a transgressive lag (e.g., the thick accumulation of conglomerate which rests on a topographic high in 10-20-41-8W5, cross section D-D' at back of thesis). Storms moved some of the shoreface gravel offshore, incorporating stringers of it into black transgressive muds. When the depth became too great for any gravel movement, a blanket of mud settled over the region (Bergman and Walker, 1987). The above sequence of events was repeated over Pembina, Willesden Green, and Ferrier fields. With each incised shoreface at the eastern margin of each of these fields came a supply of gravel, presumably from a fluvial source (Bergman, 1987; Leggitt, 1987; Bergman and Walker, 1987). Subsequent transgression drowned the river mouth(s) and cut off the gravel supply. At Ferrier field, up to 12 meters of predominantly clast-supported conglomerate occurs in a very concentrated area along a portion of the northeastern bevel edge and onto the eastern ridge at Ferrier immediately adjacent (T.41, R.8 and 9). Such a concentration suggests that this was once a point of gravel input into the Ferrier shoreface.

The model for stepwise retreat, discussed earlier, suggests a decreasing slope gradient to the southwest. At Carrot Creek, where gradients should be and are the greatest (e.g., 0.28 degrees slope at position #3; Bergman and Walker, in preparation), the average conglomerate clast size is 1-2 cm (Bergman, 1987). Roughly along strike, at eastern Pembina, the gross average clast size is approximately the same (a slight decrease exists within Pembina itself, Leggitt, 1987). To the southwest, at Ferrier, the average clast size is 5 mm. Assuming that the gravel supply (in terms of clast size) was the same at both Carrot Creek and Ferrier, then the smaller clast size found at Ferrier implies a gentler gradient along which the gravel-bearing rivers flowed before dumping their load in the Ferrier shoreface. The northeast to southwest decrease in average clast size fits into the stepwise shoreface/flexing basin model quite well.

CHAPTER 8

QUANTIFICATION OF BASIN-WIDE STEPWISE RETREAT

8.1 INTRODUCTION

With the exception of Ricinus, which appears to be channelized, Ferrier field is the western-most of the Cardium linear sand ridges. To the west of it, there exists no known "final position" of the Raven River shoreline, nor is there another E5 erosive shoreface bevel documented in the subsurface or outcrop. However, the rate of relative sea level rise in the Upper Turonian can be quantified given the known positions of the E5 bevelled shorefaces in the Cardium Formation. Paleoslope data from the Carrot Creek area (Bergman and Walker, in preparation) and from the Pembina field (Leggitt, 1987; modified figures used in this thesis), and new data from Willesden Green (Walker and Eyles, in preparation; this thesis) and Ferrier allow extensive calculations to be made regarding sea level rise and the formation of the E5 surface.

8.2 SHOREFACE RETREAT

The mechanism of erosive shoreface retreat is discussed in Chapter 7 and by Bergman and Walker (in preparation). If the datums upon which the cross sections of Bergman (1987) and Bergman and Walker (1987) are hung are given an initial dip into the basin equivalent to the present inclination of the backs of the bumps, then the bump and hollow topography at Carrot Creek becomes a series of stepped incised shorefaces (Bergman and Walker, in preparation). Such a stepped profile implies alternations of stillstand (incising horizontal erosional "bites") and relatively rapid sea level rise (to produce a series of incised steps) (Bergman and Walker, in preparation; Walker and Eyles, in preparation). The structural mechanism which causes the fluctuation in sea level may be referred to as "basinal flexure." Episodes of downward structural flexing effect relatively rapid sea level rises, preserving the remnant erosional topography. Gradual subsidence produces a relatively steady rise of sea level.

8.3 CROSS SECTION G-G'

Figure 8.1a is a cross section of the E5 surface across a portion of the Alberta Basin. It was constructed using the raw data of the various authors noted in the figure. The points which mark the position of the E5 surface at Carrot Creek and northeastern and central Pembina were taken from the base maps from which Bergman (1987) and Leggitt (1987) constructed their isopach maps of the E5 surface (Foldout #5 of Bergman, 1987; Figure 5.31 of Leggitt, 1987). The dashed line which extends from southwestern Pembina to the area to the immediate northeast of Willesden Green was plotted from Figure 3.40 of Krause and Collins (1984), which is an

Figure 8.1

A. A cross section (G-G') of the E5 surface across a portion of the Alberta Basin (see inset for location). This section is hung on horizontal markers, and shows the topography of the terraces, bevels, and the region of bumps and hollows. The numbers 1, 2, and 3 in the region of bumps and hollows correspond to the incised steps of Bergman and Walker (Figure 5; in preparation). The dip angles with respect to horizontal markers of the segments shown by projecting lines range from 0.04 to 0.20 degrees.

B. A reconstruction of cross section G-G' with respect to an inclined Raven River stratigraphy. It is not an actual representation of the E5 surface because each originally dipping stepped surface has been restored to the horizontal. By making all the terraces and the backs of the bumps horizontal, the actual differences in dip relative to a tilted underlying stratigraphy are incorporated into the bevels which separate the terraces. The lower markers undulate slightly because restoring the terraces and the backs of the bumps to the horizontal has introduced some distortion into the diagram.

The predominant direction of shoreface translation is indicated by the arrows in the inset box.

isopach map of the sediment thickness between the E7 and E5 surfaces (terminology of Plint et al., 1986). The E5 horizon which extends across northeastern and central Willesden Green was taken from cross section 4 of Walker and Eyles (in preparation). The surface across western Willesden Green, which terminates to the west of northern Ferrier, comes from cross section D-D′ (this thesis).

Each of the segments of the erosion surface was constructed using the same horizontal and vertical scale, and then they were positioned relative to one another to produce one composite section.

The relative positions of the "yellow spike," base of the yellow sand, and the "inflection point" (taken from resistivity well log signatures) markers are plotted on Figure 8.1a. The "yellow spike" datum is the datum upon which all the cross sections in this thesis were hung. The base of the yellow sand, which is a resistivity well log pick that marks the base of the "yellow sand" coarsening-upward sequence (Walker and Eyles, in preparation), was estimated from well log cross section D-D′ (this thesis) and was plotted underneath Ferrier field. In Willesden Green, the base of the yellow sand is the datum upon which all the cross sections of Walker and Eyles (in preparation) are based. The relative position of the "inflection point" underneath Pembina and Carrot Creek was estimated from cross sections B-1 and B-2 of Leggitt (1987) and cross section B-

B′ of Bergman (1987), since these sections are those which lie closest to the lines of section upon which G-G′ (this thesis) is based.

The position of the inflection point "rises" with respect to the E5 surface at Carrot Creek relative to its position at Pembina. Carrot Creek field lies along strike and to the north of Poplar Valley at Pembina (the main "bevel" of Bergman, 1987, and Bergman and Walker, 1987). If the inflection point represents the base of the stratigraphically lowest economically exploitable sand, then Pembina is producing huge quantities of oil from the thick sandy interval between the E5 surface and the inflection point. However, the same sandy interval at Carrot Creek to the north is thin, discontinuous, and presumably uneconomic. Carrot Creek is largely producing from the conglomerates which overlie the E5 surface.

The relative positions of terraces, bevels, and bumps and hollows (terminology of Bergman, 1987) are shown on Figure 8.1a. The incised steps of Bergman and Walker (in preparation) in the bumps and hollows region of Carrot Creek, numbered 1, 2, and 3, are indicated. The terraces are regionally flat areas which are usually bounded on the seaward side (northeastern side) by a relative "low." A terrace is arbitrarily defined as a flat surface which extends for at least 4 kilometers along a line of cross section which is constructed normal to the seaward bevelled edge of the terrace, or it must be bounded on the seaward side by a bevel which exhibits a minimum of 5 meters relief. Surfaces of these dimensions are readily identified along line G-G'; anything smaller than 4 kilometers in length or not bounded by a 5 meter high bevel is not considered to be a "terrace." The bevel is an area of appreciable relief where underlying hummocky cross-stratified sandstones and bioturbated mudstones are truncated by the erosion surface. The bumps and hollows are a remnant erosional topography which have recently been shown to be parts of continuous incised shorefaces (Bergman and Walker, in preparation).

8.4 EROSION AND SEA LEVEL RISE ALONG G-G'

Cross section G-G' is drawn to scale, with considerable vertical exaggeration. It is therefore possible to measure stillstand and steady rise of sea level directly from the diagram. It will be shown that 85 kilometers of horizontal shoreface translation and 132 meters of vertical shoreface translation have occurred over line G-G'.

Shoreface erosion is a function of the relative rate of sea level rise. A stillstand of sea level implies a horizontal landward translation of the erosional shoreface profile. In the following calculations, depth to fairweather wave base will be taken at a constant 10 meters (present day ranges are given as 5-15 m by Swift et al.(1987) and Swift (in Walker, 1985c). Thus the result of wave pounding during a stillstand is ordinarily to erode the shoreface down to a depth of 10 meters. If the depth to fairweather wave base is greater than 10 meters, then proportionately fewer episodes of sea level rise are required to erode a given vertical distance. A horizontal component of erosion related to stillstands may be measured along the lines with paleodip values assigned to them in Figure 8.1a. The corresponding component of vertical erosion associated with each stillstand shoreface retreat is 10 meters.

A steady rise of sea level implies a combination of horizontal and vertical shoreface translation. Each of these components of erosion may also be measured from Figure 8.1a by construction of an "erosional envelope" (Bergman, 1987; Bergman and Walker, in preparation) which approximates the slope of an inclined surface carved by erosion. It is important to emphasize that both stillstand and steady rise vertical components are <u>always</u> measured <u>normal</u> to the horizontal, keeping in mind that in Figure 8.1 a, the "horizontal" dips to the southwest when hung on horizontal markers.

A rapid rise of sea level implies a rapid translation of the shoreface. Given the gentle undulating morphology of the E5 surface (remember that Figure 8.1 a and b are grossly exaggerated), it is difficult at best to separate vertical translation of a rapid rise in sea level from the combination of horizontal and vertical translation involved in "steady rise."

The stillstands and intervals of steady rise of sea level may be differentiated from one another along line G-G' by the presence of terraces and bevels, respectively. Terraced surfaces represent stillstands with a predominantly horizontal erosional component which may be measured directly from the diagram, e.g., the terrace at western Willesden Green is 11.7 kilometers long. The vertical rise preceding the stillstand is taken to be 10 meters (the assumed depth to fairweather wave base). Bevels represent episodes of steady rise, where both the horizontal and vertical dimensions of steady shoreface retreat are measured directly from the diagram. Any bevel or northeastward-facing side of a bump in the region of bumps and hollows approximates the hypotenuse of a right triangle, the horizontal and vertical dimensions of which are measurable using the scale provided (e.g., the northeast side of the bump at position #3 on Figure 8.1a extends for 3.4 kilometers horizontally, and 10 meters vertically). Over the entire section, the sum of the horizontal distances attributable to stillstand erosion is 64 kilometers. The total vertical stillstand distance is 85 meters (the reason that this number is not a multiple of 10 is due to the undulatory nature of the E5 surface which exhibits less than 10 meters, but greater than 5 meters, erosional relief over

Pembina and on top of Willesden Green). For example, the stillstand denoted by the terrace dipping at 0.06 degrees on the back of Pembina to the immediate southwest of Buck Valley maintained 8.5 meters of vertical erosion before a steady rise of sea level shifted the position of the shoreline. The total horizontal distance attributable to steady rise is 20.5 kilometers. The total vertical steady rise distance is 48 meters.

Figure 8.1b is a reconstruction of cross section G-G' with respect to an inclined Raven River stratigraphy. It is not an actual representation of the newly-formed E5 surface because each originally dipping stepped surface has been restored to the horizontal. In fact, because the angles of the terraces differ slightly, each would be gently dipping relative to the surface being actively incised at stillstand. For example, if the terrace at western Willesden Green were being eroded by stillstand horizontal shoreface translation, then the incised terraces to the northeast of Willesden Green featured in Figure 8.1a would maintain very gentle northeastward dips, while the backs of the bumps at positions 1, 2, and 3 in the bumps and hollows region at Carrot Creek would dip very gently to the southwest.

By making all the terraces horizontal, the actual differences in dip relative to a tilted underlying stratigraphy are incorporated into the bevels which separate the terraces. For instance, the 0.07 degree difference in paleodip between the 0.11 degree slope and the 0.04 degree slope at Poplar Valley and at Buck Valley, respectively, is absorbed by a distorted bevel shape between the two slopes once each has been restored to the horizontal.

Assuming as before that the depth to an erosive fairweather wave base is 10 meters, a series of stepping shoreface profiles have been drawn. Vertical arrows suggest a relatively rapid rise of sea level, where remnant Raven River stratigraphy is preserved. Predominantly horizontal shoreface translation is given by horizontal bites, with the 10 meter shoreface profile having eroded its way to the base of the next successive bevel. From there, the profile translates upward at an oblique angle as the erosion associated with sea level rise carves a bevel (the horizontal and vertical steady rise components are measured from Figure 8.1a).

The lower markers undulate slightly with respect to the E5 surface because some distortion has been introduced into the diagram by restoring slightly dipping terraces to the horizontal.

The average regional paleodip of the Raven River stratigraphy from Carrot Creek to Ferrier over line G-G′ is 0.09 degrees. This may be calculated directly from Figure 8.1b by measuring the total horizontal and vertical (x = 85 km, y = 132 m), or may be calculated by taking the mean of all ten paleodip values indicated in Figure 8.1a. Both calculations yield 0.09 degrees.

8.5 IMPLICATIONS

As mentioned earlier, there are three relative rates of sea level rise. Stillstand suggests that the sea level does not rise at all. However, the result of wave pounding during sea level stasis ordinarily erodes the shoreface down to fairweather wave base. Through time, an erosion surface (E5) is produced, and a horizontal bite is taken out of the coastal plain.

An abrupt or rapid rise of sea level ideally suggests that sea level rose so quickly that fairweather wave base did not have time to immediately scour the bed. The dominant direction of shoreface translation is landward, hence preserving sediments immediately southwest of the former position of the shoreface prior to rapid rise.

A slow but steady rise of sea level is intermediate between the stillstand and the rapid rise, both in terms of the rate of relative sea level rise and the degree to which fairweather wave base is able to scour the bed.

Each rate of rise shall be considered quantitatively.

Stillstand

During episodes of stillstand, sixty-four kilometers of erosive horizontal shoreface translation occurred over line G-G′. Today, the shoreface is eroding at a rate of 0.6 - 1.2

m/yr on the mid-Atlantic Bight (O.H. Pilkey, personal communication, 1987). If we assume a relative rate of 1.2 meters per year, the 64 kilometers of stillstand erosion would have taken 53,333 years.

<u>Steady rise</u>

During episodes of steady rise of sea level, 20.5 kilometers of horizontal shoreface translation occurred over line G-G'. At 1.2 m/year, this would have taken 17,083 years. Forty-eight meters of vertical shoreface translation are associated with this horizontal erosion. This indicates a steady sea level rise of about 2.8 mm/year.

<u>Rapid rise</u>

The rate of rapid rise is unknown. It is not possible, as yet, to account for purely vertical rise with no erosion associated with it. By way of comparison with the calculated rate of steady rise (2.8 mm/yr) and the present rate of sea level rise off Delaware (1.5 mm/yr, Kraft, 1971), perhaps an estimate of the present rate of isostatic rebound might approximate a "rapid" rise, providing present sea level remains relatively static. Andrews (1970) has documented as much as 13 mm/yr of uplift presently occurring at southeastern Hudson Bay. However, it is difficult to get an idea of a truly rapid rise which might be operative in the tectonically active Interior Seaway.

Average rise

The cumulative total of all horizontal erosion over line G-G' is 85 kilometers. Therefore, it would have taken 70,833 years for the shoreline to move from the immediate northeast of the bumps and hollows at Carrot Creek to the immediate west of Ferrier. The cumulative total of all the vertical erosion components over line G-G' is 132 meters, indicating an average rate of relative sea level rise of 1.9 mm/year.

At first glance, it is tempting to construct an equation which expresses the rate of average sea level rise as a function of the rate of stillstand, steady rise, and rapid rise. However, the average rise is certainly a weighted average, and must be expressed as the sum of the relative rates of sea level rise multiplied by the length of time each was in effect. The unit dimensions of such a sum are expressed in terms of vertical distance over which sea level rose. Therefore,

132 m (= total vertical) = 132,000 mm =

(0 mm/yr)(53,333 years) + (2.8 mm/yr)(17,083 years)

+ (rate of rapid rise)(time).

