THE PETROGRAPHY AND DEPOSITIONAL ENVIRONMENT OF THE CARDIUM FORMATION IN THE ROCKY MOUNTAIN HOUSE AREA OF CENTRAL ALBERTA

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ABSTRACT

The Cardium Sandstone in the Rocky Mountain House area of the Garrington and Ferrier fields of Alberta is part of a progradational sequence consisting of marine shale at the base through sandstone to conglomerate, followed by an overlying marine shale. The Upper Cretaceous sandstone was deposited as an offshore shoal complex near the seaward migrating edge of the Turonian seaway.

Structure is not significant in terms of the deposition of the sandstone. A structure contour map, an isopach map, structural cross-sections, core description, thin sections and X-ray analyses were used to determine the petrography and environment.

ACKNOWLEDGEMENTS

The writer is indebted to Chevron Standard Limited in Calgary with whom she was employed during the summer of 1979. Messrs. R. Venour, Plains Division Geologist, and D. Organ, Chief Geologist, were particularly helpful in suggesting the topic as a thesis project and in supervising the work on the area for Chevron Standard Limited. The Company also generously allowed use of well logs and had thin sections cut.

The writer extends thanks to the Energy Conservation Board, Calgary, for facilities for the examination of cores and for permission to collect samples.

The writer expresses her sincere gratitude to Dr. H.B.S. Cooke under whose supervision the thesis was written. Thanks are also due to M. Douma for microscopy assistance and for his encouragement. The help of S. Harnish, who drafted several maps, and J. Horne, who assisted in typing the manuscript, is also much appreciated.

CHAPTER 1

INTRODUCTION

1.1 GENERAL STATEMENT

The object of this thesis is a subsurface study of the petrography and depositional environment of the Cardium Formation of the Upper Colorado Group (Upper Cretaceous) in the Rocky Mountain House area of the Garrington and Ferrier fields which lie in the central plains of Alberta. Rocky Mountain House is located approximately 130 miles* northwest of Calgary and 130 miles southwest of Edmonton (Figure 1). The study covers an area lying within the areas designated as Townships 37 to 40 and Ranges 6 to 9, west of the fifth meridian, an area of 576 square miles (see Appendix A for explanation).

Oil was discovered in the Cardium sandstone of the Garrington field in 1954 (Tyrrell, 1977). There is now abundant well control in the area. A total of thirty-seven wells were selected for study, twenty of which had been cored in the Cardium sandstone. Ten of these cores were examined and sixty thin sections were cut from samples of the cores. Well logs from many other wells were also examined. X-ray analyses of some samples were done to aid in the determination of the mineralogy.

Stratigraphic studies were based mainly on electric log correlations of the sandstone body and on various marker

*As all the records are in English measures, miles and feet are given in this paper and are not converted to metric units.

horizons above and below the body. Whenever necessary, other logs were employed for more accurate identification, especially of the Cardium sandstone. A structure contour map (Figure 2), an isopach map (Figure 3), and structural cross-sections (Figures 4A, B, C, D, E) were used for determination of structural elements and geometry. These factors, together with lithology and sedimentary structures were used as a basis for interpreting the environment of deposition of the Cardium sediments.

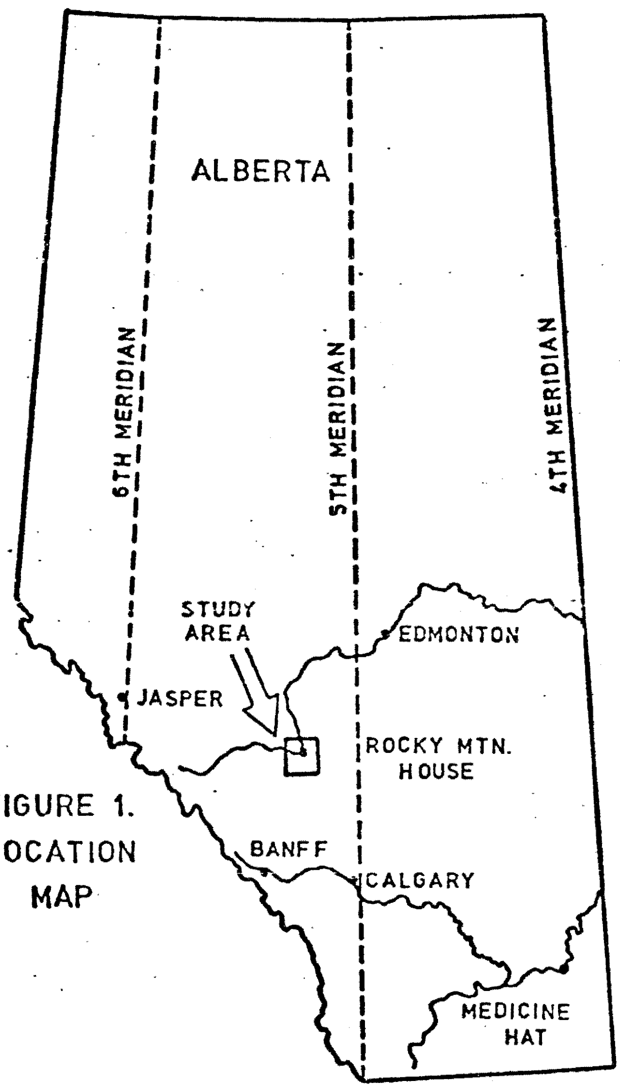

FIGURE 1. LOCATION MAP

CHAPTER 2

STRATIGRAPHY

2.1 GENERAL STATEMENT

The Cardium Formation of the central Alberta plains is of early Upper Cretaceous age (Upper Turonian). It occurs within a wide succession of dark marine shales, commonly assigned in the subsurface to the Colorado Group.

2.2 UPPER COLORADO GROUP

Upper Cretaceous rocks in the Plains and Foothills of the western Canada sedimentary basin record essentially uninterrupted deposition throughout the epoch and constitute a standard of reference for western Canada. The boundary between the Lower and Upper Cretaceous is placed on palaeontologic evidence at the top of a sandstone or sandy shale characterized by abundant fish scales and other remains near the base of the marine Colorado Group. (Table 1 shows the regional stratigraphy).

The Upper Colorado Group comprises all strata between the base of the Fish Scales marker and the First (Upper) White Specks marker in the central and southern Alberta plains (Williams and Burk, 1964). Over most of that area, the interval consists of an undivided, relatively uniform, dark grey shale, occasionally bentonitic and concretionary. The Upper Colorado Group has been divided into three formations, the Blackstone, Cardium and Wapiabi.

The Blackstone Formation lies between the Cardium Formation and the Fish Scales marker. Its total thickness averages about 1700 feet (Stott, 1961). It consists mainly of dark grey marine shales and siltstones with minor beds of argillaceous limestone, sandstone, bentonite and some ironstone concretions (Stott, 1961).

The Wapiabi Formation overlies the Cardium Formation with possibly some slight disconformity. Its total thickness averages about 2100 feet (Stott, 1961). The marine shales vary from "fissile to rubbly and platy. They are dark grey, weather rusty, and contain abundant dark organic material. Glauconite occurs in the concretionary shales" (Stott, 1961).