However, a previous calculation has showed that it would have taken approximately 70,833 years to erode the 132 meters of total vertical relief along section G-G'. This figure is already incorporated into the above equation as the sum of the stillstand plus steady rise components.

Therefore, there is no way to determine the rate of rapid rise or the time over which it was operative. Even substituting a present day value for isostatic rebound as a rate of rapid rise will not aid in the determination of the time involved.

8.6 ARE THE CALCULATIONS REASONABLE?

The above arguments pertain to the erosion of the E5 surface over cross section G-G', and are presumably valid for other and future cross sections across the Cardium oil fields. However, the E5 surface does not end at western Ferrier. The final position of the eroded shoreface has not been recognized in the subsurface, nor has it been observed in outcrop (Duke, 1985). So far (this thesis), relative sea level rise has only been calculated for a horizontal distance of 85 kilometers. Assuming that erosion along the E5 surface continued for <u>at least</u> twice the distance documented in this thesis, then the total horizontal distance becomes 170 kilometers. Since 70,833 years were required to erode the Raven River sediments between Carrot Creek and Ferrier, inclusive, it would have taken 141,666 years to erode twice that distance, assuming similar rates of erosion and sea level rise.

In order for the shoreline to have moved basinward to the northeastern edge of Carrot Creek initially (so that subsequent transgression could erode the stepped profile), Bergman and Walker (1987) have suggested a rapid lowering of sea level. This would take time, although there is no way to calculate just how much time was involved. The total time involved in producing the E5 surface must therefore be greater than 141,666 years.

Given that the Cardium Formation was deposited in approximately 1 Ma (R.G. Walker, personal communication, 1987), and that there are seven regionally extensive erosion surfaces defining six sedimentary sequences (Plint et al., 1986), one can assign 167,000 years to each sequence. However, within this relatively short period of time, tectonic uplift and downwarp must occur to produce the erosion surface, followed by the deposition of an overlying sequence. If indeed all this could occur in 167,000 years, then the 141,666 years required just to erode the E5 profile during overall sea level rise leaves very little time left in which to drop sea level initially and to deposit the overlying Dismal Rat Member. However, all of the calculated values which appear in this argument are based on many assumptions. The Cardium may not have been deposited in 1 Ma; it is possible that it may have been deposited in as much as 2 Ma. The assumption that it takes 167,000 years to form each erosion surface and the overlying sequence is probably erroneous. While it appears that the E4 surface may have formed by a mechanism similar to that responsible for the E5 surface (there are three documented stepped incisions at the E4 horizon; Pattison, 1987), the other surfaces (E1, E2, E3, E6, and E7) maintain fewer incisions and may have formed by other means. If so, the rates of formation may not approximate those required to produce E4 and E5. E4 and E5 seem exceptional, and may indeed have required more time in which to form relative to the others.

Given the flexibility inherent in the above assumptions, and remembering that the figures calculated in section 8.5 are all based on a present-day value for the rate of shoreface erosion (1.2 m/yr, which may or may not approximate the rate of shoreface erosion active at the E5 horizon) and an assumed fairweather wave base of 10 meters, the 141,666 years necessary to incise the E5 profile across the Alberta Basin is not unreasonable.

CHAPTER 9 - CONCLUSIONS

1. The Raven River Member of the Cardium Formation at Ferrier and Willesden Green fields consists of bioturbated marine mudstones, which pass upward into hummocky cross-stratified sandstones interbedded with bioturbated mudstones and sandstones. These facies are interpreted as aggrading shelf sediments deposited in a storm-dominated environment.

2. The overall coarsening-upward Raven River stratigraphy can be broken down into smaller coarsening-upward sequences of marine mudstones which pass upward into bioturbated and hummocky cross-stratified sandstones. These smaller sequences are often capped by a gritty siderite, and can be correlated between fields.

3. The cross sections show truncation of facies, markers, and sequences, which indicate the existence of a major erosion surface that can be correlated with the E5 surface in other parts of the Cardium basin.

4. The E5 surface maintains an undulating morphology of gently and steeply dipping surfaces, termed "terraces" and "bevels," respectively. Cross sections hung from horizontal markers indicate that the E5 surface dips gently to the southwest over Ferrier field (mean dip = 0.03 degrees) and western Willesden Green (mean dip = 0.07 degrees), and dips steeply to the northeast along the northeastern edge of

Ferrier (mean dip is considerably greater than those of the terraces; see Figure 8.1).

5. The E5 surface at Ferrier and Willesden Green is probably the product of shoreface erosion. Totally subaerial or totally subaqueous erosion can not account for the deep, elongate scour along the northeastern edge of Ferrier which contains neither a lag nor angle-of-repose cross-bedded sands.

6. The presently gently dipping terraces of Ferrier and western Willesden Green, if produced by shoreface erosion, must necessarily have been horizontal during their incision. Alternatively, large flat-topped islands to the northeast (Pembina and Carrot Creek) would have damped out all the wave energy necessary to incise a shoreface at the Ferrier bevel. The rotation of the terraces from their present inclination to the horizontal suggests an originally northeast-dipping Raven River stratigraphy. The terrace at western Willesden Green represents a period of sea level stillstand, whereas the bevel at eastern Ferrier was carved during a steady rise of sea level.

7. Ferrier and Willesden Green fields are erosional remnants; their elongate shapes, which lie parallel to regional strike, are largely controlled by the geometry of the E5 erosion surface. Thus, they are not "offshore bars."

8. The clast-supported conglomerate which mantles the E5 surface at Ferrier and Willesden Green is presumably

fluvially derived, but maintains none of the structures commonly associated with fluvial deposits. The locally thick concentration of the conglomerate at the northeastern edge of Ferrier (T.41, R.8,9) is interpreted as a point of gravel input into the Ferrier shoreface, where it was reworked by waves.

9. Assuming that the gravel supply (in terms of clast size) was the same at both Carrot Creek and Ferrier, then the smaller clast size found at Ferrier implies a gentler gradient along which the gravel-bearing rivers flowed before dumping their load in the Ferrier shoreface.

10. In general, the basin-wide systematic decrease in the angles of shoreface incision to the southwest suggest that the seafloor was flexed upward, followed by a progressive downward flexing during cutting of the E5 surface (Bergman and Walker, in preparation). However, along any specific line of cross section normal to regional strike, the angles of shoreface incision may not show a definite trend.

11. The rates of flexure are probably tectonically-controlled. Flexing occurs on a smaller and more rapid scale than that suggested by existing Foreland Basin models.

12. Taking the depth to fairweather wave base to be 10 meters, and the rate of erosion effective during incision of the E5 surface to be 1.2 m/year, then it would have taken over 70,000 years to cut the E5 surface from the region of

bumps and hollows at Carrot Creek to the west of Ferrier. During this time, sea level rose 132 meters, indicating an average rate of relative sea level rise of 1.9 mm/year. Assuming that erosion along the E5 surface continued for <u>at least</u> twice the distance documented in this thesis (see text), then it would have taken over 140,000 years to cut the E5 surface across the Alberta Basin.

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APPENDIX I - DATA BASE

The well locations are sorted according to township and range. The depths to resistivity well log markers UD-1, UD-2, and the E5 erosion surface are listed for each well (first four columns). Well log picks listed in feet are converted to meters (next three columns). The final three columns are the differences (in meters) between UD-1 and UD-2, UD-1 and E5 (not used in this thesis), and UD-2 to E5, respectively. Figures 5.2, 5.3, 5.6, and 5.7 were constructed using this data base.

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
14-01-37-6W5	2038.5	2050	2094	2038.50	2050.00	2094.00	11.50	55.50	44.00
04-03-37-6W5	6870	6912	7050	2093.98	2106.78	2148.84	12.80	54.86	42.06
06-03-37-6W5	2091	2103	2146	2091.00	2103.00	2146.00	12.00	55.00	43.00
10-04-37-6W5	6880	6920	7060	2097.02	2109.22	2151.50	12.19	55.47	43.28
04-05-37-6W5	6870	6912	7050	2093.98	2106.78	2148.84	12.80	54.86	42.06
14-05-37-6W5	2140	2152	2194	2140.00	2152.00	2194.00	12.00	54.00	42.00
16-05-37-6W5	2126	2139	2182.5	2126.00	2139.00	2182.50	13.00	56.50	43.50
08-07-37-6W5	2155.5	2167.5	2210	2155.50	2167.50	2210.00	12.00	54.50	42.50
06-08-37-6W5	2143	2155	2197	2143.00	2155.00	2197.00	12.00	54.00	42.00
10-09-37-6W5	6898	6932	7076	2102.51	2112.87	2156.76	10.36	54.25	43.89
15-10-37-6W5	2065	2075	2116.5	2065.00	2075.00	2116.50	10.00	51.50	41.50
07-14-37-6W5	2028	2039	2083	2028.00	2039.00	2083.00	11.00	55.00	44.00
06-16-37-6W5	6875	6913	7052	2095.50	2107.08	2149.45	11.58	53.95	42.37
10-17-37-6W5	2127	2139	2184	2127.00	2139.00	2184.00	12.00	57.00	45.00
16-18-37-6W5	2146.5	2160	2202	2146.50	2160.00	2202.00	13.50	55.50	42.00
04-21-37-6W5	6825	6867	7007	2080.26	2093.06	2135.73	12.80	55.47	42.67
07-22-37-6W5	2010	2022.5	2067.5	2010.00	2022.50	2067.50	12.50	57.50	45.00
02-26-37-6W5	2001.5	2014	2059	2001.50	2014.00	2059.00	12.50	57.50	45.00
06-25-37-6W5	2054	2066.5	2110	2054.00	2066.50	2110.00	12.50	56.00	43.50
07-29-37-6W5	2077	2088	2131.5	2077.00	2088.00	2131.50	11.00	54.50	43.50
12-30-37-6W5	6905	6942	7094	2104.64	2115.92	2162.25	11.28	57.61	46.33
13-12-37-7W5	7144	7180	7324	2177.49	2188.46	2232.36	10.97	54.86	43.89
16-17-37-7W5	7329	7365	7504	2233.88	2244.85	2287.22	10.97	53.34	42.37
10-20-37-7W5	2232	2241.5	2290	2232.00	2241.50	2290.00	9.50	58.00	48.50
04-22-37-7W5	7192	7228	7372	2192.12	2203.09	2246.99	10.97	54.86	43.89
07-22-37-7W5	7170	7204	7344	2185.42	2195.78	2238.45	10.36	53.04	42.67
10-25-37-7W5	6982	7019	7155	2128.11	2139.39	2180.84	11.28	52.73	41.45
07-28-37-7W5	2195	2207.5	2252	2195.00	2207.50	2252.00	12.50	57.00	44.50
10-29-37-7W5	7267	7308	7448	2214.99	2227.48	2270.15	12.50	55.17	42.67
07-31-37-7W5	7414	7447	7583	2259.79	2269.85	2311.30	10.06	51.51	41.45
04-32-37-7W5	2226.5	2237	2278.5	2226.50	2237.00	2278.50	10.50	52.00	41.50
11-32-37-7W5	2207	2218	2260	2207.00	2218.00	2260.00	11.00	53.00	42.00
10-33-37-7W5	2196	2206	2250	2196.00	2206.00	2250.00	10.00	54.00	44.00
07-34-37-7W5	7153	7183	7350	2180.23	2189.38	2240.28	9.14	60.05	50.90
12-34-37-7W5	2181.5	2191	2237	2181.50	2191.00	2237.00	9.50	55.50	46.00
11-01-37-8W5	2403.5	2415	2455	2403.50	2415.00	2455.00	11.50	51.50	40.00
12-05-37-8W5	2541	2552.5	2597.5	2541.00	2552.50	2597.50	11.50	56.50	45.00
04-08-37-8W5	8292	8343	8500	2527.40	2542.95	2590.80	15.54	63.40	47.85
11-11-37-8W5	2418.5	2431.5	2479	2418.50	2431.50	2479.00	13.00	60.50	47.50
11-28-37-8W5	7700	7731	7885	2346.96	2356.41	2403.35	9.45	56.39	46.94
11-31-37-8W5	2383	2393	2439	2383.00	2393.00	2439.00	10.00	56.00	46.00
10-33-37-8W5	7754	7781	7943	2363.42	2371.65	2421.03	8.23	57.61	49.38
11-36-37-8W5	2267	2274.5	2323	2267.00	2274.50	2323.00	7.50	56.00	48.50
02-04-37-9W5	9110	9153	9327	2776.73	2789.83	2842.87	13.11	66.14	53.04
03-04-37-9W5	9136	9180	9330	2784.65	2798.06	2843.78	13.41	59.13	45.72
07-05-37-9W5	9044	9088	9250	2756.61	2770.02	2819.40	13.41	62.79	49.38
09-12-37-9W5	2562	2577.5	2626	2562.00	2577.50	2626.00	15.50	64.00	48.50
06-17-37-9W5	8990	9032	9205	2740.15	2752.95	2805.68	12.80	65.53	52.73
10-21-37-9W5	8234	8286	8458	2509.72	2525.57	2578.00	15.85	68.28	52.43
10-24-37-9W5	8053	8093	8247	2454.55	2466.75	2513.69	12.19	59.13	46.94
11-27-37-9W5	8200	8238	8426	2499.36	2511.03	2568.24	[illegible]	68.88	58.22
12-27-37-9W5	2510	2523.5	2580	2510.00	2523.50	2580.00	13.50	70.00	56.50
16-28-37-9W5	8381	8424	8583	2554.53	2567.64	2616.10	13.11	61.57	48.46
11-28-37-9W5	8410	8450	8610	2563.37	2575.56	2624.33	12.19	60.96	48.77
10-30-37-9W5	9047	9090	9248	2757.53	2770.63	2818.79	13.11	61.26	48.16
12-31-37-9W5	8918	8970	9118	2718.21	2734.06	2779.17	15.85	60.96	45.11
06-33-37-9W5	8419	8450	8622	2565.81	2575.56	2627.99	9.75	62.18	52.43
10-36-37-9W5	2509	2517	2568.00	2509.00	2517.00	2568.00	8.00	59.00	51.00
07-01-37-10W5	9445	9481	9646	2878.84	2889.80	2940.10	10.97	61.26	50.29
07-19-37-10W5	9810	9850	10046	2990.09	3002.28	3062.02	12.19	71.93	59.74
07-12-37-11W5	2849	2863.5	2915	2849.00	2863.50	2915.00	14.50	66.00	51.50
10-16-37-11W5	9609	9653	9880	2928.82	2942.23	3011.42	13.41	82.60	69.19
10-23-37-11W5	9184	9227	9386	2799.28	2812.39	2860.85	13.11	61.57	48.46
11-25-37-11W5	2798	2812	2862	2798.00	2812.00	2862.00	14.00	64.00	50.00
10-26-37-11W5	2806	2820	2869	2806.00	2820.00	2869.00	14.00	63.00	49.00
08-28-37-11W5	2853	2867.5	2906	2853.00	2867.50	2906.00	14.50	53.00	38.50
11-28-37-11W5	9595	9634	9780	2924.56	2936.44	2980.94	11.89	56.39	44.50
11-12-38-6W5	1971	1979	2022	1971.00	1979.00	2022.00	8.00	51.00	43.00
06-10-38-6W5	6526	6554	6708	1989.12	1997.66	2044.60	8.53	55.47	46.94
09-18-38-6W5	6634	6664	6824	2022.04	2031.19	2079.96	9.14	57.91	48.77
16-22-38-6W5	1970	1977.5	2029	1970.00	1977.50	2029.00	7.50	59.00	51.50
07-24-38-6W5	6306	6335	6496	1922.07	1930.91	1979.98	8.84	57.91	49.07
02-31-38-6W5	2012	2019.5	2067.5	2012.00	2019.50	2067.50	7.50	55.50	48.00
04-31-38-6W5	2017.5	2025	2073	2017.50	2025.00	2073.00	7.50	55.50	48.00
10-02-38-7W5	6914.0	6942.0	7095.0	2107.39	2115.92	2162.56	8.53	55.17	46.63
05-03-38-7W5	2168.5	2177.0	2225.0	2168.50	2177.00	2225.00	8.50	56.50	48.00
16-03-38-7W5	2127.5	2136.0	2183.0	2127.50	2136.00	2183.00	8.50	55.50	47.00
03-04-38-7W5	2223.0	2232.5	2278.5	2223.00	2232.50	2278.50	9.50	55.50	46.00
12-04-38-7W5	7150.0	7178.0	7331.0	2179.32	2187.85	2234.49	8.53	55.17	46.63
15-04-38-7W5	2157.5	2166.5	2213.0	2157.50	2166.50	2213.00	9.00	55.50	46.50

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
04-15-38-7W5	2216.5	2227.0	2274.0	2216.50	2227.00	2274.00	10.50	57.50	47.00
10-15-38-7W5	2203.5	2213.0	2261.0	2203.50	2213.00	2261.00	9.50	57.50	48.00
04-16-38-7W5	2242.5	2252.0	2302.0	2242.50	2252.00	2302.00	9.50	59.50	50.00
10-16-38-7W5	2226.0	2235.0	2283.5	2226.00	2235.00	2283.50	9.00	57.50	48.50
03-07-38-7W5	2242.0	2251.0	2300.0	2242.00	2251.00	2300.00	9.00	58.00	49.00
02-08-38-7W5	2165.0	2174.5	2223.0	2165.00	2174.50	2223.00	9.50	58.00	48.50
04-08-38-7W5	2180.0	2188.0	2234.0	2180.00	2188.00	2234.00	8.00	54.00	46.00
06-08-38-7W5	2156.0	2166.0	2213.0	2156.00	2166.00	2213.00	10.00	57.00	47.00
12-08-38-7W5	2162.0	2174.0	2222.0	2162.00	2174.00	2222.00	12.00	60.00	48.00
02-09-38-7W5	2145.0	2155.0	2201.0	2145.00	2155.00	2201.00	10.00	56.00	46.00
03-09-38-7W5	2152.0	2165.0	2212.0	2152.00	2165.00	2212.00	13.00	60.00	47.00
11-09-38-7W5	2136.0	2148.0	2194.0	2136.00	2148.00	2194.00	12.00	58.00	46.00
12-09-38-7W5	2136.0	2148.0	2194.0	2136.00	2148.00	2194.00	12.00	58.00	46.00
04-10-38-7W5	2132.5	2140.5	2187.5	2132.50	2140.50	2187.50	8.00	55.00	47.00
10-10-38-7W5	2115.0	2125.0	2172.0	2115.00	2125.00	2172.00	10.00	57.00	47.00
06-11-38-7W5	2103.0	2113.0	2159.0	2103.00	2113.00	2159.00	10.00	56.00	46.00
10-12-38-7W5	2037.0	2048.0	2095.0	2037.00	2048.00	2095.00	11.00	58.00	47.00
04-13-38-7W5	2114.0	2125.0	2171.5	2114.00	2125.00	2171.50	11.00	57.50	46.50
15-15-38-7W5	2071.0	2083.0	2128.0	2071.00	2083.00	2128.00	12.00	57.00	45.00
12-15-38-7W5	6896.0	6928.0	7079.0	2101.90	2111.65	2157.68	9.75	55.78	46.02
01-16-38-7W5	2120.0	2130.0	2172.0	2120.00	2130.00	2172.00	10.00	52.00	42.00
05-16-38-7W5	2127.5	2136.0	2182.0	2127.50	2136.00	2182.00	8.50	54.50	46.00
13-16-38-7W5	2127.5	2137.0	2182.5	2127.50	2137.00	2182.50	9.50	55.00	45.50
15-16-38-7W5	2106.0	2117.0	2162.5	2106.00	2117.00	2162.50	11.00	56.50	45.50
03-17-38-7W5	7065.0	7106.0	7254.0	2153.41	2165.91	2211.02	12.50	57.61	45.11
07-17-38-7W5	2132.0	2142.0	2193.5	2132.00	2142.00	2193.50	10.00	61.50	51.50
10-17-38-7W5	2138.0	2148.0	2195.0	2138.00	2148.00	2195.00	10.00	57.00	47.00
14-17-38-7W5	2147.0	2157.0	2204.5	2147.00	2157.00	2204.50	10.00	57.50	47.50
12-18-38-7W5	2195.0	2205.0	2253.5	2195.00	2205.00	2253.50	10.00	58.50	48.50
04-18-38-7W5	2248.0	2259.0	2312.0	2248.00	2259.00	2312.00	11.00	64.00	53.00
09-18-38-7W5	2172.0	2182.0	2232.0	2172.00	2182.00	2232.00	10.00	60.00	50.00
11-18-38-7W5	7210.0	7247.0	7400.0	2197.61	2208.89	2255.52	11.28	57.91	46.63
02-19-38-7W5	2163.0	2173.5	2218.5	2163.00	2173.50	2218.50	10.50	55.50	45.00
04-19-38-7W5	2190.0	2202.0	2248.0	2190.00	2202.00	2248.00	12.00	58.00	46.00
12-19-38-7W5	2185.0	2196.5	2242.0	2185.00	2196.50	2242.00	11.50	57.00	45.50
04-20-38-7W5	2156.5	2168.0	2213.5	2156.50	2168.00	2213.50	11.50	57.00	45.50
06-20-38-7W5	2159.0	2169.0	2216.0	2159.00	2169.00	2216.00	10.00	57.00	47.00
08-20-38-7W5	2132.5	2146.0	2192.0	2132.50	2146.00	2192.00	13.50	59.50	46.00
16-20-38-7W5	2144.0	2153.0	2199.5	2144.00	2153.00	2199.50	9.00	55.50	46.50
11-20-38-7W5	7072.0	7108.0	7254.0	2155.55	2166.52	2211.02	10.97	55.47	44.50
02-21-38-7W5	2108.5	2119.5	2168.0	2108.50	2119.50	2168.00	11.00	59.50	48.50
04-21-38-7W5	2132.0	2143.0	2190.5	2132.00	2143.00	2190.50	11.00	58.50	47.50
09-21-38-7W5	2090	2101	2146	2090.00	2101.00	2146.00	11.00	56.00	45.00
11-21-38-7W5	2107.5	2117	2165	2107.50	2117.00	2165.00	9.50	57.50	48.00
14-21-38-7W5	2106.5	2116	2163.5	2106.50	2116.00	2163.50	9.50	57.00	47.50
02-22-38-7W5	2065	2074.5	2122.5	2065.00	2074.50	2122.50	9.50	57.50	48.00
10-22-38-7W5	6762	6795	6950	2061.06	2071.12	2118.36	10.06	57.30	47.24
14-22-38-7W5	2051.5	2061.5	2108	2051.50	2061.50	2108.00	10.00	56.50	46.50
02-23-38-7W5	2047.5	2057.5	2106.5	2047.50	2057.50	2106.50	10.00	59.00	49.00
04-23-38-7W5	2064	2075	2124	2064.00	2075.00	2124.00	11.00	60.00	49.00
10-23-38-7W5	6684	6717	6877	2037.25	2047.34	2096.11	10.06	58.86	48.77
04-24-38-7W5	6705	6740	6907	2043.68	2054.35	2105.25	10.67	61.57	50.90
10-24-38-7W5	6642	6675	6831	2024.79	2034.54	2081.79	9.75	57.00	47.24
13-24-38-7W5	6651	6690	6850	2030.27	2040.03	2087.88	9.76	57.61	47.85
06-25-38-7W5	6627	6655	6812	2019.91	2028.44	2076.30	8.53	56.39	47.85
12-25-38-7W5	2019	2027.5	2073.5	2019.00	2027.50	2073.50	8.50	54.50	46.00
04-26-38-7W5	6692	6725	6877	2039.72	2049.78	2096.11	10.06	56.39	46.33
10-26-38-7W5	6700	6730	6885	2042.16	2051.30	2098.55	9.14	56.39	47.24
10-27-38-7W5	6709	6742	6900	2044.90	2054.96	2103.12	10.06	58.22	48.16
02-28-38-7W5	2083.5	2093.5	2137.5	2083.50	2093.50	2137.50	10.00	54.00	44.00
04-28-38-7W5	2106	2116.5	2160	2106.00	2116.50	2160.00	10.50	54.00	43.50
10-28-38-7W5	2080	2089	2137.5	2080.00	2089.00	2137.50	9.00	57.50	48.50
12-28-38-7W5	2096	2105	2153	2096.00	2105.00	2153.00	9.00	57.00	48.00
02-29-38-7W5	2131	2140	2186	2131.00	2140.00	2186.00	9.00	55.00	46.00
04-29-38-7W5	2149	2160	2207.5	2149.00	2160.00	2207.50	11.00	58.50	47.50
12-29-38-7W5	2140	2149	2197	2140.00	2149.00	2197.00	9.00	57.00	48.00
02-30-38-7W5	2161.5	2173	2217	2161.50	2173.00	2217.00	11.50	55.50	44.00
04-30-38-7W5	2192	2203	2247.5	2192.00	2203.00	2247.50	11.00	55.50	44.50
10-30-38-7W5	2165.5	2175	2221	2165.50	2175.00	2221.00	9.50	55.50	46.00
11-30-38-7W5	2187	2197.5	2243	2187.00	2197.50	2243.00	10.50	56.00	45.50
02-31-38-7W5	2145	2154.5	2200	2145.00	2154.50	2200.00	9.50	55.00	45.50
03-31-38-7W5	2165	2175	2224.5	2165.00	2175.00	2224.50	10.00	59.50	49.50
09-31-38-7W5	2127	2138.5	2182.5	2127.00	2138.50	2182.50	11.50	55.50	44.00
12-31-38-7W5	2157	2167	2212.5	2157.00	2167.00	2212.50	10.00	55.50	45.50
07-32-38=7W5	6943	6973	7131	2116.23	2125.37	2173.53	9.14	57.30	48.16
02-33-38-7W5	2075.5	2084.5	2132	2075.50	2084.50	2132.00	9.00	56.50	47.50
10-33-38-7W5	2063	2072.5	2118	2063.00	2072.50	2118.00	9.50	55.00	45.50
06-34-38-7W5	2041	2049	2097	2041.00	2049.00	2097.00	8.00	56.00	48.00
03-35-38-7W5	6690	6720	6875	2039.11	2048.26	2095.50	9.14	56.39	47.24
08-35-38-7W5	2023	2030	2077.5	2023.00	2030.00	2077.50	7.00	54.50	47.50
10-35-38-7W5	6615	6640	6800	2016.25	2023.87	2072.64	7.62	56.39	48.77

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
10-25-38-7W5	2037	2044.5	2092.5	2037.00	2044.50	2092.50	7.50	55.50	48.00
12-26-38-7W5	2024	2031.5	2080	2024.00	2031.50	2080.00	7.50	56.00	48.50
14-26-38-7W5	6720	6750	6913	2048.26	2057.40	2107.18	9.14	58.92	49.78
[illegible]-26-38-7W5	6656	6692	6850	2028.75	2039.72	2087.88	10.97	59.12	48.16
12-26-38-7W5	2034.5	2045	2093	2034.50	2045.00	2093.00	10.50	58.50	48.00
[illegible]-38-8W5	2394.50	2405.00	2450.00	2394.50	2405.00	2450.00	10.50	55.50	45.00
[illegible]-38-8W5	2403.00	2413.00	2459.50	2403.00	2413.00	2459.50	10.00	56.50	46.50
11-14-38-8W5	7270.00	7310.00	7460.00	2215.90	2228.09	2273.81	12.19	57.91	45.72
16-15-38-8W5	2223.50	2234.50	2280.00	2223.50	2234.50	2280.00	11.00	56.50	45.50
16-18-38-8W5	2370.00	2381.00	2434.00	2370.00	2381.00	2434.00	11.00	64.00	53.00
08-21-38-8W5	2254.00	2266.50	2312.50	2254.00	2266.50	2312.50	12.50	58.50	46.00
11-25-38-8W5	2185.00	2197.00	2241.50	2185.00	2197.00	2241.50	12.00	56.50	44.50
08-26-38-8W5	7204.00	7241.00	7395.00	2195.78	2207.06	2254.00	11.28	58.22	46.94
11-27-38-8W5	2216.00	2229.00	2274.50	2216.00	2229.00	2274.50	13.00	58.50	45.50
16-28-38-8W5	2234.00	2247.50	2293.00	2234.00	2247.50	2293.00	13.50	59.00	45.50
19-33-38-8W5	7257.00	7300.00	7451.00	2211.93	2225.04	2271.06	13.11	59.13	46.02
07-33-38-8W5	2205.00	2216.00	2266.00	2205.00	2216.00	2266.00	11.00	61.00	50.00
11-35-38-8W5	7170.00	7205.00	7352.00	2185.42	2196.08	2240.89	10.67	55.47	44.81
11-35-38-8W5	7170.00	7205.00	7353.00	2185.42	2196.08	2241.19	10.67	55.78	45.11
02-36-38-8W5	2174.00	2184.00	2228.50	2174.00	2184.00	2228.50	10.00	54.50	44.50
06-36-38-8W5	2172.00	2184.00	2228.00	2172.00	2184.00	2228.00	12.00	56.00	44.00
11-36-38-8W5	2161.00	2172.00	2217.00	2161.00	2172.00	2217.00	11.00	56.00	45.00
12-36-38-8W5	2163.00	2173.50	2218.00	2163.00	2173.50	2218.00	10.50	55.00	44.50
[illegible]-38-9W5	2527.5	2540	2588.5	2527.50	2540.00	2588.50	12.50	61.00	48.50
07-12-38-9W5	2398.5	2410	2458	2398.50	2410.00	2458.00	11.50	59.50	48.00
10-17-38-9W5	8205	8254	8419	2500.88	2515.82	2566.11	14.94	65.23	50.29
09-21-38-9W5	8314	8355	8524	2534.11	2546.60	2598.12	12.50	64.01	51.51
11-28-38-9W5	7557	7597	7762	2303.37	2315.57	2365.86	12.19	62.48	50.29
[illegible]-01-38-10W5	8568	8620	8800	2611.53	2627.38	2682.24	15.85	70.71	54.86
[illegible]-11-38-10W5	2653	2667.5	2724	2653.00	2667.50	2724.00	14.50	71.00	56.50
[illegible]-12-38-10W5	2646	2660	2711	2646.00	2660.00	2711.00	14.00	65.00	51.00
[illegible]-21-38-10W5	9193	9234	9377	2802.02	2814.52	2858.11	12.50	56.09	43.59
[illegible]-21-38-10W5	2754	2768	2818.5	2754.00	2768.00	2818.50	14.00	64.50	50.50
17-22-38-10W5	2858	2872	2920	2858.00	2872.00	2920.00	14.00	62.00	48.00
[illegible]-24-38-10W5	2686	2700	2752	2686.00	2700.00	2752.00	14.00	66.00	52.00
04-06-39-6W5	6620	6656	6810	2017.78	2028.75	2075.69	10.97	57.91	46.94
04-07-39-6W5	6560	6590	6750	1999.49	2008.63	2057.40	9.14	57.91	48.77
07-08-39-6W5	1973	1980	2031.5	1973.00	1980.00	2031.50	7.00	58.50	51.50
10-08-39-6W5	6465	6495	6667	1970.53	1979.68	2032.10	9.14	61.57	52.42
14-09-39-6W5	1951	1958.5	2015	1951.00	1958.50	2015.00	7.50	64.00	56.50
10-12-39-6W5	6095	6125	6273	1857.76	1866.90	1912.01	9.14	54.25	45.11
10-13-39-6W5	6070	6095	6247	1850.14	1857.76	1904.09	7.62	53.95	46.33
10-18-39-6W5	1975	1983	2031.5	1975.00	1983.00	2031.50	8.00	56.50	48.50
10-21-39-6W5	1911	1917	1970	1911.00	1917.00	1970.00	6.00	59.00	53.00
10-22-39-6W5	1885	1892	1941.5	1885.00	1892.00	1941.50	7.00	56.50	49.50
11-23-39-6W5	1878.5	1884.5	1932.5	1878.50	1884.50	1932.50	6.00	54.00	48.00
15-23-39-6W5	1860	1867.5	1915	1860.00	1867.50	1915.00	7.50	55.00	47.50
16-24-39-6W5	1839	1845	1893	1839.00	1845.00	1893.00	6.00	54.00	48.00
17-25-39-6W5	1824	1830	1877.5	1824.00	1830.00	1877.50	6.00	53.50	47.50
06-26-39-6W5	1864	1870	1919	1864.00	1870.00	1919.00	6.00	55.00	49.00
07-26-39-6W5	6068	6090	6250	1849.53	1856.23	1905.00	6.71	55.47	48.77
12-26-39-6W5	6110	6135	6296	1862.33	1869.95	1919.02	7.62	56.69	49.07
06-27-39-6W5	1887.5	1894	1947	1887.50	1894.00	1947.00	6.50	59.50	53.00
02-32-39-6W5	1916.5	1924	1976.5	1916.50	1924.00	1976.50	7.50	60.00	52.50
10-32-39-6W5	6293	6321	6496	1918.11	1926.64	1979.98	8.53	61.87	53.34
07-34-39-6W5	1860	1867.5	1919	1860.00	1867.50	1919.00	7.50	59.00	51.50
06-36-39-6W5	5958	5980	6134	1816.00	1822.70	1869.64	6.71	53.64	46.94
12-01-39-7W5	2014	2023	2070	2014.00	2023.00	2070.00	9.00	56.00	47.00
07-01-39-7W5	6656	6695	6849	2028.75	2040.64	2087.58	11.89	58.83	46.94
06-01-39-7W5	2026	2036.5	2084	2026.00	2036.50	2084.00	10.50	58.00	47.50
10-01-39-7W5	6620	6653	6807	2017.78	2027.83	2074.77	10.06	57.00	46.94
12-01-39-7W5	2025	2034	2082	2025.00	2034.00	2082.00	9.00	57.00	48.00
04-02-39-7W5	2025	2033	2081	2025.00	2033.00	2081.00	8.00	56.00	48.00
10-02-39-7W5	6630	6657	6814	2020.82	2029.05	2076.91	8.23	56.08	47.85
11-02-39-7W5	2011	2019	2067.5	2011.00	2019.00	2067.50	8.00	56.50	48.50
04-03-39-7W5	2053	2062	2110	2053.00	2062.00	2110.00	9.00	57.00	48.00
10-03-39-7W5	6611	6639	6800	2015.03	2023.57	2072.64	8.53	57.61	49.07
02-04-39-7W5	2061	2071	2117.5	2061.00	2071.00	2117.50	10.00	56.50	46.50
04-04-39-7W5	2079	2088	2135	2079.00	2088.00	2135.00	9.00	56.00	47.00
09-04-39-7W5	2056	2064.5	2111	2056.00	2064.50	2111.00	8.50	55.00	46.50
06-05-39-7W5	6530	6560	6713	1990.34	1999.49	2046.12	9.14	55.78	46.63
02-06-39-7W5	2131.5	2141	2190	2131.50	2141.00	2190.00	9.50	58.50	49.00
04-06-39-7W5	2144	2154.5	2200.5	2144.00	2154.50	2200.50	10.50	56.50	46.00
12-06-39-7W5	2121	2131	2179	2121.00	2131.00	2179.00	10.00	58.00	48.00
04-08-39-7W5	2093	2103	2152	2093.00	2103.00	2152.00	10.00	59.00	49.00
10-08-39-7W5	6777	6805	6965	2065.63	2074.16	2122.93	8.53	57.30	48.77
04-09-39-7W5	6750	6784	6940	2057.40	2067.76	2115.31	10.36	57.91	47.55
10-09-39-7W5	6645	6678	6835	2025.40	2035.45	2083.31	10.06	57.91	47.85
04-10-39-7W5	2030	2040	2088.5	2030.00	2040.00	2088.50	10.00	58.50	48.50