Table 1. Table of Formations

Upper Colorado Group

	First White Specks Marker
WAPIABI	
CARDIUM	
	Second White Specks Marker
BLACKSTONE	
	Fish Scales Marker

2.3 THE CARDIUM FORMATION

The name Cardium Formation is applied to the sandstone member within the general shale sequence. In the Pembina area, where it has been extensively described (Williams and Burk, 1964), the Cardium Formation is composed of well-sorted, very fine- to fine-grained quartz sandstones, pebble conglomerates of varicoloured chert and quartz, dark grey to black micromicaceous and partly carbonaceous shales, complexly interlaminated and mottled siltstones and silty sandstones. The formation, which can be 300 to 400 feet thick in western Alberta thins eastward to its line of disappearance in central Alberta. As the individual sand lenses pass into shale to the southeast and thicken to the northwest, a source to the northwest is indicated (Williams and Burk, 1964, Figure 12-9).

Generally, the sandstone has a sharp and, in places, erosional contact with the overlying Wapiabi Formation, a marine shale unit. The lower contact with the Blackstone shale is also quite sharp (Stott, 1961).

In some areas, an informal subdivision of the Cardium has developed as several distinct sandstone bodies can sometimes be seen. The Cardium "A" sandstone occurs near the middle of the formation and the Cardium "B" occurs near the base (Sinha, 1968). There may be more than two bodies in some locations but in this study area, only one sandstone body was developed and it could be called the Cardium "A" sandstone.

No type section of the Cardium Formation was specifically designated by Cairnes (1907) or other early workers who studied the formation in the vicinity of the Bow River. Due to the poor exposure of the few outcrops of the Cardium, resulting from the construction of power dams, the sections on the Bow River are not suitable for a type section. Stott (1961) refers to a section described by G.S. Malloch in 1911, in the Bighorn Coal Basin area, which has been designated as the type section. "In the type section, marine and nonmarine shales separate the basal and middle sandstone members, and marine shale is present below the upper sandstone" (Stott, 1961).

Numerous papers have been published on the Cardium sandstone in the subsurface of the Central Alberta plains. Cairnes (1907) introduced the name Cardium for a sandstone series observed by a Dr. Hector in 1858. Cairnes states: "Specimens of Cardium pauperculum are so plentiful in this sandstone series that Dr. Hector, in 1858, called the whole shale series along the Bow River, including the Claggett and Niobrara-Benton, the Cardium shales. Farther south this sandstone series, which for convenience, I shall call the Cardium sandstones, is not so prominent...". Cairnes described the Cardium as consisting of three sandstone members separated by dark shales as follows:

	Feet
Upper sandstone bed	70
Dark shales with a few calcareous sandstone layers	60
Middle sandstone bed with 18 inches of conglomerate at top	30
Dark shales	20
Lower sandstone bed, conglomerate at top, considerable amounts of intercalated dark shales	40

In 1955, Beach published a short paper suggesting that because of the regional distribution of conglomerate at the top of the Cardium, then perhaps the Cardium is a turbidity current deposit. This idea was disputed by DeWiel (1956) in the following year and more or less discarded because of lack of supporting evidence. DeWiel, as well as several other authors of the time (Nielsen, 1957; Michaelis, 1957; Roessingh, 1957; MacDonald, 1957; Mountjoy, 1957), regarded the Cardium as a normal offshore sand body representing lagoonal, swampy, and shallow-marine environments. Many descriptive papers were published in the late 1950's and early 1960's because of the interest caused by the sizeable hydrocarbon discovery in the Cardium sands of the Pembina Field in 1953.

Berven (1966) described the Cardium Formation of the Crossfield-Garrington area as "long, narrow, en echelon sandstone bodies...(which) have many features similar to those of recent offshore bar deposits.... The bodies are interpreted as offshore bars which formed along the western margin of the Turonian (early Late Cretaceous) seaway. Sinha (1968) calls the Cardium an "offshore bar". Michaelis and Dixon (1969) interpret the Cardium as "a shoal complex in a shallow shelf sea subject to tidal currents". Reports by researchers at Chevron Standard Limited refer to the bodies as barrier beach ridges at successive shoreline stages of the Upper Cardium regressive cycle, and to the siltstone facies as the intervening lagoonal sediments.

CHAPTER 3

STRATIGRAPHIC ANALYSIS

3.1 ELECTRIC WELL-LOGS

An electric log consists of two basic types of recordings; on the left side of the log the spontaneous potential of the beds is shown while the right side is devoted to recordings of their electrical resistivities.

A spontaneous potential curve is a record of naturally occurring potentials measured in a mud-filled bore hole and delineates relatively permeable and nonpermeable strata. The presence of a natural potential implies that conductive fluids are present in the rocks penetrated by the hole. The curve records to the right or positive side of the track opposite shales and to the left or negative side opposite porous and permeable sands or limestones. The curve is thus an indirect method of recording sand and shale lithologies. The thickness of each bed is determined by measuring the vertical distance between the upper and lower inflection points for the deflection (Tizzard and Lerbekmo, 1975; Khamesra, 1963).

Resistivity logs record the changes in the resistivity of the rocks and their contained fluids. The sharp contrast in electrical resistivity between rock types usually permits an electrical resistivity log to be interpreted uniquely in terms of lithology, porosity and water saturation of the beds penetrated (Khamesra, 1963). Thus, the curves are useful in locating boundaries of electrically resistive and nonresistive strata and in determining the character and extent of fluids in the formation.

Electric logs were used in the construction of the cross-sections given in Figure 4. Other logs, such as sonic logs (which record the time required for a sound wave to travel a short distance) and gamma ray logs (which record the naturally occurring gamma radiation emitted by radiative elements in the strata traversed) were also used in helping to verify bed thicknesses.

3.2 MARKER HORIZONS

Electric-log marker horizons associated with distinctive deflections were used as aids in the construction of the cross-sections. Above the Cardium sandstone, a persistent resistivity high in the centre of a "W-shaped" part of the curve could be correlated over the area of study with a reasonable degree of reliability. Below the Cardium sandstone, other resistivity highs persisted over the area and either the upper or lower inflection point of these deflections was used as a marker horizon.

The First and Second White Specks markers which occur respectively above and below the Cardium Formation, are generally used as markers in studies of the Cardium. They require use of much longer sections of logs than was employed in this study, however.

3.3 CARDIUM SANDSTONE

The stratigraphic limits of the Cardium 'A' sandstone shown in the accompanying cross-sections (Figures 4A, B, C, D, E) are based on electric-log characteristics and correspond to those used in previous studies of the sandstone (e.g. Sinha, 1968, Fig. 3). Both the upper and lower boundaries are marked by abrupt changes in the resistivity curves in all wells and in the spontaneous potential curves of some wells. The elevation of the top of the sandstone and its thickness for the structure contour and isopach maps were thus easily determined.

3.4 DISCUSSION OF MAPS

The structurel geology is illustrated by the structure contour map (Figure 2) and the isopach map (Figure 3). The values used in the construction of both maps are presented in Appendix B. The structure contour map, drawn from electric-log data was prepared for the top of the Cardium sandstone. The elevations on which the contours are drawn were obtained by subtracting the well depth to the top of the sandstone from the elevation of the Kelly Bushing (abbr. K.B.) of the well. The Kelly Bushing is a plate on the rotary table of the drilling rig which has a square or hexagonal hole in which the Kelly sits. The Kelly is a steel pipe which transmits torque from the rotary table to the drilling string, thus rotating the string and bit. The elevation of the Kelly Bushing, which is generally 15 to 20 feet above ground level, is the elevation that is surveyed and all other elevations for the well are relative to it.

The structure contour map presented here is similar to maps of other horizons, such as the base of Fish Scales marker and the top of the Upper Colorado shale drawn by Berven (1966) for the Crossfield-Garrington area, slightly south of the study area. The maps all show similar features, none of which appears significant in terms of sedimentation of the Cardium sandstone.