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
06-10-39-7W5	2027.5	2037.5	2084	2027.50	2037.50	2084.00	10.00	56.50	46.50
10-10-39-7W5	6651	6683	6838	2027.22	2036.98	2084.22	9.75	57.00	47.24
02-11-39-7W5	2023.5	2034	2083.5	2023.50	2034.00	2083.50	10.50	60.00	49.50
04-11-39-7W5	6640	6670	6825	2023.87	2033.02	2080.26	9.14	56.39	47.24
10-11-39-7W5	6675	6705	6865	2034.54	2043.68	2092.45	9.14	57.91	48.77
04-12-39-7W5	6615	6645	6800	2016.25	2025.40	2072.64	9.14	56.39	47.24
07-12-39-7W5	6578	6609	6762	2004.97	2014.42	2061.06	9.45	56.08	46.63
04-15-39-7W5	2021	2030	2077.5	2021.00	2030.00	2077.50	9.00	56.50	47.50
10-15-39-7W5	6630	6660	6813	2020.82	2029.97	2076.60	9.14	55.78	46.63
04-16-39-7W5	6675	6710	6867	2034.54	2045.21	2093.06	10.67	58.52	47.85
10-16-39-7W5	6587	6618	6770	2007.72	2017.17	2063.50	9.45	55.78	46.33
02-17-39-7W5	6735	6769	6920	2052.83	2063.19	2109.22	10.36	56.39	46.02
10-17-39-7W5	6636	6667	6824	2022.65	2032.10	2079.96	9.45	57.30	47.85
[illegible]-18-39-7W5	6696	6729	6885	2040.94	2051.00	2098.55	10.06	57.61	47.55
[illegible]-18-39-7W5	6720	6756	6913	2048.26	2059.23	2107.08	10.97	58.82	47.85
04-19-39-7W5	6793	6827	6986	2070.51	2080.87	2129.33	10.36	58.82	48.46
16-19-39-7W5	2068.5	2079	2125	2068.50	2079.00	2125.00	10.50	56.50	46.00
10-19-39-7W5	6724	6758	6907	2049.48	2059.84	2105.25	10.36	55.78	45.42
05-21-39-7W5	6674	6714	6859	2034.24	2046.43	2090.62	12.19	56.39	44.20
10-21-39-7W5	6615	6648	6795	2016.25	2026.31	2071.12	10.06	54.86	44.81
04-21-39-7W5	6570	6600	6766	2002.54	2011.68	2062.28	9.14	59.74	50.60
06-21-39-7W5	1989.5	1999	2044.5	1989.50	1999.00	2044.50	9.50	55.00	45.50
10-21-39-7W5	6530	6563	6716	1990.34	2000.40	2047.04	10.06	56.69	46.63
14-22-39-7W5	6630	6661	6810	2020.82	2030.27	2075.69	9.45	54.86	45.42
[illegible]-23-39-7W5	[illegible]	[illegible]	6757	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-24-39-7W5	6555	6583	6740	1997.96	2006.50	2054.35	8.53	56.39	47.85
06-25-39-7W5	6480	6507	6665	1975.10	1983.33	2031.49	8.23	56.39	48.16
07-26-39-7W5	6530	6560	6715	1990.34	1999.49	2046.73	9.14	56.39	47.24
[illegible]-27-39-7W5	6558	6588	6747	1998.88	2008.02	2056.49	9.14	57.61	48.46
[illegible]-28-39-7W5	6558	6590	6748	1998.88	2008.63	2056.79	9.75	57.91	48.16
[illegible]-28-39-7W5	6520	6557	6710	1987.30	1998.57	2045.21	11.28	57.91	46.63
04-29-39-7W5	6668	6700	6850	2032.41	2042.16	2087.88	9.75	55.47	45.72
[illegible]-29-39-7W5	6566	6600	6754	2001.32	2011.68	2058.62	10.36	57.30	46.94
04-30-39-7W5	6778	6814	6960	2065.93	2076.91	2121.41	10.97	55.47	44.50
06-30-39-7W5	2064	2075	2121.5	2064.00	2075.00	2121.50	11.00	57.50	46.50
[illegible]-31-39-7W5	6746	6780	6930	2056.18	2066.54	2112.26	10.36	56.08	45.72
[illegible]-31-39-7W5	6658	6696	6854	2029.36	2040.94	2089.10	11.58	59.74	48.16
[illegible]-31-39-7W5	6703	6742	6893	2043.07	2054.96	2100.99	11.89	57.91	46.02
04-32-39-7W5	6667	6702	6860	2032.10	2042.77	2090.93	10.67	58.83	48.16
[illegible]-32-39-7W5	6554	6594	6745	1997.66	2009.85	2055.88	12.19	58.22	46.02
11-33-39-7W5	6470	6500	6650	1972.06	1981.20	2026.92	9.14	54.86	45.72
11-34-39-7W5	6506	6543	6699	1983.03	1994.31	2041.86	11.28	58.83	47.55
12-36-39-7W5	6437	6472	6660	1962.00	1972.67	2029.97	10.67	67.97	57.30
02-02-39-8W5	2165.5	2176	2223	2165.50	2176.00	2223.00	10.50	57.50	47.00
11-02-39-8W5	2164	2175	2221.5	2164.00	2175.00	2221.50	11.00	57.50	46.50
01-03-39-8W5	7158	7194	7345	2181.76	2192.73	2238.76	10.97	57.00	46.02
11-04-39-8W5	2199	2209.5	2258.5	2199.00	2209.50	2258.50	10.50	59.50	49.00
10-07-39-8W5	2226	2238	2287.5	2226.00	2238.00	2287.50	12.00	61.50	49.50
06-09-39-8W5	7186	7225	7381	2190.29	2202.18	2249.73	11.89	59.44	47.55
07-10-39-8W5	2165.5	2177	2224	2165.50	2177.00	2224.00	11.50	58.50	47.00
04-11-39-8W5	2144.5	2155	2202.5	2144.50	2155.00	2202.50	10.50	58.00	47.50
14-12-39-8W5	6829	6863	7025	2081.48	2091.84	2141.22	10.36	59.74	49.38
08-14-39-8W5	2114	2125	2173.5	2114.00	2125.00	2173.50	11.00	59.50	48.50
14-14-39-8W5	7030	7067	7239	2142.74	2154.02	2206.45	11.28	63.70	52.43
07-16-39-8W5	2143	2155	2202	2143.00	2155.00	2202.00	12.00	59.00	47.00
11-17-39-8W5	2207.5	2220	2266.5	2207.50	2220.00	2266.50	12.50	59.00	46.50
11-18-39-8W5	2234.5	2247	2295.5	2234.50	2247.00	2295.50	12.50	61.00	48.50
14-22-39-8W5	7063	7104	7265	2152.80	2165.30	2214.37	12.50	61.57	49.07
16-22-39-8W5	6978	7019	7179	2126.89	2139.39	2188.16	12.50	61.26	48.77
[illegible]-23-39-8W5	6983	7023	7192	2128.42	2140.61	2192.12	12.19	63.70	51.51
[illegible]-24-39-8W5	6847	6882	7043	2086.97	2097.63	2146.71	10.67	59.74	49.07
10-24-39-8W5	2080.5	2091.5	2140	2080.50	2091.50	2140.00	11.00	59.50	48.50
10-25-39-8W5	2066.5	2078	2123.5	2066.50	2078.00	2123.50	11.50	57.00	45.50
14-27-39-8W5	6995	7037	7195	2132.08	2144.88	2193.04	12.80	60.96	48.16
06-28-39-8W5	7115	7157	7330	2168.65	2181.45	2234.18	12.80	65.53	52.73
02-29-39-8W5	2179.5	2192	2241	2179.50	2192.00	2241.00	12.50	61.50	49.00
10-30-39-8W5	2200	2213.5	2259.5	2200.00	2213.50	2259.50	13.50	59.50	46.00
07-32-39-8W5	7126	7164	7322	2172.00	2183.59	2231.75	11.58	59.74	48.16
02-33-39-8W5	2170	2182.5	2247	2170.00	2182.50	2247.00	12.50	77.00	64.50
14-34-39-8W5	2136	2148.5	[illegible]	2136.00	2148.50	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11-36-39-8W5	6739	6779	6925	2054.05	2066.24	2110.74	12.19	56.69	44.50
05-09-39-9W5	7976	8020	8175	2431.08	2444.50	2491.74	13.41	60.66	47.24
06-10-39-9W5	2401.5	2415	2462.5	2401.50	2415.00	2462.50	13.50	61.00	47.50
10-12-39-9W5	2271	2283.5	2332	2271.00	2283.50	2332.00	12.50	61.00	48.50
10-13-39-9W5	7378	7418	7582	2248.81	2261.01	2310.99	12.19	62.18	49.99
06-14-39-9W5	7518	7559	7722	2291.49	2303.98	2353.67	12.50	62.18	49.68
06-24-39-9W5	7336	7380	7542	2236.01	2249.42	2298.80	13.41	62.79	49.38
06-31-39-9W5	2363.5	2376	2425	2363.50	2376.00	2425.00	12.50	61.50	49.00
10-10-39-10W5	2655.5	2668	2719	2655.50	2668.00	2719.00	12.50	63.50	51.00
07-21-39-10W5	8535	8575	8752	2601.47	2613.66	2667.61	12.19	66.14	53.95