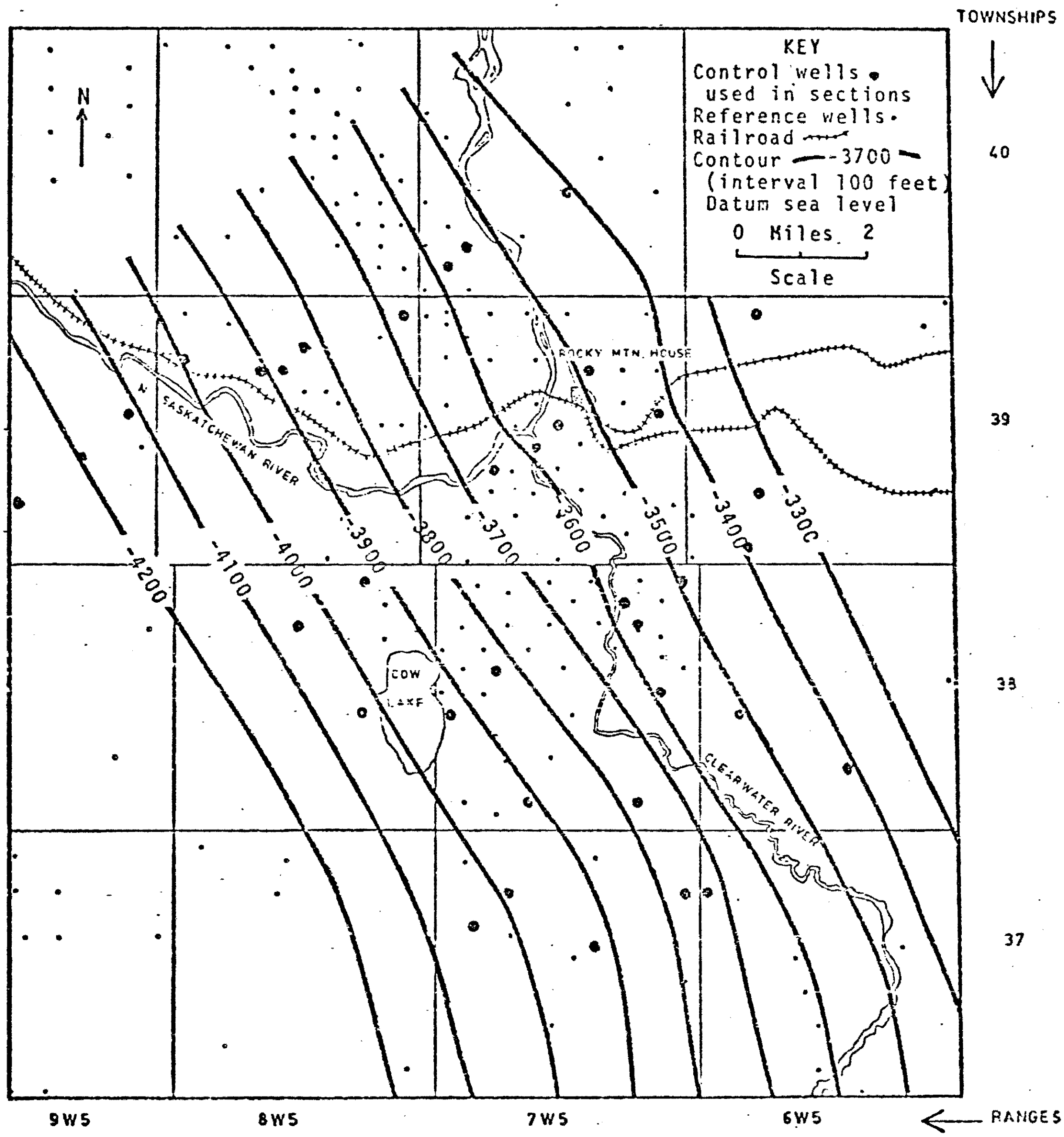

Figure 2. Structure contours for the top of the Cardium Sandstone in feet below sea level.

The contours strike approximately north 20° west. The regional dip is on the average, approximately 60 to 70 feet per mile, sloping towards the northwest. The small structural features which do exist, as in Township 39, Range 7 west 5th meridian, are the result of structures in underlying strata. Berven (1966) explains "highs" and "lows" in his maps by saying that they reflect the presence or absence of the Mississippian Turner Valley Formation, or that "lows" are collapsed dolines or sink holes which subsided earlier, or that Devonian reefs at depth have created "highs" on the relatively flat, westward dipping surfaces.

An isopach map for the Cardium sandstone (Figure 3) was compiled from electric-log data. Thicknesses were determined by measuring the distance between the upper and lower inflection points of the deflection in the trace (Appendix B).

The sandstone body trends approximately north 35° west. The eastern margin, marked by the 10 foot isopach contour, is quite sinuous while the western margin within the study area appears straighter. The east side is also more steeply sloping than the west side. Two ridges are evident within the study area. They are quite straight and near parallel trending at approximately north 35° west. One extends from the central region of Township 40, Range 8 west 5th meridian to Township 37, Range 6 west 5th meridian and the second extends from Township 39, Range 9 west 5th meridian to Township 37, Range 7 west 5th meridian. The maximum gross thickness of the body is approximately 25 feet but the average thickness