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
07-22-39-11W5	8664	8705	8874	2640.79	2651.28	2704.8[illegible]	12.[illegible]	[illegible]	[illegible]
06-32-39-11W5	8379	8420	8613	2553.92	2566.42	2625.24	12.5[illegible]	71.32	58.87
10-36-39-10W5	8007	8047	8205	2440.53	2452.73	2500.88	12.19	60.35	48.1[illegible]
16-01-40-6W5	1811.00	1823.00	1865.00	1811.00	1823.00	1865.00	12.00	54.00	42.[illegible]
16-01-40-6W5	5921.00	5959.00	6094.00	1804.72	1816.30	1857.45	11.58	52.73	41.15
11-03-40-6W5	1848.50	1862.00	1904.00	1848.50	1862.00	1904.00	13.50	55.50	42.00
13-06-40-6W5	1934.00	1947.00	2000.00	1934.00	1947.00	2000.00	13.00	66.00	53.00
06-08-40-6W5	6273.00	6312.00	6470.00	1912.01	1923.90	1972.06	11.89	60.05	48.16
10-09-40-6W5	1882.00	1892.00	1933.50	1882.00	1892.00	1933.50	10.00	51.50	41.50
06-12-40-6W5	5910.00	5954.00	6090.00	1801.37	1814.78	1856.23	13.41	54.86	41.45
15-13-40-6W5	6019.00	6060.00	6193.00	1834.59	1847.09	1887.63	12.50	53.04	40.54
15-14-40-6W5	1819.00	1832.00	1873.50	1819.00	1832.00	1873.50	13.00	54.50	41.50
13-17-40-6W5	1893.00	1906.00	1948.50	1893.00	1906.00	1948.50	13.00	55.50	42.50
07-20-40-6W5	1877.50	1889.00	1930.00	1877.50	1889.00	1930.00	11.50	52.50	41.00
14-20-40-6W5	1890.00	1900.00	1942.00	1890.00	1900.00	1942.00	10.00	52.00	42.00
14-21-40-6W5	1890.00	1902.50	1943.00	1890.00	1902.50	1943.00	12.50	53.00	40.50
06-22-40-6W5	1845.00	1858.00	1900.00	1845.00	1858.00	1900.00	13.00	55.00	42.00
14-23-40-6W5	6048.00	6090.00	6224.00	1843.43	1856.23	1897.08	12.80	53.64	40.84
06-24-40-6W5	1834.50	1845.00	1886.50	1834.50	1845.00	1886.50	10.50	52.00	41.50
14-24-40-6W5	6005.00	6044.00	6178.00	1830.32	1842.21	1883.05	11.89	52.73	40.84
04-26-40-6W5	6060.00	6100.00	6234.00	1847.09	1859.28	1900.12	12.19	53.04	40.84
03-27-40-6W5	6140.00	6183.00	6317.00	1871.47	1884.58	1925.42	13.11	53.95	40.84
02-28-40-6W5	1894.00	1907.00	1949.00	1894.00	1907.00	1949.00	13.00	55.00	42.00
07-29-40-6W5	1893.50	1906.50	1947.00	1893.50	1906.50	1947.00	13.00	53.50	40.50
11-29-40-6W5	1897.00	1910.00	1950.50	1897.00	1910.00	1950.50	13.00	53.50	40.50
03-31-40-6W5	1907.00	1920.00	1961.50	1907.00	1920.00	1961.50	13.00	54.50	41.50
11-31-40-6W5	1916.50	1930.00	1971.00	1916.50	1930.00	1971.00	13.50	54.50	41.00
03-32-40-6W5	1913.00	1926.00	1967.50	1913.00	1926.00	1967.50	13.00	54.50	41.50
10-32-40-6W5	1909.00	1922.50	1963.50	1909.00	1922.50	1963.50	13.50	54.50	41.00
11-33-40-6W5	1920.00	1933.00	1975.00	1920.00	1933.00	1975.00	13.00	55.00	42.00
02-35-40-6W5	5945.00	5981.00	6118.00	1812.04	1823.01	1864.77	10.97	52.73	41.76
09-36-40-6W5	1822.00	1835.00	1877.50	1822.00	1835.00	1877.50	13.00	55.50	42.50
04-05-40-7W5	6580	6620	6774	2005.58	2017.78	2064.72	12.19	59.13	46.94
04-06-40-7W5	6686	6695	6854	2025.75	2040.64	2089.10	11.89	63.35	48.46
11-06-40-7W5	6590	6630	6790	2008.63	2020.82	2069.59	12.19	60.96	48.77
12-06-40-7W5	2079	2091	2141.5	2079.00	2091.00	2141.50	12.00	62.50	50.50
04-07-40-7W5	6620	6660	6820	2017.78	2029.97	2078.74	12.19	60.96	48.77
10-07-40-7W5	6545	6587	6744	1994.92	2007.72	2055.57	12.80	60.66	47.85
04-08-40-7W5	6530	6570	6722	1990.34	2002.54	2048.87	12.19	58.52	46.33
06-09-40-7W5	6515	6560	6744	1985.77	1999.49	2055.57	13.72	69.80	56.08
16-10-40-7W5	6325	6361	6563	1927.86	1938.83	2000.40	10.97	72.54	61.57
16-15-40-7W5	6410	6445	6652	1953.77	1964.44	2027.53	10.67	73.76	63.09
14-18-40-7W5	6524	6566	6723	1988.52	2001.32	2049.17	12.80	60.66	47.85
10-19-40-7W5	6356	6399	6553	1937.31	1950.42	1997.35	13.11	60.05	46.94
03-21-40-7W5	1921	1933	1989	1921.00	1933.00	1989.00	12.00	68.00	56.00
16-20-40-7W5	6304	6345	6520	1921.46	1933.96	1987.30	12.50	65.84	53.34
15-21-40-7W5	1945	1959	2021	1945.00	1959.00	2021.00	14.00	76.00	62.00
14-22-40-7W5	6354	6394	6562	1936.70	1948.89	2000.10	12.19	63.40	51.21
06-25-40-7W5	1915.5	1929	1977.5	1915.50	1929.00	1977.50	13.50	62.00	48.50
08-25-40-7W5	1917	1930	1977.5	1917.00	1930.00	1977.50	13.00	60.50	47.50
15-25-40-7W5	1936	1949	1997	1936.00	1949.00	1997.00	13.00	61.00	48.00
11-26-40-7W5	6295	6337	6500	1918.72	1931.52	1981.20	12.80	62.48	49.68
06-27-40-7W5	6333	6368	6538	1930.30	1940.97	1992.78	10.67	62.48	51.82
04-30-40-7W5	6368	6406	6558	1940.97	1952.55	1998.88	11.58	57.91	46.33
16-31-40-7W5	1953	1964	2018	1953.00	1964.00	2018.00	11.00	65.00	54.00
11-32-40-7W5	6279	6315	6490	1913.84	1924.81	1978.15	10.97	64.31	53.34
01-01-40-8W5	2147	2159.5	2205	2147.00	2159.50	2205.00	12.50	58.00	45.50
06-01-40-8W5	2051	2064	2110	2051.00	2064.00	2110.00	13.00	59.00	46.00
11-01-40-8W5	6676	6717	6862	2034.84	2047.34	2091.54	12.50	56.69	44.20
11-01-40-8W5	6710	6752	6900	2045.21	2058.01	2103.12	12.80	57.91	45.11
10-02-40-8W5	6762	6807	6960	2061.06	2074.77	2121.41	13.41	60.35	46.63
11-03-40-8W5	2090	2103.5	2150.5	2090.00	2103.50	2150.50	13.50	60.50	47.00
14-03-40-8W5	2098	2112	2158.5	2098.00	2112.00	2158.50	14.00	60.50	46.50
06-07-40-8W5	7069	7110	7262	2154.63	2167.13	2213.46	12.50	58.83	46.33
07-08-40-8W5	7033	7077	7250	2143.66	2157.07	2209.80	13.41	66.14	52.73
09-09-40-8W5	2103	2116	2165	2103.00	2116.00	2165.00	13.00	62.00	49.00
02-11-40-8W5	2057	2070	2116.5	2057.00	2070.00	2116.50	13.00	59.50	46.50
04-11-40-8W5	6775	6818	6976	2065.02	2078.13	2126.28	13.11	61.26	48.16
10-11-40-8W5	6730	6770	6919	2051.30	2063.50	2108.91	12.19	57.61	45.42
12-11-40-8W5	2056.5	2070	2118	2056.50	2070.00	2118.00	13.50	61.50	48.00
01-12-40-8W5	2032	2045	2094	2032.00	2045.00	2094.00	13.00	62.00	49.00
04-12-40-8W5	6690	6730	6883	2039.11	2051.30	2097.94	12.19	58.83	46.63
10-12-40-8W5	6591	6633	6790	2008.94	2021.74	2069.59	12.80	60.66	47.85
11-12-40-8W5	2020.5	2034	2081.5	2020.50	2034.00	2081.50	13.50	61.00	47.50
12-12-40-8W5	6633	6679	6832	2021.74	2035.76	2082.39	14.02	60.66	46.63
02-13-40-8W5	2001	2014.5	2063	2001.00	2014.50	2063.00	13.50	62.00	48.50
10-13-40-8W5	6535	6577	6740	1991.87	2004.67	2054.35	12.80	62.48	49.68
12-13-40-8W5	6667	6713	6868	2032.10	2046.12	2093.37	14.02	61.26	47.24
02-14-40-8W5	2050	2063.5	2108.5	2050.00	2063.50	2108.50	13.50	58.50	45.00

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
04-14-40-8W5	6797	6841	6990	2071.73	2085.14	2130.58	13.41	58.83	45.42
07-14-40-8W5	6718	6760	6913	2047.65	2060.45	2107.08	12.80	59.44	46.63
10-14-40-8W5	2069.5	2083	2129	2069.50	2083.00	2129.00	13.50	59.50	46.00
02-15-40-8W5	2074	2087.5	2135	2074.00	2087.50	2135.00	13.50	61.00	47.50
10-15-40-8W5	6827	6870	7020	2080.87	2093.98	2139.70	13.11	58.83	45.72
10-16-40-8W5	2103	2117	2164	2103.00	2117.00	2164.00	14.00	61.00	47.00
10-20-40-8W5	2113	2128	2176	2113.00	2128.00	2176.00	15.00	63.00	48.00
04-21-40-8W5	2137	2152	2200	2137.00	2152.00	2200.00	15.00	63.00	48.00
10-21-40-8W5	2080	2094	2142	2080.00	2094.00	2142.00	14.00	62.00	48.00
12-21-40-8W5	2104.5	2117.5	2165.5	2104.50	2117.50	2165.50	13.00	61.00	48.00
04-22-40-8W5	6865	6933	7087	2092.55	2113.18	2160.12	14.63	61.57	46.94
10-22-40-8W5	6699	6745	6912	2041.86	2055.88	2106.78	14.02	64.92	50.90
12-22-40-8W5	2057.5	2072	2120	2057.50	2072.00	2120.00	14.50	62.50	48.00
11-23-40-9W5	7107	7157	7334	2166.21	2181.45	2235.40	15.24	69.19	53.95
04-24-40-8W5	6597	6640	6788	2010.77	2023.87	2068.98	13.11	58.22	45.11
04-26-40-8W5	6614	6658	6810	2015.95	2029.36	2075.69	13.41	59.74	46.33
10-26-40-8W5	6535	6580	6740	1991.87	2005.58	2054.35	13.72	62.48	48.77
02-27-40-8W5	2104.5	2118	2167	2104.50	2118.00	2167.00	13.50	62.50	49.00
04-27-40-8W5	6703	6744	6912	2043.07	2055.57	2106.78	12.50	63.70	51.21
10-27-40-8W5	6626	6666	6820	2019.60	2031.80	2078.74	12.19	59.13	46.94
12-27-40-8W5	6673	6714	6870	2033.93	2046.43	2093.98	12.50	60.05	47.55
02-28-40-7W5	2061.5	2074	2122	2061.50	2074.00	2122.00	12.50	60.50	48.00
06-28-40-8W5	2065.5	2078	2127.5	2065.50	2078.00	2127.50	12.50	61.90	49.50
11-28-40-7W5	6720	6760	6917	2048.26	2060.45	2108.30	12.19	60.05	47.85
06-29-40-8W5	2086.5	2099	2148.5	2086.50	2099.00	2148.50	12.50	62.00	49.50
10-29-40-8W5	2064.5	2077	2126	2064.50	2077.00	2126.00	12.50	61.50	49.00
10-32-40-8W5	6698	6740	6912	2041.55	2054.35	2106.78	12.80	65.23	52.43
04-33-40-8W5	6731	6772	6934	2051.61	2064.11	2113.48	12.50	61.87	49.38
10-33-40-8W5	6641	6683	6838	2024.18	2036.98	2084.22	12.80	60.05	47.24
04-34-40-8W5	6635	6675	6835	2022.33	2034.54	2083.31	12.19	60.96	48.77
16-34-40-8W5	1989	2000	2047.5	1989.00	2000.00	2047.50	11.00	58.50	47.50
08-01-40-9W5	2237	2248	2295	2237.00	2248.00	2295.00	11.00	58.00	47.00
04-02-40-9W5	7370	7410	7562	2246.38	2258.57	2304.90	12.19	58.52	46.33
11-05-40-9W5	7646	7683	7842	2330.50	2341.78	2390.12	11.28	59.62	48.34
10-12-40-9W5	7364	7400	7550	2244.55	2255.52	2301.24	10.97	56.69	45.72
11-13-40-9W5	7304	7340	7491	2226.26	2237.23	2283.26	10.97	57.00	46.02
10-15-40-9W5	7238	7274	7425	2206.14	2217.12	2263.14	10.97	57.00	46.02
10-17-40-9W5	2274	2285	2333	2274.00	2285.00	2333.00	11.00	59.00	48.00
10-22-40-9W5	7219	7255	7410	2200.35	2211.32	2258.57	10.97	58.22	47.24
09-23-40-9W5	7290	7324	7470	2221.99	2232.36	2276.86	10.36	54.86	44.50
10-23-40-9W5	7248	7285	7434	2209.19	2220.47	2265.88	11.28	56.69	45.42
16-28-40-9W5	2202	2213	2261.5	2202.00	2213.00	2261.50	11.00	59.50	48.50
11-30-40-9W5	7381	7419	7578	2249.73	2261.31	2309.77	11.58	60.05	48.46
11-33-40-9W5	7251	7286	7438	2210.10	2220.77	2267.10	10.67	57.00	46.33
10-34-40-9W5	7207	7240	7382	2196.69	2206.75	2250.03	10.06	53.34	43.28
06-07-40-10W5	8992	9030	9190	2740.76	2752.34	2801.11	11.58	60.35	48.77
10-14-40-10W5	7925	7962	8118	2415.54	2426.82	2474.37	11.28	58.83	47.55
06-21-40-10W5	8148	8186	8344	2483.51	2495.09	2543.25	11.58	59.74	48.16
13-28-40-10W5	8013	8050	8207	2442.36	2453.64	2501.49	11.28	59.13	47.85
[illegible]-29-40-10W5	2470	2481	2528	2470.00	2481.00	2528.00	11.00	58.00	47.00
14-01-41-6W5	5975	6010	6166	1821.18	1831.85	1879.40	10.67	58.22	47.55
07-03-41-6W5	1840.5	1853	1901	1840.50	1853.00	1901.00	12.50	60.50	48.00
16-04-41-6W5	1855.5	1868	1913	1855.50	1868.00	1913.00	12.50	57.50	45.00
06-05-41-6W5	6330	6371	6524	1929.38	1941.88	1988.52	12.50	59.13	46.63
05-06-41-6W5	1930.5	1943	1990	1930.50	1943.00	1990.00	12.50	59.50	47.00
06-07-41-6W5	1957.5	1968.5	2015	1957.50	1968.50	2015.00	11.00	57.50	46.50
15-10-41-6W5	1837.5	1849.5	1897	1837.50	1849.50	1897.00	12.00	59.50	47.50
16-13-41-6W5	5883	5915	6070	1793.14	1802.89	1850.14	9.75	57.00	47.24
16-14-41-6W5	6015	6050	6207	1833.37	1844.04	1891.89	10.67	58.52	47.85
06-15-41-6W5	6163	6200	6352	1878.48	1889.76	1936.09	11.28	57.61	46.33
14-15-41-6W5	6130	6168	6320	1868.42	1880.01	1926.34	11.58	57.91	46.33
16-16-41-6W5	6186	6225	6380	1885.49	1897.38	1944.62	11.89	59.13	47.24
01-19-41-6W5	6190	6227	6379	1886.71	1897.99	1944.32	11.28	57.61	46.33
10-20-41-6W5	6137	6171	6322	1870.56	1880.92	1926.95	10.36	56.39	46.02
06-22-41-6W5	6113	6150	6307	1863.24	1874.52	1922.37	11.28	59.13	47.85
06-23-41-6W5	5998	6033	6188	1828.19	1838.86	1886.10	10.67	57.91	47.24
16-23-41-6W5	5967	6000	6154	1818.74	1828.80	1875.74	10.06	57.00	46.94
16-24-41-6W5	6032	6065	6217	1838.55	1848.61	1894.94	10.06	56.39	46.33
14-24-41-6W5	6041	6074	6230	1841.30	1851.36	1898.90	10.06	57.61	47.55
06-25-41-6W5	6054	6087	6242	1845.26	1855.32	1902.56	10.06	57.30	47.24
08-25-41-6W5	6040	6070	6224	1840.99	1850.14	1897.08	9.14	56.08	46.94
16-25-41-6W5	1830	1840	1887	1830.00	1840.00	1887.00	10.00	57.00	47.00
06-26-41-6W5	5930	5966	6117	1807.46	1818.44	1864.46	10.97	57.00	46.02
08-26-41-6W5	1832	1842.5	1890	1832.00	1842.50	1890.00	10.50	58.00	47.50
16-26-41-6W5	5928	5961	6113	1806.85	1816.91	1863.24	10.06	56.39	46.33
06-27-41-6W5	6098	6136	6286	1858.67	1870.25	1915.97	11.58	57.30	45.72
06-31-41-6W5	6278	6314	6467	1913.53	1924.51	1971.14	10.97	57.61	46.63
10-31-41-6W5	6348	6382	6534	1934.87	1945.23	1991.56	10.36	56.69	46.33
06-32-41-6W5	6312	6352	6508	1923.90	1936.09	1983.64	12.19	59.74	47.55