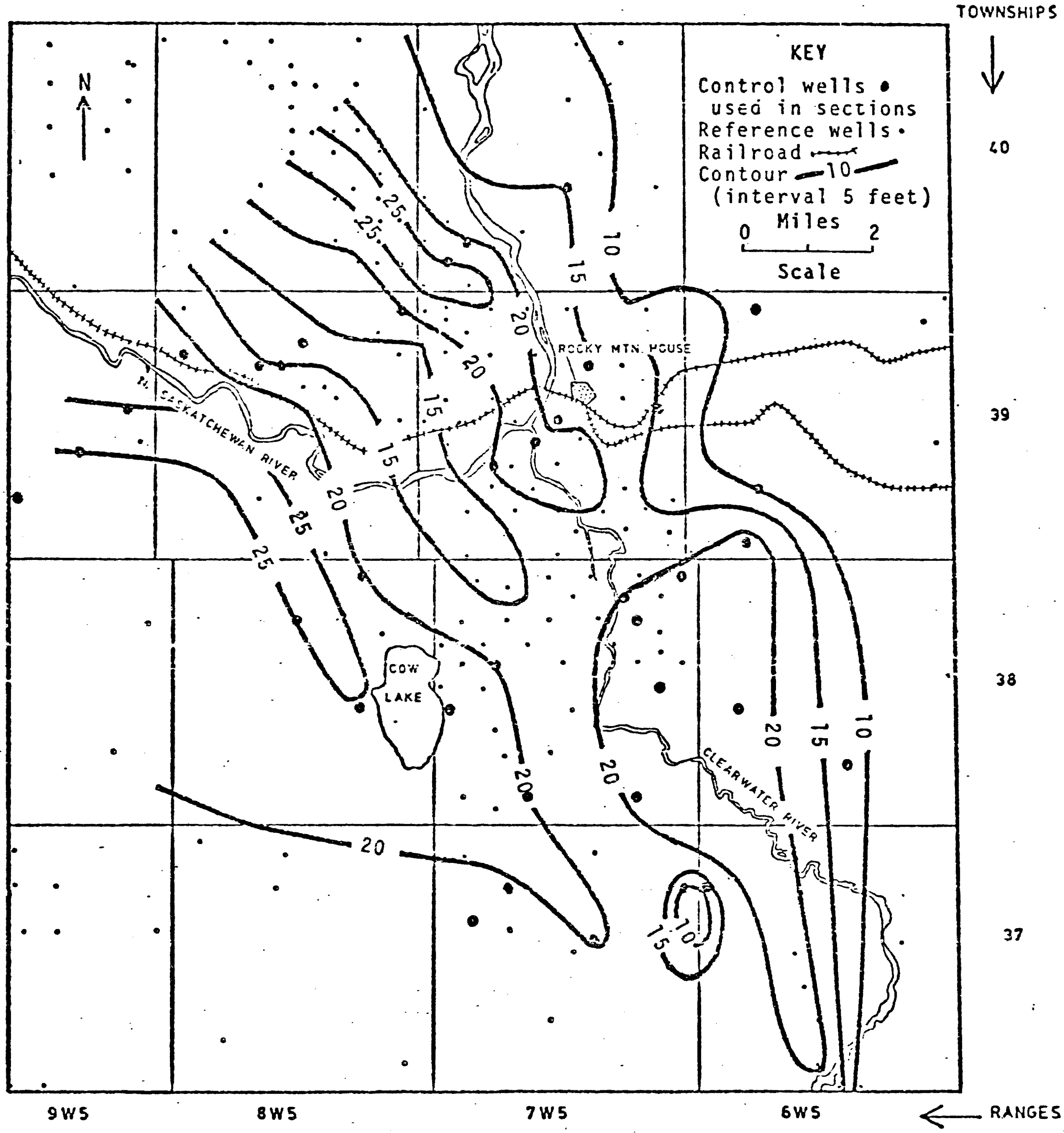

Figure 3. Isopach map of the Cardium Sandstone with thicknesses in feet.

is approximately 18 feet. However, the whole body is not contained within the study area.

3.5 DISCUSSION OF CROSS-SECTIONS

Five structural cross-sections were drawn across the shorter dimension (approximately SW-NE) of the sandstone body (Figures 4A, B, C, D, E) in order to show the structure and geometry of the body.

The sections were based, for convenience, on a datum plane of 3700 feet below sea level so that for a well with a K.B. of 3450 feet, for example, the well depth to -3700 feet would be 7150 feet (Appendix B). The sections are all quite similar. The sandstone body is now dipping at approximately 15° NW. The sand thins at the edges of the body (Figure 4C, well 10-8-39-6 W5). There is also some thinning locally within the body (Figure 4A, wells 8-28-39-8W5 and 14-27-39-8W5). The log markers above and below the sandstone demonstrate almost constant stratigraphic thickness and do not show any evidence of differential compaction.

The exact cross-sectional shape of the Cardium sandstone is difficult to determine due to its limited thickness. Stratigraphic sections based on a datum plane which was considered to represent a reliable time surface were prepared by the author during summer employment. These sections, as well as several prepared by Berven (1966, Figure 11) indicated a flat lower surface and a convex upper surface.

CHAPTER 4

SEDIMENTOLOGY AND SEDIMENTARY PETROGRAPHY

4.1 GENERAL STATEMENT

Of the thirty-seven wells used in the construction of the cross-sections, twenty had been cored in the Cardium sandstone and ten of these were examined and sampled. Sixty samples were taken and thin sections cut from them. Seven X-ray analyses were also done to aid in mineral identification. Descriptions of the samples are given in Appendix C.

Shale, sand and a pebble conglomerate are the main lithotypes of the study area. Sinha (1968) distinguished between arenites and wackes but the present author does not.

4.1.1 Shale

The shale overlying the Cardium sandstone is dark grey, hard and generally quite massive. Some planar laminations were visible where silty material was present. The underlying shale is dark grey and hard as well but not as massive as the overlying shale. Shales and siltstones are interlaminated with both sharp and gradational contacts. In some places the siltstone is similar to the fine-grained sandstone while, in others, it grades into mudstone. Generally, shales and silts are irregularly intermixed with one another and lenticular laminations of silt and sand are common in the shale resulting in a mottled appearance (Plate I, Figure 1*). Little trace of primary lamination remains as bioturbation has been so extensive.

*For Plates, see pages 21 to 24.

Shaly zones within the sandstone occur occasionally. In well 11-18-38-7W5, for example, a shaly zone was present near the middle of the sand layer and it showed some unusual structures possibly from the ripping up of layers caused by storms (Plate I, Figure 2).

The shales consist dominantly of clay minerals (approximately 70 percent), carbonaceous and bituminous matter, sand and silt and appreciable quantities of authigenic pyrite and secondary carbonates. X-ray diffraction patterns indicated that the shale was dominantly composed of illite with some chlorite. Other clay minerals may have been present but were difficult to identify with certainty.

Pyrite occurs mainly as single, euhedral crystals dispersed throughout the shale. Carbonate, generally siderite (as indicated by X-ray analysis) occurs in various patches.

4.1.2 Sand

The fine-grained Cardium sandstone is generally 15 to 20 feet thick and is light grey to brownish grey in colour. The sand is occasionally quite massive toward the bottom of the zone. The most common form of stratification is a thin, regular plane lamination marked by colour banding and sometimes by thin shale layers near the top and bottom of the sand zone. (Plate I, Figure 3 and Plate II, Figure 1). Another common feature of the sandstones is low-angle crossbedding observed in, for examples, wells 11-18-38-7W5 and 10-36-38-7W5 (Plate II, Figures 2 and 3). Simple ripple forms occur in the Cardium sand but are not very common. In well 10-36-38-7W5, ripples were observed near the top of the sand body (Plate II, Figure 4). As stated, some shale layers were observed within the sand body and can be seen in thin section (Plate III, Figure 1). Silty layers also existed and sometimes small silt lenses were observed (Plate II, Figure 3). Occasionally there was a silt matrix for the sand (Plate III, Figure 2).

The sands are dominantly fine- to very fine-grained (3 to 4 phi). Grain size was determined with a binocular microscope using a transparent guide produced by the Canadian Stratigraphic Service. The finest sand occurs towards the base of the unit. The sands commonly contain subangular grains (Plate III, Figure 3). Roundness was classified using Pettijohn's (1957) scheme with divisions from angular to rounded grains. Sorting was quite variable from poor to good. The relatively more coarsely-grained, cleaner sand was better sorted. For example, in well 10-26-38-7W5, the fine-grained, massive sand was quite sucrosic and well sorted, while in well 6-5-39-6W5, the whole sand zone was interrupted by thin shale layers and the very fine sand was shaly and poorly sorted. There were thus three different types of sand observed, a coarse, "clean" sand (Plate III, Figure 3), a finer, shaly sand (Plate III, Figure 4) and rarely, a silt matrix sand (Plate III, Figure 2).

The sand was generally comprised of 60 to 80 percent quartz. The percentage of quartz is low in the relatively coarser grained material in which chert is more abundant as in well 10-16-39-7W5, for example. The sub-angular quartz grains commonly show undulose extinction.

Feldspar was identified only when twinned and such grains were rare. Measurement of the extinction angle was difficult due to the fine grain size but they seemed to be in the albite to oligoclase composition range. Plagioclase grains were definitely present in only three wells (11-18-38-7W5, 9-18-36-6W5 and 10-26-38-7W5).

Other components include mica (muscovite), apatite, chlorite and zircon or rutile. Siderite and pyrite were common. The pyrite occurs as individual euhedral crystals. Identification of these components, except for pyrite, was made from the X-ray analyses.

Cementation is generally siliceous but some cementing by secondary carbonate was also observed (Plate IV, Figure 1). Some tiny veins of carbonate were also present (Plate IV, Figure 2).