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
06-33-41-6W5	6223	6265	6418	1896.77	1909.57	1956.21	12.80	59.44	46.63
08-33-41-6W5	6132	6172	6324	1869.03	1881.23	1927.56	12.19	58.52	46.33
06-34-41-6W5	6043	6080	6235	1841.91	1853.18	1900.43	11.28	58.52	47.24
08-34-41-6W5	5957	5989	6140	1814.47	1825.45	1871.47	10.97	57.00	46.02
14-34-41-6W5	6028	6066	6222	1837.33	1848.92	1896.47	11.58	59.13	47.55
16-34-41-6W5	6008	6045	6200	1831.24	1842.52	1889.76	11.28	58.52	47.24
06-35-41-6W5	6014	6050	6205	1833.07	1844.04	1891.28	10.97	58.22	47.24
[illegible]-35-41-6W5	6107	6147	6295	1861.41	1873.47	1918.72	[illegible]	[illegible]	[illegible]
[illegible]-35-41-6W5	6108	6147	6296	1861.72	[illegible]	1919.02	[illegible]	[illegible]	[illegible]
16-35-41-6W5	6154	6187	6240	1845.26	1855.32	1901.95	[illegible]	56.69	46.33
[illegible]-36-41-6W5	6054	6086	6240	1845.26	1855.01	1901.95	9.75	56.69	46.94
16-01-41-7W5	1937.5	1950	1998	1937.50	1950.00	1998.00	12.50	61.50	48.00
[illegible]-01-41-7W5	1942	1952.5	2000	1942.00	1952.50	2000.00	10.50	58.00	47.50
[illegible]-01-41-7W5	1929	1941	1988.5	1929.00	1941.00	1988.50	12.00	59.50	47.50
16-01-41-7W5	1942	1954.5	2002	1942.00	1954.50	2002.00	12.50	60.00	47.50
06-02-41-7W5	1952.5	1965	2014	1952.50	1965.00	2014.00	12.50	61.50	49.00
07-05-41-7W5	1905	1917	1970	1905.00	1917.00	1970.00	12.00	65.04	53.00
02-06-41-7W5	6380	6420	6594	1944.62	1956.82	2009.85	12.19	65.23	53.04
16-09-41-7W5	1937.5	1949.5	1998.5	1937.50	1949.50	1998.50	12.00	61.00	49.00
07-10-41-7W5	1936	1947.5	1996	1936.00	1947.50	1996.00	11.50	60.00	48.50
11-11-41-7W5	1943	1954.5	2003	1943.00	1954.50	2003.00	11.50	60.00	48.50
16-12-41-7W5	6470	6510	6664	1972.06	1984.25	2031.19	12.19	59.13	46.94
06-21-41-7W5	6339	6381	6537	1932.13	1944.93	1992.48	12.80	61.35	47.55
14-22-41-7W5	1924.5	1936.5	1983.5	1924.50	1936.50	1983.50	12.00	59.00	47.00
16-22-41-7W5	6298	6340	6494	1919.63	1932.43	1979.37	12.80	59.74	46.94
06-25-41-7W5	1933.5	1945	1991.5	1933.50	1945.00	1991.50	11.50	58.00	46.50
06-26-41-7W5	1933.5	1945	1993	1933.50	1945.00	1993.00	11.50	59.50	48.00
14-26-41-7W5	6326	6368	6520	1928.16	1940.97	1987.30	12.80	59.13	46.33
07-28-41-7W5	6232	6275	6422	1899.51	1912.62	1959.25	13.11	59.74	46.63
07-29-41-7W5	1912	1923.5	1971.5	1912.00	1923.50	1971.50	11.50	59.50	48.00
10-30-41-7W5	6282	6323	6480	1914.75	1927.25	1975.10	12.50	60.35	47.85
16-32-41-7W5	6188	6233	6386	1886.10	1899.82	1946.45	13.72	60.35	46.63
12-33-41-7W5	1895.5	1908.5	1955	1895.50	1908.50	1955.00	13.00	59.50	46.50
06-34-41-7W5	6223	6264	6413	1896.77	1909.27	1954.68	12.50	57.91	45.42
08-34-41-7W5	6240	6282	6433	1901.95	1914.75	1960.78	12.80	58.83	46.02
14-34-41-7W5	6293	6334	6486	1918.11	1930.60	1976.93	12.50	58.83	46.33
16-34-41-7W5	6364	6404	6550	1939.75	1951.94	1996.44	12.19	56.69	44.50
06-35-41-7W5	6360	6400	6550	1938.53	1950.72	1996.44	12.19	57.91	45.72
14-35-41-7W5	1969	1982	2027	1969.00	1982.00	2027.00	13.00	58.00	45.00
06-36-41-7W5	6263	6302	6450	1908.96	1920.85	1965.96	11.89	57.00	45.11
14-36-41-7W5	1912.5	1925	1970	1912.50	1925.00	1970.00	12.50	57.50	45.00
11-02-41-8W5	6383	6420	6586	1945.54	1956.82	2007.41	11.28	61.87	[illegible]
10-03-41-8W5	6546	6585	6737	1995.22	2007.11	2053.44	11.89	58.22	46.33
04-04-41-8W5	6656	6690	6853	2028.75	2039.11	2088.79	10.36	60.05	49.68
10-04-41-8W5	6590	6624	6776	2008.63	2019.00	2065.32	10.36	56.69	46.33
02-05-41-8W5	2037.5	2048	2103	2037.50	2048.00	2103.00	10.50	65.50	55.00
10-05-41-8W5	6676	6712	6868	2034.84	2045.82	2093.37	10.97	58.52	47.55
02-07-41-8W5	2046	2057	2105	2046.00	2057.00	2105.00	11.00	59.00	48.00
04-07-41-8W5	6720	6754	6916	2048.26	2058.62	2108.00	10.36	59.74	49.38
10-07-41-8W5	6812	6848	7003	2076.30	2087.27	2134.51	10.97	58.22	47.24
12-07-41-8W5	2077	2087	2138	2077.00	2087.00	2138.00	10.00	61.00	51.00
02-08-41-8W5	2033.5	2044	2093	2033.50	2044.00	2093.00	10.50	59.50	49.00
04-08-41-8W5	6695	6730	6890	2040.64	2051.30	2100.07	10.67	59.44	48.77
10-08-41-8W5	6674	6713	6868	2034.24	2046.12	2093.37	11.89	59.13	47.24
12-08-41-8W5	2065.5	2076	2123	2065.50	2076.00	2123.00	10.50	57.50	47.00
04-09-41-8W5	6610	6648	6800	2014.73	2026.31	2072.64	11.58	57.91	46.33
16-09-41-8W5	6580	6620	6783	2005.58	2017.78	2067.46	12.19	61.87	49.68
10-11-41-8W5	6487	6527	6710	1977.24	1989.43	2045.21	12.19	67.97	55.78
06-12-41-8W5	2002.5	2013	2075	2002.50	2013.00	2075.00	10.50	72.50	62.00
12-12-41-8W5	6606	6645	6803	2013.51	2025.40	2073.55	11.89	60.05	48.16
02-17-41-8W5	2031	2043	2090	2031.00	2043.00	2090.00	12.00	59.00	47.00
04-17-41-8W5	6788	6828	6979	2068.98	2081.17	2127.20	12.19	58.22	46.02
10-17-41-8W5	6634	6674	6836	2022.04	2034.24	2083.61	12.19	61.57	49.38
02-18-41-8W5	2100	2112	2160	2100.00	2112.00	2160.00	12.00	60.00	48.00
04-18-41-8W5	6910	6946	7104	2106.17	2117.14	2165.30	10.97	59.13	48.16
10-18-41-8W5	6768	6804	6957	2062.89	2073.86	2120.45	10.97	57.61	46.63
12-18-41-8W5	2082.5	2094	2142	2082.50	2094.00	2142.00	11.50	59.50	48.00
04-19-41-8W5	6754	6789	6940	2058.62	2069.29	2115.31	10.67	56.69	46.02
10-19-41-8W5	6687	6722	6860	2038.20	2048.87	2090.93	10.67	52.73	42.06
04-20-41-8W5	2029.5	2040	2083.5	2029.50	2040.00	2086.50	10.50	57.00	46.50
10-20-41-8W5	6610	6644	6805	2014.73	2025.09	2074.16	10.36	59.44	49.07
06-26-41-8W5	6376	6410	6573	1943.40	1953.77	2003.45	10.36	60.05	49.68
04-28-41-8W5	6585	6620	6878	2007.11	2017.78	2096.41	10.67	89.31	78.64
04-29-41-8W5	6683	6716	6890	2036.98	2047.04	2100.07	10.06	63.09	53.04
04-30-41-8W5	6738	6772	6935	2053.74	2064.11	2113.79	10.36	60.05	49.68
10-30-41-8W5	6759	6798	6960	2060.14	2072.03	2121.41	11.89	61.26	49.38
04-31-41-8W5	6741	6779	6950	2054.66	2066.24	2118.36	11.58	63.70	52.12
10-31-41-8W5	6416	6455	6648	1955.60	1967.48	2026.31	11.89	70.71	58.83
02-36-41-8W5	6111	6150	6312	1862.63	1874.52	1923.90	11.89	61.26	49.38
12-36-41-8W5	6130	6170	6327	1868.42	1880.62	1928.47	12.19	60.05	47.85
07-03-41-9W5	7137	7174	[illegible]	[illegible]	[illegible]	2247.29	11.28	[illegible]	[illegible]
10-07-41-9W5	[illegible]	7336	7452	2225.04	[illegible]	2280.51	10.97	55.47	44.50

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
[illegible]	7340	7375	7530	[illegible]	2247.90	2295.14	10.67	[illegible]	[illegible]
06-10-41-9W5	2091	2102	2153	2091.00	2102.00	2153.00	11.00	62.00	51.00
12-10-41-9W5	2114	2124.5	2174	2114.00	2124.50	2174.00	10.50	60.00	49.50
14-10-41-9W5	6850	6885	7048	2087.88	2098.55	2148.23	10.67	60.35	49.68
10-13-41-9W5	6920	6955	7113	2109.22	2119.88	2168.04	10.67	58.83	48.16
12-13-41-9W5	2128.5	2139	2189	2128.50	2139.00	2189.00	10.50	60.50	50.00
10-14-41-9W5	6892	.6928	7090	2100.68	2111.65	2161.03	10.97	60.35	49.38
16-19-41-9W5	2182.5	2193	2245	2182.50	2193.00	2245.00	10.50	62.50	52.00
10-22-41-9W5	6968	7003	7164	2123.85	2134.51	2183.59	10.67	59.74	49.07
12-23-41-9W5	2132.5	2143	2193.5	2132.50	2143.00	2193.50	10.50	61.00	50.50
14-23-41-9W5	6917	6952	7117	2108.30	2118.97	2169.26	10.67	60.96	50.29
10-23-41-9W5	6890	6924	7083	2100.07	2110.44	2158.90	10.36	58.83	48.46
12-23-41-9W5	2122	2133	2180.5	2122.00	2133.00	2180.50	11.00	58.50	47.50
12-24-41-9W5	2085.5	2095.5	2144	2085.50	2095.50	2144.00	10.00	58.50	48.50
14-24-41-9W5	6936	6970	7130	2114.09	2124.46	2173.22	10.36	59.13	48.77
10-24-41-9W5	6765	6800	6955	2061.97	2072.64	2119.88	10.67	57.91	47.24
12-24-41-9W5	2084.5	2094.5	2142.5	2084.50	2094.50	2142.50	10.00	58.00	48.00
12-25-41-9W5	2052.5	2062.5	2110	2052.50	2062.50	2110.00	10.00	57.50	47.50
10-25-41-9W5	6819	6855	7005	2078.43	2089.40	2135.12	10.97	56.69	45.72
12-25-41-9W5	6816	6850	7000	2077.52	2087.88	2133.60	10.36	56.08	45.72
02-26-41-9W5	2073.5	2083.5	2135	2073.50	2083.50	2135.00	10.00	61.50	51.50
14-26-41-9W5	6873	6908	7068	2094.89	2105.56	2154.33	10.67	59.44	48.77
10-26-41-9W5	6830	6864	7020	2081.78	2092.15	2139.70	10.36	57.91	47.55
12-26-41-9W5	2102	2112.5	2159.5	2102.00	2112.50	2159.50	10.50	57.50	47.00
12-27-41-9W5	2114.5	2125	2175	2114.50	2125.00	2175.00	10.50	60.50	50.00
14-27-41-9W5	7057	7091	7254	2150.97	2161.34	2211.02	10.36	60.05	49.68
10-27-41-9W5	7000	7036	7193	2133.60	2144.57	2192.43	10.97	58.83	47.85
12-27-41-9W5	2136.5	2147	2195	2136.50	2147.00	2195.00	10.50	58.50	48.00
10-28-41-9W5	7090	7125	7292	2161.03	2171.70	2222.60	10.67	61.57	50.90
10-31-41-9W5	2169.5	2180.5	2231	2169.50	2180.50	2231.00	11.00	61.50	50.50
10-33-41-9W5	7000	7034	7198	2133.60	2143.96	2193.95	10.36	60.35	49.99
11-33-41-9W5	2147	2157.5	2207	2147.00	2157.50	2207.00	10.50	60.00	49.50
12-34-41-9W5	2130	2140	2190	2130.00	2140.00	2190.00	10.00	60.00	50.00
04-34-41-9W5	6995	7030	7187	2132.08	2142.74	2190.60	10.67	58.52	47.85
10-34-41-9W5	6945	6980	7139	2116.84	2127.50	2175.97	10.67	59.13	48.46
12-34-41-9W5	2120	2130	2178.5	2120.00	2130.00	2178.50	10.00	58.50	48.50
10-35-41-9W5	6998	7032	7185	2132.99	2143.35	2189.99	10.36	57.00	46.63
10-35-41-9W5	6836	6870	7021	2083.61	2093.98	2140.00	10.36	56.39	46.02
12-35-41-9W5	2099	2109	2156	2099.00	2109.00	2156.00	10.00	57.00	47.00
14-36-41-9W5	6842	6877	7030	2085.44	2096.11	2142.74	10.67	57.30	46.63
10-36-41-9W5	6633	6666	6828	2021.74	2031.80	2081.17	10.06	59.44	49.38
[illegible]-41-10W5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16-05-41-10W5	2394	2406	2453.5	2394.00	2406.00	2453.50	12.00	59.50	47.50
09-11-41-10W5	7386	7424	7586	2251.25	2262.84	2312.21	11.58	61.96	49.38
16-13-41-10W5	7329	7364	7516	2233.88	2244.55	2290.88	10.67	57.00	46.33
10-15-41-10W5	7320	7357	7517	2231.14	2242.41	2291.18	11.28	60.05	48.77
10-16-41-10W5	2303	2314	2355	2303.00	2314.00	2355.00	11.00	52.00	41.00
07-23-41-10W5	2231	2241	2285	2231.00	2241.00	2285.00	10.00	54.00	44.00
06-24-41-10W5	2253	2263.5	2310	2253.00	2263.50	2310.00	10.50	57.00	46.50
16-28-41-10W5	2261.5	2272	2322.5	2261.50	2272.00	2322.50	10.50	61.00	50.50
11-29-41-10W5	2334.5	2345.5	2396.5	2334.50	2345.50	2396.50	11.00	62.00	51.00
10-34-41-10W5	2255	2266	2315	2255.00	2266.00	2315.00	11.00	60.00	49.00
[illegible]-42-6W5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06-02-42-6W5	6020	6054	6210	1834.90	1845.26	1892.81	10.36	57.91	47.55
14-02-42-6W5	6001	6036	6191	[illegible]	1839.77	1887.02	10.97	58.22	47.24
16-02-42-6W5	5891	5927	6083	1795.58	1806.55	1854.10	10.97	58.52	47.55
06-03-42-6W5	6069	6104	6257	1849.83	1860.50	1907.13	10.67	57.30	46.63
1?-03-42-6W5	1869	1879.5	1926.5	1869.00	1879.50	1926.50	10.50	57.50	47.00
06-04-42-6W5	6157	6193	6350	1876.65	1887.63	1935.48	10.97	58.83	47.85
14-04-42-6W5	6133	6168	6318	1869.34	1880.01	1925.73	10.67	56.39	45.72
06-05-42-6W5	6300	6336	6487	1920.24	1931.21	1977.24	10.97	57.00	46.03
04-06-42-6W5	1932	1943	1989	1932.00	1943.00	1989.00	11.00	57.00	46.00
06-06-42-6W5	6335	6373	6523	1930.91	1942.49	1988.21	11.58	57.30	45.72
08-06-42-6W5	6325	6362	6514	1927.86	1939.14	1985.47	11.28	57.61	46.33
06-07-42-6W5	6244	6280	6432	1903.17	1914.14	1960.47	10.97	57.30	46.33
06-08-42-6W5	6162	6198	6353	1878.18	1889.15	1936.39	10.97	58.22	47.24
08-08-42-6W5	6226	6262	6419	1897.68	1908.66	1956.51	10.97	58.83	47.85
14-08-42-6W5	6248	6284	6440	1904.39	1915.36	1962.91	10.97	58.52	47.55
16-08-42-6W5	6279	6314	6470	1913.84	1924.51	1972.06	10.67	58.22	47.55
06-09-42-6W5	6228	6263	6420	1898.29	1908.96	1956.82	10.67	58.52	47.85
06-10-42-6W5	6190	6224	6378	1886.71	1897.08	1944.01	10.36	57.30	46.94
08-10-42-6W5	6063	6097	6252	1848.00	1858.37	1905.61	10.36	57.61	47.24
14-10-42-6W5	6214	6249	6402	1894.03	1904.70	1951.33	10.67	57.30	46.63
16-10-42-6W5	6215	6250	6403	1894.33	1905.00	1951.63	10.67	57.30	46.63
06-11-42-6W5	6050	6084	6240	1844.04	1854.40	1901.95	10.36	57.91	47.55
08-11-42-6W5	5918	5953	6110	1803.81	1814.47	1862.33	10.67	58.52	47.85
14-11-42-6W5	6044	6077	6238	1842.21	1852.27	1901.34	10.06	59.13	49.07
16-11-42-6W5	6025	6058	6214	1836.42	1846.48	1894.03	10.06	57.61	47.55
06-12-42-6W5	5881	5916	6072	1792.53	1803.20	1850.75	10.67	58.22	47.55