No fossils were observed in this area although a variety of species was identified in the Edson area farther north (Sinha, 1968).

4.1.3 Conglomerate

Conglomerate occurs at the top of the sandstone and is commonly less than a foot thick although a thickness of 8 feet was observed in one well (10-16-39-7W5). The conglomerate consists of chert, quartz and rock fragments in a silty or shaly to sandy matrix. In some wells, such as 6-14-39-9W5, the conglomerate has a sandy matrix (Plate IV, Figure 3) while in well 11-18-38-7W5, the conglomerate has a silty matrix. Well 11-18-38-7W5 actually has conglomerate with both types of matrix - the shaly matrix conglomerate at the base of the shale and the silty matrix conglomerate directly overlying the sandstone.

The pebbles average 3 to 5 millimetres in size and reach a maximum of greater than 10 millimetres. Sorting is good and rounding is sometimes excellent (Plate IV, Figure 3).

PLATES I - IV

PLATE I

CORE PHOTOGRAPHS

Figure 1. Shale containing lenticular laminations of silt resulting in a mottled appearance.

Home Pembina Ferrier 11-18-38-7W5 at 7392.0 feet.

Figure 2. Shaley zone in a sand unit showing rip-up structures (?). Note the sharp contact with the underlying sand.

Home Pembina Ferrier 11-18-38-7W5 at 7409.0 feet.

Figure 3. Planar laminations in sand with thin shale layers.

Southern Production Atlantic Ferrier 14-27-39-8W5 at 7194.5 feet.

PLATE I

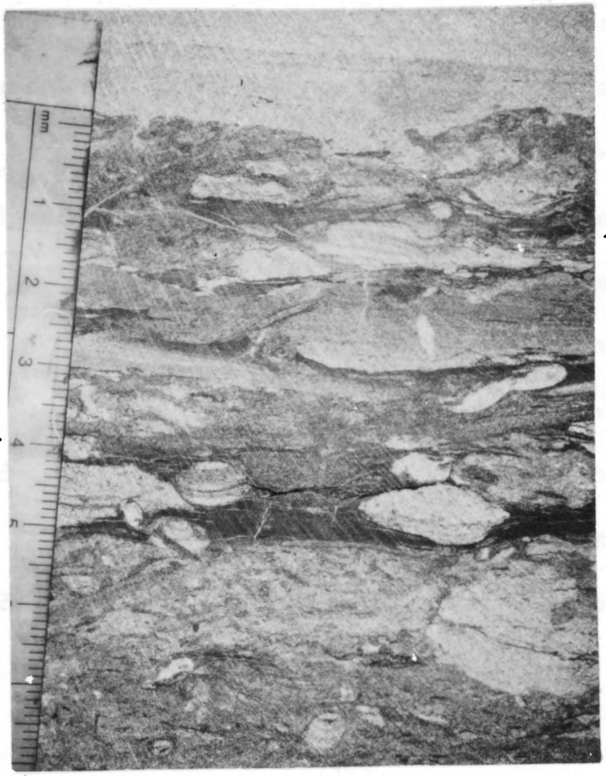

Figure 1.

Figure 2.

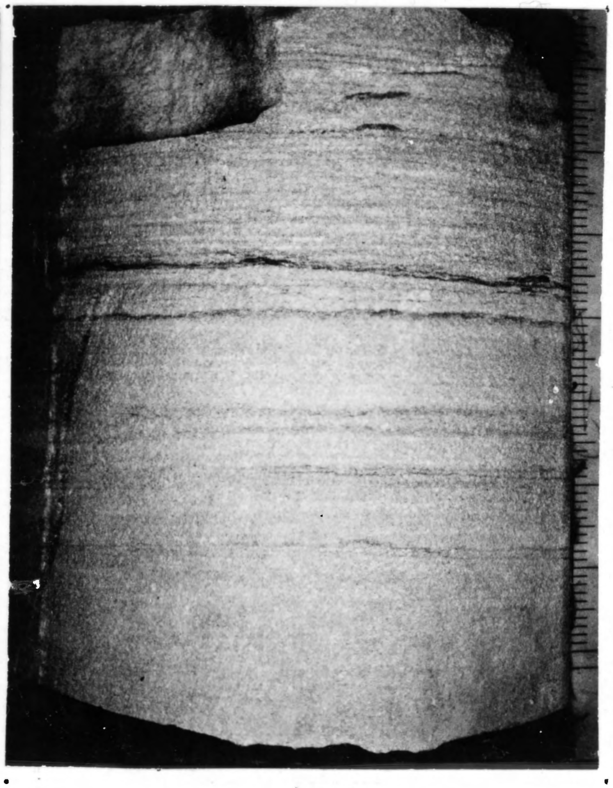

Figure 3.

PLATE II

CORE PHOTOGRAPHS

Figure 1. Planar lamination marked by colour banding in sand.
Husky et al Ferrier 06-14-39-9W5 at 7730.0 feet.

Figure 2. Low-angle cross-stratification in sand.
Sinclair Pacific Cow Lake 11-18-38-7W5 at 7400.5 feet.

Figure 3. Low-angle cross-stratification in sand. Note silt lens.
Cox SE Ferrier 10-36-38-7W5 at 6858.0 feet.

Figure 4. Simple ripple in sand.
Cox SE Ferrier 10-36-38-7W5 at 6852.3 feet.

PLATE II

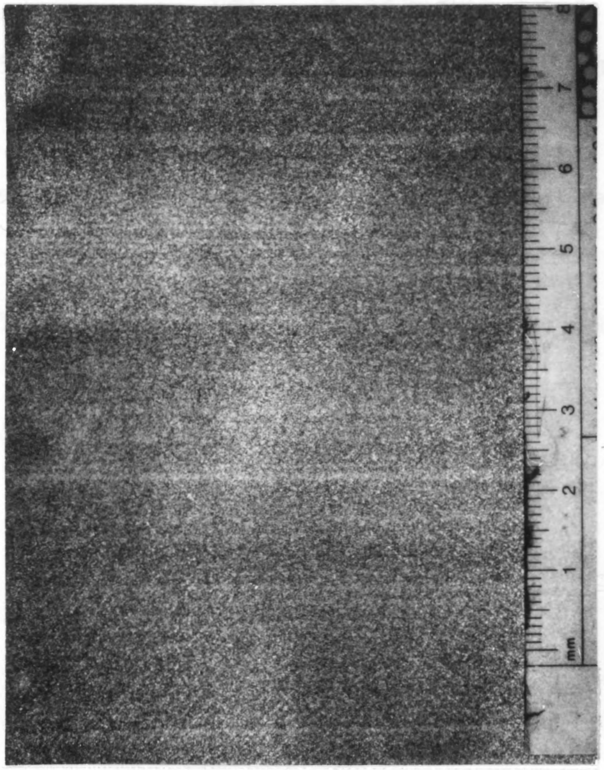

Figure 1.

Figure 2.

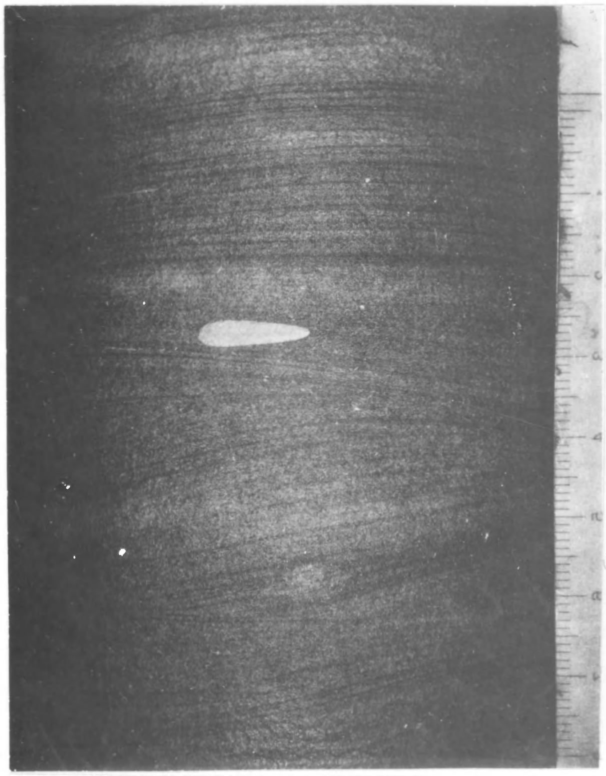

Figure 3.

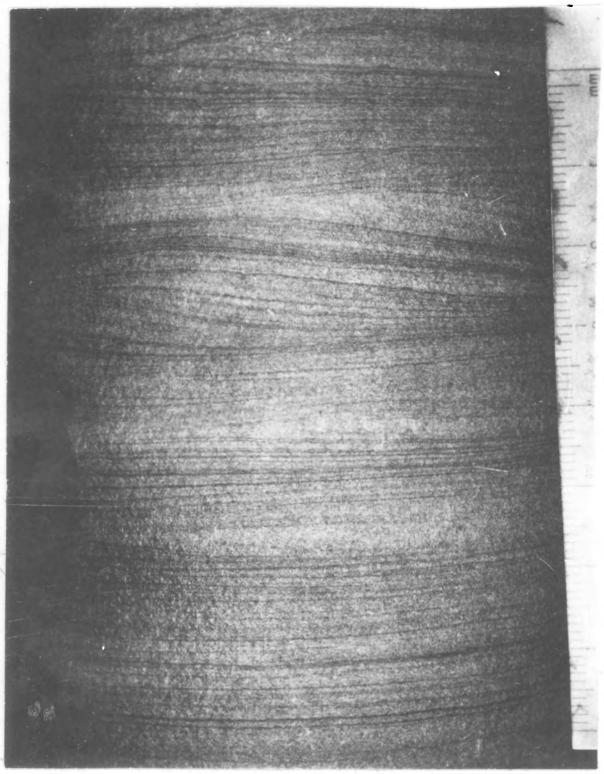

Figure 4.

PLATE III

PHOTOMICROGRAPHS

Figure 1. Interlaminated sand and shale. 25X

Seafort et al Ferrier 06-05-39-6W5 at 6741.8 feet.

Figure 2. Sand in a silt matrix. 100X

Home Pembina Ferrier 11-18-38-7W5 at 7403.5 feet.

Figure 3. "Clean" sand. 100X

Seafort et al Ferrier 08-27-39-7W5 at 6745.8 feet.

Figure 4. "Dirty" sand. 100X

Cox SE Ferrier 10-36-38-7W5 at 6852 feet.

PLATE III

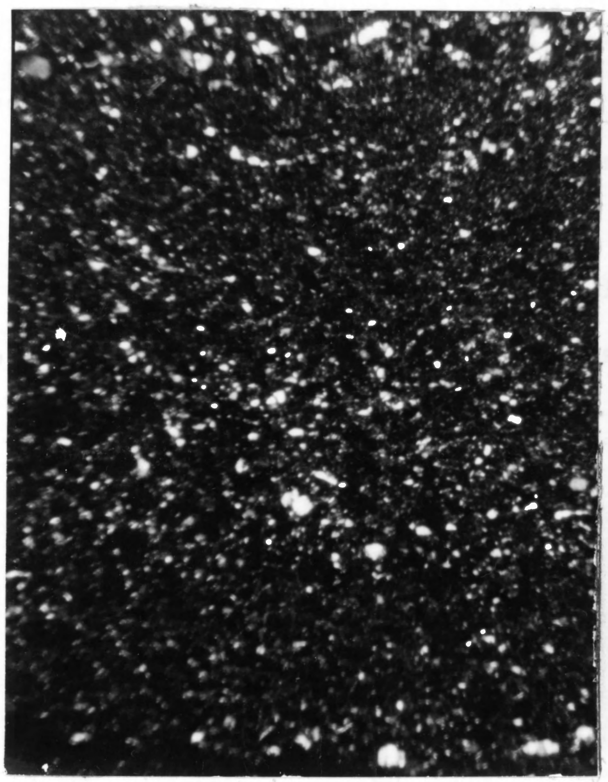

Figure 1.

Figure 2.

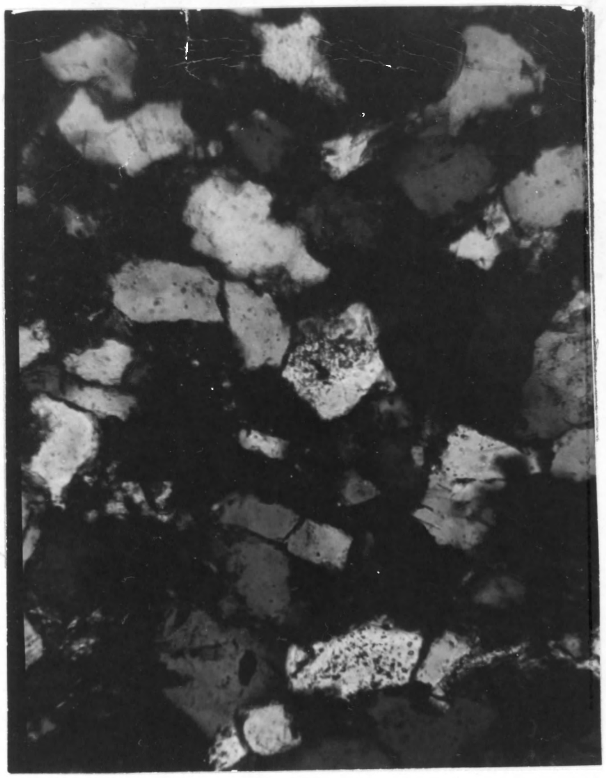

Figure 3.

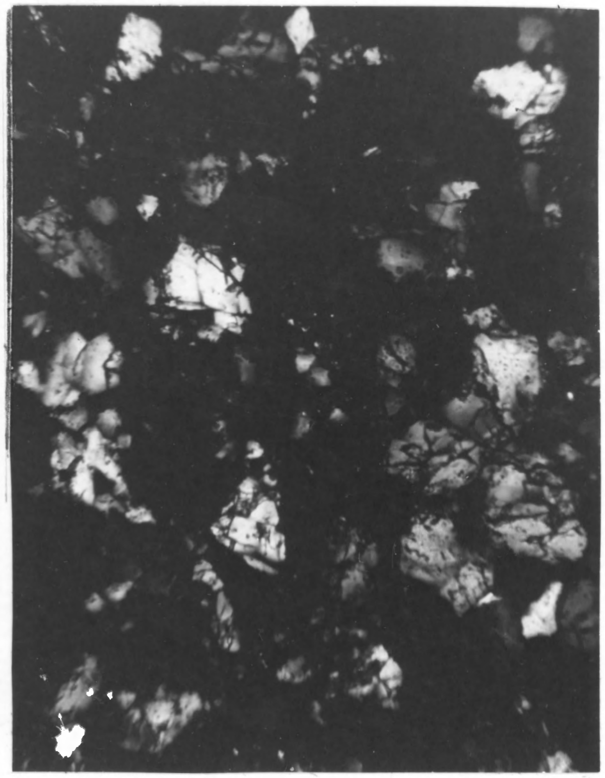

Figure 4.