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
08-12-42-6W5	5831	5865	6017	1777.29	1787.65	1833.98	10.36	56.69	46.33
14-12-42-6W5	5942	5976	6132	1811.12	1821.48	1869.03	10.36	57.91	47.55
16-12-42-6W5	5933	5969	6123	1808.38	1819.35	1866.29	10.97	57.91	46.94
06-13-42-6W5	5883	5916	6070	1793.14	1803.20	1850.14	10.06	57.00	46.94
08-13-42-6W5	5843	5876	6029	1780.95	1791.00	1837.64	10.06	56.69	46.63
16-13-42-6W5	5923	5956	6106	1805.33	1815.39	1861.11	10.06	55.78	45.72
06-14-42-6W5	6076	6110	6264	1851.96	1862.33	1909.27	10.36	57.30	46.94
14-14-42-6W5	6162	6195	6347	1878.18	1888.24	1934.57	10.06	56.39	46.33
06-15-42-6W5	6172	6206	6360	1881.23	1891.59	1938.53	10.36	57.30	46.94
08-15-42-6W5	6168	6203	6356	1880.01	1890.67	1937.31	10.67	57.30	46.63
14-15-42-6W5	5981	6017	6170	1823.01	1833.98	1880.62	10.97	57.61	46.63
16-15-42-6W5	6188	6220	6373	1886.10	1895.86	1942.49	9.75	56.39	46.63
08-16-42-6W5	6175	6210	6367	1882.14	1892.81	1940.66	10.67	58.52	47.85
14-16-42-6W5	6031	6066	6220	1838.25	1848.92	1895.86	10.67	57.61	46.94
16-16-42-6W5	5992	6026	6180	1826.36	1836.72	1883.66	10.36	57.30	46.94
06-17-42-6W5	6318	6350	6507	1925.73	1935.48	1983.33	9.75	57.61	47.85
14-17-42-6W5	6164	6195	6348	1878.79	1888.24	1934.87	9.45	56.08	46.63
16-17-42-6W5	6135	6167	6320	1869.95	1879.70	1926.34	9.75	56.39	46.63
06-18-42-6W5	6195	6230	6384	1888.24	1898.90	1945.84	10.67	57.61	46.94
08-18-42-6W5	6325	6360	6515	1927.86	1938.53	1985.77	10.67	57.91	47.24
14-18-42-6W5	6347	6380	6534	1934.57	1944.62	1991.56	10.06	57.00	46.94
16-18-42-6W5	6355	6388	6540	1937.00	1947.06	1993.39	10.06	56.39	46.33
06-19-42-6W5	6180	6218	6372	1883.66	1895.25	1942.19	11.58	58.52	46.94
08-19-42-6W5	6256	6290	6444	1906.83	1917.19	1964.13	10.36	57.30	46.94
14-19-42-6W5	6134	6169	6327	1869.64	1880.31	1928.47	10.67	58.83	48.16
02-20-42-6W5	1874.5	1885	1934	1874.50	1885.00	1934.00	10.50	59.50	49.00
06-21-42-6W5	6071	6107	6260	1850.44	1861.41	1908.05	10.97	57.91	46.94
08-21-42-6W5	5993	6028	6182	1826.67	1837.33	1884.27	10.67	57.61	46.94
14-21-42-6W5	[illegible]	[illegible]	6244	[illegible]	1851.86	1903.17	11.89	[illegible]	[illegible]
16-21-42-6W5	5968	6003	6156	1819.05	1829.71	1876.35	10.67	57.30	46.63
06-22-42-6W5	6157	6193	6346	1876.65	1887.63	1934.26	10.97	57.61	46.63
08-22-42-6W5	6169	6200	6356	1880.31	1889.76	1937.31	9.45	57.00	47.55
10-22-42-6W5	6170	6204	6356	1880.62	1890.98	1937.31	10.36	56.69	46.33
02-22-42-6W5	1877	1888	1934.5	1877.00	1888.00	1934.50	11.00	57.50	46.50
14-22-42-6W5	6072	6105	6259	1850.75	1860.80	1907.74	10.06	57.00	46.94
16-22-42-6W5	6158	6193	6347	1876.96	1887.63	1934.57	10.67	57.61	46.94
06-23-42-6W5	6148	6170	6322	1873.91	1880.62	1926.95	6.71	53.04	46.33
08-23-42-6W5	1807.5	1817.5	1864.5	1807.50	1817.50	1864.50	10.00	57.00	47.00
16-23-42-6W5	5824	5858	6008	1775.16	1785.52	1831.24	10.36	56.08	45.72
08-24-42-6W5	1753	1763	1809	1753.00	1763.00	1809.00	10.00	56.00	46.00
14-24-42-6W5	5790	5823	5976	1764.79	1774.85	1821.48	10.06	56.69	46.63
06-25-42-6W5	5744	5776	5928	1750.77	1760.52	1806.85	9.75	56.08	46.33
06-26-42-6W5	5851	5885	6034	1783.38	1793.75	1839.16	10.36	55.78	45.42
08-26-42-6W5	5810	5843	5987	1768.49	1778.51	1824.84	10.06	56.39	46.33
14-26-42-6W5	6034	6070	6220	1839.16	1850.14	1895.86	10.97	56.69	45.72
16-26-42-6W5	6067	6100	6255	1849.22	1859.28	1906.52	10.06	57.30	47.24
08-27-42-6W5	5959	5994	6145	1816.30	1826.97	1872.99	10.67	56.69	46.02
14-27-42-6W5	5950	5986	6138	1813.56	1824.53	1870.86	10.97	57.30	46.33
16-27-42-6W5	5951	5986	6140	1813.86	1824.53	1871.47	10.67	57.61	46.94
06-28-42-6W5	6030	6065	6220	1837.94	1848.61	1895.86	10.67	57.91	47.24
08-28-42-6W5	6132	6169	6322	1869.03	1880.31	1926.95	11.28	57.91	46.63
16-28-42-6W5	5933	5969	6120	1808.38	1819.35	1865.38	10.97	57.00	46.02
06-29-42-6W5	5910	5946	6104	1801.37	1812.34	1860.50	10.97	59.13	48.16
14-29-42-6W5	5870	5905	6063	1789.18	1799.84	1848.00	10.67	58.83	48.16
16-29-42-6W5	5877	5911	6070	1791.31	1801.67	1850.14	10.36	58.83	48.46
16-30-42-6W5	6105	6140	6293	1860.80	1871.47	1918.11	10.67	57.30	46.63
06-31-42-6W5	5960	5996	6146	1816.61	1827.58	1873.30	10.97	56.69	45.72
08-31-42-6W5	5873	5905	6055	1790.09	1799.84	1845.56	9.75	55.47	45.72
16-31-42-6W5	5814	5846	5996	1772.11	1781.86	1827.58	9.75	55.47	45.72
06-32-42-6W5	5865	5897	6048	1787.65	1797.41	1843.43	9.75	55.78	46.02
14-32-42-6W5	5865	5903	6070	1787.65	1799.23	1850.14	11.58	62.49	50.90
16-32-42-6W5	5898	5935	6085	1797.71	1808.99	1854.71	11.28	57.00	45.72
08-33-42-6W5	5871	5906	6058	1789.48	1800.15	1846.48	10.67	57.00	46.33
14-33-42-6W5	5807	5843	5990	1769.97	1780.95	1825.75	10.97	55.78	44.81
16-33-42-6W5	5874	5907	6061	1790.40	1800.45	1847.39	10.06	57.00	46.94
06-34-42-6W5	6124	6160	6320	1866.60	1877.57	1926.34	10.97	59.74	48.77
08-34-42-6W5	5932	5968	6116	1808.07	1819.05	1864.16	10.97	56.08	45.11
14-34-42-6W5	5905	5940	6080	1799.84	1810.51	1853.18	10.67	53.34	42.67
02-35-42-6W5	1852.5	1863	1910.5	1852.50	1863.00	1910.50	10.50	58.00	47.50
06-35-42-6W5	6066	6100	6253	1848.92	1859.28	1905.91	10.36	57.00	46.63
02-01-42-7W5	6364	6397	6548	1939.75	1949.81	1995.83	10.06	56.08	46.02
14-01-42-7W5	6356	6390	6540	1937.31	1947.67	1993.39	10.36	56.08	45.72
16-01-42-7W5	6267	6299	6448	1910.18	1919.94	1965.35	9.75	55.17	45.42
08-02-42-7W5	1917	1927	1973	1917.00	1927.00	1973.00	10.00	56.00	46.00
14-02-42-7W5	1907	1917	1963	1907.00	1917.00	1963.00	10.00	56.00	46.00
16-02-42-7W5	6229	6261	6412	1898.60	1908.35	1954.38	9.75	55.78	46.02
06-03-42-7W5	6368	6400	6554	1940.97	1950.72	1997.66	9.75	56.69	46.94
08-03-42-7W5	6330	6365	6511	1929.38	1940.05	1984.55	10.67	55.17	44.50
16-03-42-7W5	6325	6359	6504	1927.86	1938.22	1982.42	10.36	54.56	44.20
04-04-42-7W5	1912	1922.5	1968	1912.00	1922.50	1968.00	10.50	56.00	45.50
06-04-42-7W5	6300	6334	6483	1920.24	1930.60	1976.02	10.36	55.78	45.42

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
02-04-42-7W5	1932	1942.5	1987.5	1932.00	1942.50	1987.50	10.50	55.50	45.00
14-04-42-7W5	1936	1946.5	1992	1936.00	1946.50	1992.00	10.50	56.00	45.50
06-05-42-7W5	6185	6221	6380	1885.19	1896.16	1944.62	10.97	59.44	48.46
16-05-42-7W5	1920.5	1931	1977	1920.50	1931.00	1977.00	10.50	56.50	46.00
07-06-42-7W5	1896	1907.5	1954.5	1896.00	1907.50	1954.50	11.50	58.50	47.00
16-07-42-7W5	6134	6170	6322	1869.64	1880.62	1926.95	10.97	57.30	46.33
16-08-42-7W5	6191	6227	6372	1887.02	1897.99	1942.19	10.97	55.17	44.20
06-09-42-7W5	6290	6324	6470	1917.19	1927.56	1972.06	10.36	54.86	44.50
08-09-42-7W5	6203	6239	6385	1890.67	1901.65	1946.15	10.97	55.47	44.50
14-09-42-7W5	1886	1897	1940	1886.00	1897.00	1940.00	11.00	54.00	43.00
15-09-42-7W5	1881.5	1892	1936.5	1881.50	1892.00	1936.50	10.50	55.00	44.50
16-09-42-7W5	6162	6198	6343	1878.18	1889.15	1933.35	10.97	55.17	44.20
06-10-42-7W5	6240	6273	6420	1901.95	1912.01	1956.82	10.06	54.86	44.81
08-10-42-7W5	1897	1907	1954.5	1897.00	1907.00	1954.50	10.00	57.50	47.50
14-10-42-7W5	1874.5	1884.5	1925.5	1874.50	1884.50	1925.50	10.00	51.00	41.00
16-10-42-7W5	6188	6222	6370	1886.10	1896.47	1941.58	10.36	55.47	45.11
06-11-42-7W5	6176	6214	6362	1882.44	1894.03	1939.14	11.58	56.69	45.11
14-11-42-7W5	6284	6319	6468	1915.36	1926.03	1971.45	10.67	56.08	45.42
16-11-42-7W5	6275	6308	6458	1912.62	1922.68	1968.40	10.06	55.78	45.72
06-12-42-7W5	6281	6316	6466	1914.45	1925.12	1970.84	10.67	56.39	45.72
06-13-42-7W5	6243	6277	6428	1902.87	1913.23	1959.25	10.36	56.39	46.02
06-14-42-7W5	6238	6271	6420	1901.34	1911.40	1956.82	10.06	55.47	45.42
14-14-42-7W5	6295	6329	6477	1918.72	1929.08	1974.19	10.36	55.47	45.11
06-15-42-7W5	6203	6238	6387	1890.67	1901.34	1946.76	10.67	56.08	45.42
08-15-42-7W5	1904	1914	1959.5	1904.00	1914.00	1959.50	10.00	55.50	45.50
11-15-42-7W5	1893	1903.5	1948.5	1893.00	1903.50	1948.50	10.50	55.50	45.00
14-15-42-7W5	1881.5	1892	1937	1881.50	1892.00	1937.00	10.50	55.50	45.00
16-15-42-7W5	6170	6202	6350	1880.62	1890.37	1935.48	9.75	54.86	45.11
08-16-42-7W5	6120	6154	6300	1865.38	1875.74	1920.24	10.36	54.86	44.50
14-16-42-7W5	6126	6161	6310	1867.20	1877.87	1923.29	10.67	56.08	45.42
16-16-42-7W5	6126	6161	6310	1867.20	1877.87	1923.29	10.67	56.08	45.42
06-17-42-7W5	6155	6190	6336	1876.04	1886.71	1931.21	10.67	55.17	44.50
08-17-42-7W5	1873.5	1884.5	1929	1873.50	1884.50	1929.00	11.00	55.50	44.50
16-17-42-7W5	6186	6220	6367	1885.49	1895.86	1940.66	10.36	55.17	44.81
16-18-42-7W5	1884.5	1895.5	1940	1884.50	1895.50	1940.00	11.00	55.50	44.50
06-19-42-7W5	6137	6171	6319	1870.56	1880.92	1926.03	10.36	55.47	45.11
16-19-42-7W5	6222	6257	6400	1896.47	1907.13	1950.72	10.67	54.25	43.59
06-20-42-7W5	6263	6298	6440	1908.96	1919.63	1962.91	10.67	53.95	43.28
08-20-42-7W5	6272	6307	6450	1911.71	1922.37	1965.96	10.67	54.25	43.59
14-20-42-7W5	1907	1917	1961	1907.00	1917.00	1961.00	10.00	54.00	44.00
[illegible]	6286	6321	6474	1915.97	[illegible]	[illegible]	10.67	55.78	45.11
12-21-42-7W5	1868.5	1879	1925	1868.50	[illegible]	[illegible]	10.50	56.50	46.00
14-21-42-7W5	6121	6154	6300	1865.68	1875.74	1921.15	10.06	55.47	45.42
16-21-42-7W5	6228	6260	6410	1897.38	1908.05	1953.77	10.67	56.39	45.72
06-22-42-7W5	6169	6203	6350	1880.31	1890.67	1935.48	10.36	55.17	44.81
08-22-42-7W5	6220	6255	6403	1895.86	1906.52	1951.63	10.67	55.78	45.11
14-22-42-7W5	1910.5	1920.5	1967	1910.50	1920.50	1967.00	10.00	56.50	46.50
16-23-42-7W5	6327	6360	6510	1928.47	1938.53	1984.25	10.06	55.78	45.72
16-24-42-7W5	6320	6354	6507	1926.34	1936.70	1983.33	10.36	57.00	46.63
08-24-42-7W5	6203	6238	6392	1890.67	1901.34	1948.28	10.67	57.61	46.94
16-24-42-7W5	6224	6257	6410	1897.08	1907.13	1953.77	10.06	56.69	46.63
16-25-42-7W5	6354	6388	6540	1936.70	1947.06	1993.39	10.36	56.69	46.33
06-26-42-7W5	6393	6428	6579	1948.59	1959.25	2005.28	10.67	56.69	46.02
16-27-42-7W5	6296	6332	6480	1919.02	1929.99	1975.10	10.97	56.08	45.11
08-27-42-7W5	1953.5	1964	2009.5	1953.50	1964.00	2009.50	10.50	56.00	45.50
14-27-42-7W5	6290	6324	6470	1917.19	1927.56	1972.06	10.36	54.86	44.50
16-27-42-7W5	6396	6432	6580	1949.50	1960.47	2005.58	10.97	56.08	45.11
06-28-42-7W5	6222	6258	6405	1896.47	1907.44	1952.24	10.97	55.78	44.81
16-28-42-7W5	1930	1940.5	1985.5	1930.00	1940.50	1985.50	10.50	55.50	45.00
06-29-42-7W5	6309	6344	6495	1922.98	1933.65	1979.68	10.67	56.69	46.02
08-29-42-7W5	6203	6238	6387	1890.67	1901.34	1946.76	10.67	56.08	45.42
16-29-42-7W5	6153	6188	6333	1875.43	1886.10	1930.30	10.67	54.86	44.20
06-30-42-7W5	6246	6280	6420	1903.78	1914.14	1956.82	10.36	53.04	42.67
16-30-42-7W5	6204	6239	6383	1890.98	1901.65	1945.54	10.67	54.56	43.89
06-31-42-7W5	6125	6162	6305	1866.90	1878.18	1921.76	11.28	54.86	43.59
16-31-42-7W5	1892	1902	1947	1892.00	1902.00	1947.00	10.00	55.00	45.00
06-32-42-7W5	6146	6182	6330	1873.30	1884.27	1929.38	10.97	56.08	45.11
06-33-42-7W5	1921	1931	1977	1921.00	1931.00	1977.00	10.00	56.00	46.00
08-33-42-7W5	1930	1940.5	1990	1930.00	1940.50	1990.00	10.50	60.00	49.50
01-34-42-7W5	1918	1928	1974	1918.00	1928.00	1974.00	10.00	56.00	46.00
06-34-42-7W5	6232	6267	6415	1899.51	1910.18	1955.29	10.67	55.78	45.11
06-35-42-7W5	1883.5	1893.5	1945	1883.50	1893.50	1945.00	10.00	61.50	51.50
12-35-42-7W5	1881	1891	1937	1881.00	1891.00	1937.00	10.00	56.00	46.00
16-35-42-7W5	6108	6142	6297	1861.72	1872.08	1919.33	10.36	57.61	47.24
06-36-42-7W5	6189	6220	6372	1886.41	1895.86	1942.19	9.45	55.78	46.33
16-36-42-7W5	6154	6186	6337	1875.74	1885.49	1931.52	9.75	55.78	46.02
12-01-42-8W5	1884	1895	1943	1884.00	1895.00	1943.00	11.00	59.00	48.00
10-11-42-8W5	6166	6202	6361	1879.40	1890.37	1938.83	10.97	59.44	48.46
12-01-42-8W5	1879.5	1890	1940	1879.50	1890.00	1940.00	10.50	60.50	50.00
10-02-42-8W5	6113	6150	6313	1863.24	1874.52	1924.20	11.28	60.96	49.68
14-10-42-8W5	6314	6353	6511	1924.51	1936.39	1964.55	11.89	60.05	48.16