PLATE IV

PHOTOMICROGRAPHS

Figure 1. Sand with some carbonate cement marked "C". 100X

Amerada CR GM Ferrier 10-06-40-7W5 at 6793 feet.

Figure 2. Sand with a carbonate vein. 25X.

Seafort et al Ferrier 08-27-39-7W5 at 6743.5 feet.

Figure 3. Conglomerate in a sandy matrix. 25X

Husky et al Ferrier 06-14-39-9W5 at 7721.5 feet.

PLATE IV

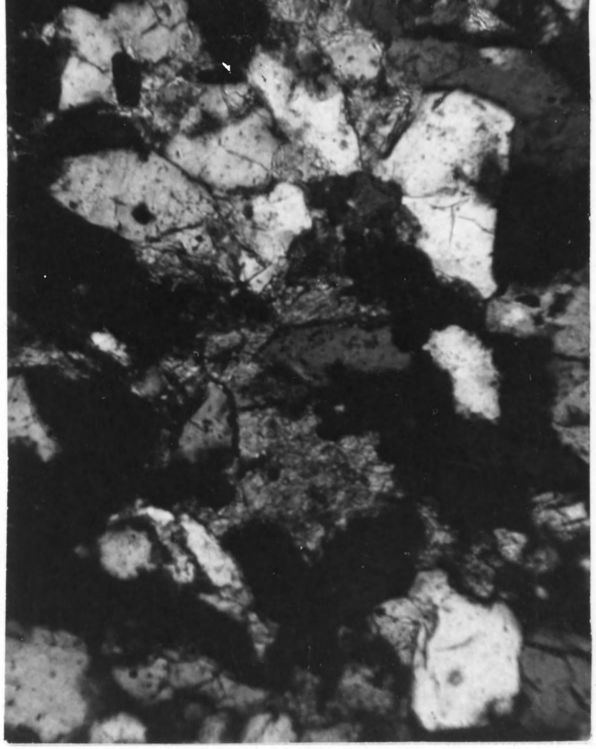

Figure 1.

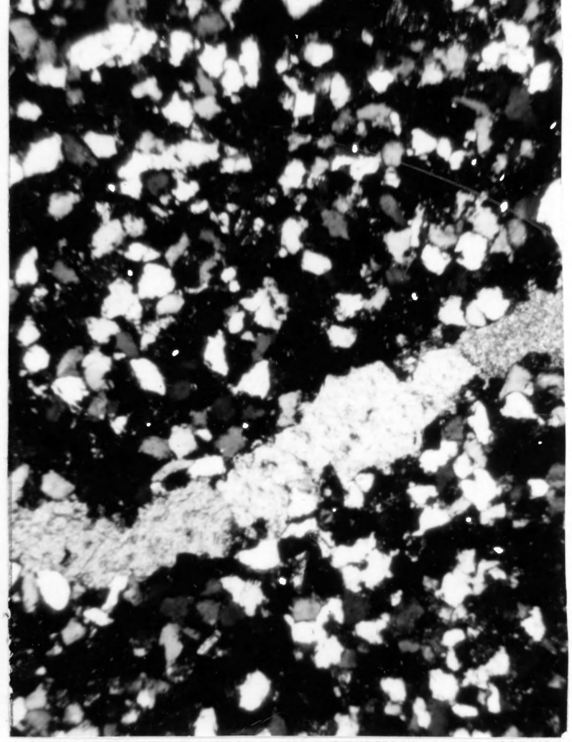

Figure 2.

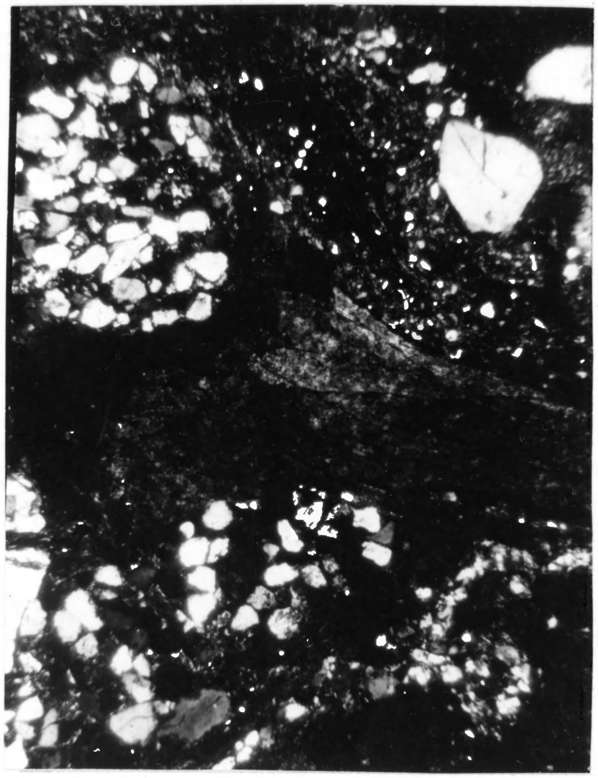

Figure 3.

CHAPTER 5

SEDIMENTARY ENVIRONMENT

5.1 MODELS OF DEPOSITION

The controversy over the depositional environment of the Cardium sandstone was discussed briefly in Chapter 2. Recently, several papers have been published in which comparisons between recent and ancient offshore beach and barrier environments have been made. Before discussing these environments, it is necessary to define the various terms.

The term "bar" is generally restricted to constructional features that are submerged at high tide while "barrier islands", "barrier beaches" and "spits" are emergent features (Davies *et al*, 1971). Pettijohn *et al* (1972) on the other hand, write that "barrier-island complex includes sand bodies that formed as submerged or offshore bars, as beaches and spits, and as dunes". Selley (1978) states that a "barrier may be no more than an offshore bar exposed only at low tide, or it can form an island with eolian dunes on the crest". Some authors group shoreface, beach, dune and washover environments together as a bar or barrier (e.g. Sabins, 1963). "Offshore shoal" is another term used and, according to Blatt *et al* (1972), it is employed when there is evidence of deposition tens of miles from the shore or where there is lack of evidence of a restricted lagoon or of emergence of the bar above sea level. Determining whether an ancient feature was ever emergent may be difficult as penecontemporaneous erosion may have resulted in the destruction of emerged parts (Davies *et al*, 1971).

The Galveston Island complex of Texas has served as the basis for many barrier models. This complex has been subdivided into four distinct units (Davies _et al_, 1971). The lower shoreface sediments are deposited seaward of the break in the offshore slope and consist of interbedded, burrowed and bioturbated, very fine-grained sand, silt and silty clay. The middle shoreface sediments were deposited shoreward of lower shoreface sediments and consist of extensively bioturbated very fine-grained structureless sand. Beach and upper shoreface sediments are farther shoreward and consist of fine- to very fine-grained, well laminated sediments with planar lamination, and low-angle cross-lamination. Burrowing is scarce. Finally, the eolian sediments are generally cross-laminated and parallel-laminated. With increasing age, bioturbation and weathering destroy the structures. Landward from the barrier island are lagoonal sediments of interbedded, burrowed and churned clay and silt with fine-grained sand. Bioturbation obscures structures here as well. The Cretaceous Muddy Sandstone of Montana was described by Davies _et al_ (1971) and the four subenvironments were all observed. These authors noted that if units are absent, they are generally the eolian or beach-upper shoreface units.