WELL NO.	UD-1	UD-2	E5	UD-1 (m)	UD-2 (m)	E5 (m)	UD-1: UD-2	UD-1: E5	UD-2: E5
14-11-42-8W5	1866	1877	1926.5	1866.00	1877.00	1926.50	11.00	60.50	49.5
10-11-42-8W5	6081	6118	6274	1853.49	1864.77	1912.32	11.28	58.83	47.55
16-12-42-8W5	6190.5	6227	6355	1886.86	1897.99	1946.15	11.13	59.28	48.16
08-12-42-8W5	6174	6210	6364	1881.84	1892.81	1939.75	10.97	57.91	46.94
10-12-42-8W5	6175	6212	6368	1882.14	1893.42	1940.97	11.28	58.83	47.55
14-12-42-8W5	1888.5	1899	1947	1888.50	1899.00	1947.00	10.50	58.50	48.00
11-13-42-8W5	6290	6326	6478	1917.19	1928.16	1974.49	10.97	57.30	46.33
10-13-42-8W5	6249	6285	6440	1904.70	1915.67	1962.91	10.97	58.22	47.24
01-14-42-8W5	6163	6200	6359	1878.48	1889.76	1938.22	11.28	59.74	48.46
04-14-42-8W5	6071	6109	6267	1850.44	1862.02	1910.18	11.58	59.74	48.16
11-15-42-8W5	6078	6115	6276	1852.57	1863.85	1912.92	11.28	60.35	49.07
12-16-42-8W5	6460	6497	6661	1969.01	1980.29	2030.27	11.28	61.26	49.98
11-20-42-8W5	1936.5	1947.5	1995	1936.50	1947.50	1995.00	11.00	58.50	47.5
02-21-42-8W5	6344	6380	6543	1933.65	1944.62	1994.30	10.97	60.35	49.38
10-21-42-8W5	6262	6298	6457	1908.66	1919.63	1968.09	10.97	59.44	48.46
12-21-42-8W5	6336	6372	6530	1931.21	1942.19	1990.34	10.97	59.13	48.16
04-22-42-8W5	6232	6267	6431	1899.51	1910.18	1960.17	10.67	60.66	49.99
10-22-42-8W5	6053	6090	6250	1844.95	1856.23	1905.00	11.28	60.05	48.77
12-22-42-8W5	6090	6126	6286	1856.23	1867.20	1915.97	10.97	59.74	48.77
13-22-42-8W5	6200	6234	6389	1889.76	1900.12	1947.37	10.36	57.61	47.24
15-22-42-8W5	1869	1879	1926	1869.00	1879.00	1926.00	10.00	57.00	47.00
04-24-42-8W5	6224	6260	6413	1897.08	1908.05	1954.68	10.97	57.61	46.63
14-25-42-8W5	1860	1871	1914	1860.00	1871.00	1914.00	11.00	54.00	43.00
08-26-42-8W5	6160	6194	6342	1877.57	1887.93	1933.04	10.36	55.47	45.11
14-26-42-8W5	6106	6140	6284	1861.11	1871.47	1915.36	10.36	54.25	43.89
06-27-42-8W5	6184	6220	6370	1884.88	1895.86	1941.58	10.97	56.69	45.72
10-27-42-8W5	5995	6030	6179	1827.28	1837.94	1883.36	10.67	56.08	45.42
12-27-42-8W5	6201	6237	6398	1890.06	1901.04	1950.11	10.97	60.05	49.07
02-28-42-8W5	6229	6262	6422	1898.60	1908.66	1957.43	10.06	58.83	48.77
10-28-42-8W5	6192	6228	6384	1887.32	1898.29	1945.84	10.97	58.52	47.55
12-28-42-8W5	6196	6230	6386	1888.54	1898.90	1946.45	10.36	57.91	47.55
10-29-42-8W5	6184	6220	6383	1884.88	1895.86	1945.54	10.97	60.66	49.68
02-32-42-8W5	1893	1904.5	1952	1893.00	1904.50	1952.00	11.50	59.00	47.50
10-32-42-8W5	6253	6288	6441	1905.91	1916.58	1963.22	10.67	57.30	46.63
14-32-42-8W5	1926	1936	1984	1926.00	1936.00	1984.00	10.00	58.00	48.00
16-32-42-8W5	6337	6373	6525	1931.52	1942.49	1988.82	10.97	57.30	46.33
02-33-42-8W5	6154	6190	6342	1875.74	1886.71	1933.04	10.97	57.30	46.33
04-33-42-8W5	6047	6083	6236	1843.13	1854.10	1900.73	10.97	57.61	46.63
12-33-42-8W5	6284	6320	6476	1915.36	1926.34	1973.88	10.97	58.52	47.55
15-33-42-8W5	6258	6294	6443	1907.44	1918.41	1963.83	10.97	56.39	45.42
12-34-42-8W5	6026	6061	6209	1836.72	1847.39	1892.50	10.67	55.78	45.11
11-34-42-8W5	1821	1832	1876	1821.00	1832.00	1876.00	11.00	55.00	44.00
14-34-42-8W5	5933	5968	6106	1808.38	1819.05	1861.11	10.67	52.73	42.06
16-34-42-8W5	1804.5	1815	1856.5	1804.50	1815.00	1856.50	10.50	52.00	41.50
07-35-42-8W5	1852	1862.5	1904	1852.00	1862.50	1904.00	10.50	52.00	41.50
10-35-42-8W5	6060	6096	6234	1847.09	1858.06	1900.12	10.97	53.04	42.06
11-36-42-8W5	6129	6163	6304	1867.81	1878.48	1921.46	10.67	53.64	42.98
04-01-42-9W5	2006	2017	2075	2006.00	2017.00	2075.00	11.00	69.00	58.00
04-02-42-9W5	6754	6789	6939	2058.62	2069.29	2115.96	10.67	57.34	46.67
02-03-42-9W5	2079.5	2089.5	2138	2079.50	2089.50	2138.00	10.00	58.50	48.50
04-03-42-9W5	6840	6876	7030	2084.83	2095.80	2142.74	10.97	57.91	46.94
10-03-42-9W5	6722	6758	6898	2049.17	2059.84	2102.51	10.67	53.34	42.67
12-03-42-9W5	2067	2078	2122	2067.00	2078.00	2122.00	11.00	55.00	44.00
02-04-42-9W5	2106	2116.5	2165	2106.00	2116.50	2165.00	10.50	59.00	48.50
10-04-42-9W5	6844	6879	7030	2086.05	2096.72	2142.74	10.67	56.69	46.02
10-07-42-9W5	7055	7089	7243	2150.36	2160.73	2207.67	10.36	57.30	46.94
02-09-42-9W5	2068	2079.5	2121.5	2068.00	2079.50	2121.50	11.50	53.50	42.00
04-09-42-9W5	6842	6880	7027	2085.44	2097.02	2141.83	11.58	56.39	44.81
10-09-42-9W5	6740	6776	6915	2054.35	2065.32	2107.69	10.97	53.34	42.37
04-10-42-9W5	6707	6743	6884	2044.29	2055.27	2098.24	10.97	53.95	42.98
04-16-42-9W5	6746	6783	6928	2056.19	2067.46	2111.66	11.28	55.47	44.20
02-17-42-9W5	6859	6894	7046	2090.62	2101.29	2147.62	10.67	57.00	46.33
10-17-42-9W5	6689	6725	6882	2038.81	2049.78	2097.73	10.97	58.92	47.95
10-18-42-9W5	6935	6970	7135	2113.79	2124.46	2174.75	10.67	60.96	50.29
06-22-42-9W5	6555	6590	6780	1997.96	2008.63	2066.54	10.67	68.58	57.91
11-22-42-9W5	1997	2007.5	2064	1997.00	2007.50	2064.00	10.50	67.00	56.50
06-25-42-9W5	1949.5	1960	2010	1949.50	1960.00	2010.00	10.50	60.50	50.00
10-27-42-9W5	1992.5	2002.5	2054.5	1992.50	2002.50	2054.50	10.00	62.00	52.00
12-32-42-9W5	2038	2048	2101	2038.00	2048.00	2101.00	10.00	63.00	53.00
07-06-42-10W5	2341	2352	2402.5	2341.00	2352.00	2402.50	11.00	61.50	50.50
11-12-42-10W5	7185	7220	7380	2189.99	2200.66	2249.42	10.67	59.44	48.77
06-17-42-10W5	7397	7434	7596	2254.61	2265.88	2315.26	11.28	60.66	49.38
03-23-42-10W5	2212	2222.5	2274	2212.00	2222.50	2274.00	10.50	62.00	51.50
07-36-42-10W5	6754	6790	6970	2058.62	2069.59	2124.46	10.97	65.84	54.86

APPENDIX - II

The following is a list of the cores which were examined and measured during the summer of 1986. The well locations are sorted according to township and range. The cored intervals are listed in feet or meters as given for the well; values > 5000 are listed in feet, and values < 5000 are listed in meters. The drafted sections and written descriptions ("field notes") for the cored intervals listed are on file with Dr. R.G. Walker, Department of Geology, McMaster University, Hamilton, Ontario, L8S 4M1.

10-20-37-7W5	2287-2306	06-09-40-7W5	6680-6790
12-30-37-7W5	7060-7110	04-23-40-7W5	6528-6614
07-34-37-7W5	7257-7317	11-26-40-7W5	6460-6533
10-31-37-8W5	8036-8101	04-30-40-7W5	6561-6604
10-31-37-8W5	2438-2448	12-01-40-8W5	6897-6957
07-01-37-10W5	9620-9680	06-07-40-8W5	7258-7290
11-28-37-10W5	9755-9812	09-07-40-8W5	2196-2214
06-10-38-6W5	6714-6774	07-08-40-8W5	7236-7275
09-18-38-6W5	6768-6810	09-09-40-8W5	2155-2173
07-24-38-6W5	6440-6530	10-12-40-8W5	6770-6830
02-31-38-6W5	2067-2085	10-15-40-8W5	7025-7085
10-05-38-7W5	2252-2270	10-16-40-8W5	2157-2176
03-07-38-7W5	2286-2301	04-22-40-8W5	7078-7118
04-10-38-7W5	2188-2193	10-22-40-8W5	6873-6933
13-16-38-7W5	2181-2192	04-23-40-8W5	6863-6907
02-22-38-7W5	2110-2128	04-24-40-8W5	6771-6813
10-24-38-7W5	6819-6870	04-26-40-8W5	6814-6858
04-26-38-7W5	6875-6906	10-26-40-8W5	6718-6794
04-30-38-7W5	2242-2260	06-29-40-8W5	2150-2169
10-30-38-7W5	2224-2242	10-32-40-8W5	6915-6945
07-32-38-7W5	7129-7179	04-36-40-8W5	2027-2045
02-33-38-7W5	2123-2141	08-01-40-9W5	2293-2302
13-35-38-7W5	2082-2102	04-02-40-9W5	7548-7600
13-03-38-8W5	2451-2469	11-13-40-9W5	7464-7524
16-13-38-8W5	2448-2466	10-17-40-9W5	6096-6103
16-15-38-8W5	2275-2293	10-21-40-9W5	2284-2292
11-27-38-8W5	2262-2286	10-27-40-9W5	7371-7460
09-24-38-10W5	2752-2771	16-28-40-9W5	2234-2272
04-07-39-6W5	6729-6766	11-30-40-9W5	7530-7591
10-08-39-6W5	6637-6735	11-33-40-9W5	7423-7480
12-26-39-6W5	6236-6338	10-34-40-9W5	7390-7450
06-36-39-6W5	6140-6190	06-07-40-10W5	9164-9241
04-02-39-7W5	2074-2089	06-21-40-10W5	8293-8364
11-02-39-7W5	2078-2087	01-19-41-6W5	6340-6397
04-03-39-7W5	2108-2123	10-20-41-6W5	6318-6398
04-06-39-7W5	2195-2210	06-22-41-6W5	6298-6318
10-16-39-7W5	6751-6793	06-24-41-6W5	6225-6250
10-18-39-7W5	6905-6955	06-27-41-6W5	6207-6228
06-24-39-7W5	6689-6749	16-12-41-7W5	6637-6687
07-26-39-7W5	6717-6750	06-21-41-7W5	6557-6574
05-28-39-7W5	6740-6771	16-26-41-7W5	6564-6609
10-30-39-7W5	6916-6968	11-02-41-8W5	6573-6613
11-34-39-7W5	6670-6730	10-08-41-8W5	6819-6904
11-04-39-8W5	2251-2269	16-09-41-8W5	6767-6827
04-11-39-8W5	2201-2219	10-10-41-8W5	6675-6735
14-22-39-8W5	7246-7289	04-19-41-8W5	6920-6980
10-30-39-8W5	2256-2278	10-19-41-8W5	6830-6905
04-36-39-8W5	2117-2135	04-20-41-8W5	6818-6877
08-09-39-9W5	8175-8230	10-20-41-8W5	6782-6854
10-12-39-9W5	2325-2348	04-28-41-8W5	6795-6913
06-31-39-9W5	2414-2440	10-31-41-8W5	6618-6682
08-23-40-6W5	1887-1896	02-36-41-8W5	6292-6352

12-27-40-6W5	6290-6410	10-08-41-9W5	7496-7562
10-07-40-7W5	6733-6763	08-10-41-9W5	2155-2173
04-13-41-9W5	7063-7110	06-19-42-7W5	6300-6350
10-13-41-9W5	7100-7136	06-22-42-7W5	6322-6375
10-22-41-9W5	7140-7193	06-31-42-7W5	6305-6325
12-26-41-9W5	2160-2175	06-32-42-7W5	6288-6329
10-33-41-9W5	7172-7218	06-35-42-7W5	1943-1957
09-11-41-10W5	7570-7629	04-10-42-8W5	6505-6550
10-15-41-10W5	7510-7570	04-11-42-8W5	6313-6348
07-23-41-10W5	2280-2297	10-11-42-8W5	6269-6329
11-29-41-10W5	2378-2396	01-14-42-8W5	6341-6401
02-01-42-6W5	6037-6180	10-20-42-8W5	1983-2001
06-05-42-6W5	6478-6523	06-27-42-8W5	6367-6442
08-11-42-6W5	6098-6131	04-02-42-9W5	6918-6976
16-15-42-6W5	6366-6431	10-07-42-9W5	7190-7291
14-19-42-6W5	6325-6340	10-10-42-9W5	6753-6802
08-22-42-6W5	6355-6383	06-15-42-9W5	2027-2038
14-34-42-6W5	6095-6126	10-17-42-9W5	6869-6943
16-01-42-7W5	6438-6468	06-17-42-10W5	7436-7496
06-02-42-7W5	6502-6535	07-36-42-10W5	6934-6994