Davies _et al_ (1971) list eleven characteristics of a model for dominantly regressive barrier sedimentation.

1. For any given time interval, the sands will be lenticular and thin landward and seaward.

2. The sand body will be elongate parallel with depositional strike.
3. The barrier islands may be underlain by either marine or non-marine sediments, or both.
4. The base of the barrier sands should be nonerosive (unless the barrier system originated as a beach abutting a coastal plain).
5. The barrier sands should show an internal sequence of sedimentary structures representing upward transition from the lower shoreface environment to successively shallower marine environments.
6. Tidal channels may be present and interrupt the typical vertical sequence of sedimentary structures and textures.
7. Grain size should increase upward.
8. True barrier sands will be flanked on their landward side by lagoonal sediments.
9. The thickness of the sands will depend upon the complex interrelation of sediment supply and rate of subsidence.
10. The barrier sands will be capped by marine or non-marine sediments, depending upon the tectonic situation and the sediment supply at the close of barrier formation.
11. The model is independent of composition and should apply to both carbonate and noncarbonate sediments if the material is granular and not of uniform grain size.

Shelton (1967) lists the most diagnostic characteristics of a "coastal sand-barrier feature" as

1. Low-angle inclined bedding in the upper part

2. Mottled structure in the lower part
3. Upward increase in grain size
4. Gradational lower and lateral contacts.

He believes that these features also characterize the Galveston Island complex.

Other examples of characteristic structures of barrier bars and associated marine sequences are listed by Embry et al (1974). He refers to Visher (1965) who characterized the sequences by parallel bedding, ripples and festoon cross-bedding in the upper portion and graded, thin-bedded, current structures, churned and laminated sediments in the lower portion. The sediments are very fine- to coarse-grained with a poorly-sorted basal unit and a well-sorted top. Potter (1967) is also referred to by Embry et al (1974) as characterizing the sequence as having ripples, laminations, current lineations, cross-bedding and burrows.

5.2 CARDIUM SANDSTONE

5.2.1 Geological History

The geological history of the late Cretaceous in western Canada is given by Williams and Burk (1964) and is summarized here.

At the beginning of late Cretaceous time, the interior of western Canada was occupied by a broad, epeiric sea joining the Arctic Ocean and the Gulf of Mexico. The uplands of the central Cordillera flanked the sea to the west while the eastern extent is unknown. During the Cenomanian Age, while dark grey shales (Blackstone) were being deposited in the southern parts of the interior sea, uplift and intrusion began to occur in north-central British Columbia. A delta complex was built up in northern Alberta and British Columbia. Following this, the sea transgressed and sedimentation of mud prevailed. Early in the Turonian, conditions of maximum transgression favoured the deposition of calcium carbonate and the Second White Specks marker was deposited. Shallowing continued during the late Turonian and terriginous clastics, deposited from the northwest, caused the western margin to migrate seaward as the elongate Cardium sand bodies were deposited parallel to depositional strike. Renewed subsidence in Coniacian time shifted the shoreline west and the Wapiabi shale covered the Cardium.

5.2.2 Interpretations

Berven (1966) interpreted the Cardium bodies as "offshore bars" deposited along the western margin of the Turonian seaway. The evidence he used was the extreme length of the bodies in relation to width, the linear form and en echelon arrangement, the flat bottom and convex upper surface, the abrupt east dip and the more sinuous eastern margin. These compared with features given by other authors as characterizing offshore bars.

Sinha (1968) believed that the basal Cardium beds of dark silty shale and siltstone with pyrite were deposited in a quiet water euxinic and marine environment. Shallow water deposition followed in a marine, brackish, partly reducing and restricted environment. He believed all features observed could be explained by this and he called the formation an "offshore bar".

Michaelis and Dixon (1969) used sedimentary structures to interpret the Cardium sandstone. For examples, primary stratification records a dominance of low but constant fluid motion and burrowing indicates agitated and aerated water bottoms and low sedimentation rates. He calls the Cardium sandstone an "offshore shoal".

This author finds the model on the Galveston Island complex presented by Davies et al (1971) which was previously outlined to be the most favourable in determining regressive barrier sedimentation. Three of the four distinct units described by those authors were observed in the Cardium sandstone and described in Chapter 4. Interbedded, burrowed and bioturbated, very fine-grained sand, silt and silty clay (characterizing lower shoreface sediments) were observed (Plate I, Figure 1). These sediments were overlain by very fine-grained structureless sands (characterizing middle shoreface sediments). Overlying these were fine- to very fine-grained, well laminated sediments with planar lamination, and low-angle cross-lamination (characterizing beach and upper shoreface sediments) (Plate 1, Figure 3 and Plate II, Figures 1 and 2). The eolian deposit was absent but this does not destroy the model. The overlying shale perhaps represents lagoonal sediments. The conglomerate was not explained by the model and can perhaps be regarded as a basal unit of the overlying section (Michaelis and Dixon, 1969). Some brief change in environment producing a very high flow regime before deposition of the Wapiabi shale may have caused its deposition.

The eleven characteristics listed by Davies et al (1971) of a model for dominantly regressive barrier sedimentation all apply to the Cardium sandstone. These were presented in a previous section and are now listed in reference to the Cardium sandstone.

1. The Cardium sand body is lenticular and thins landward and seaward as shown by the isopach map and by previous work.
2. The Cardium sand body is elongate parallel with depositional strike (Williams and Burk, 1964).
3. The Cardium is underlain by marine sediments.
4. The base of the Cardium is nonerosive as the contact with the underlying shale appears conformable.
5. The Cardium sand shows an internal sequence of sedimentary structures representing upward transition from the lower shoreface environment to successively shallower marine environments. This was discussed in the previous paragraph.
6. Tidal channels may be present according to the model but none was observed in the study area.
7. Grain size increases upwards.
8. The Wapiabi shale may represent lagoonal sediments.
9. No information on sediment supply or subsidence rate is available.
10. The Cardium sand is capped by marine sediments (Wapiabi shale).

11. The Cardium sand is made up of noncarbonate granular sediments which are not of uniform grain size.

Thus, this author believes that the Cardium sand body may be considered the result of dominantly regressive barrier sedimentation.

The confusion caused by the nomenclature is not eliminated by calling the sand body a 'barrier' since there is no evidence of aerial exposure in the Cardium sandstone and since a definition of barrier may or may not imply emergence. Therefore, the best term for describing the depositional environment of the Cardium sandstone is an offshore shoal since according to Blatt _et al_ (1972), this term is used when there is no evidence of emergence.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study of the Cardium Sandstone in the Rocky Mountain House area of the Garrington and Ferrier fields of central Alberta, was undertaken in an attempt to describe the petrography and suggest a depositional environment.

The study was based on the examination of well logs, cores, thin sections and X-ray analyses.

Structure on the top of the Cardium Sandstone does not appear significant in terms of its deposition. The structure contours strike approximately 60 to 70 feet per mile, sloping towards the NW.

An isopach map of the body shows a trend of approximately north 35° west. The eastern margin of the body is sinuous and pinches out steeply while the western margin is straighter and gently sloping. The average thickness is approximately 18 feet. Two prominent ridges were evident.

Structural cross-sections show a dip of approximately 15° NW. The body thins at its edges and has a flat lower surface and a convex upper surface.

The sandstone unit is underlain by a dark, grey shale which has interlaminated sands and siltstones and shows extensive bioturbation. The sand is fine- to very fine-grained and consists mainly of quartz with occasional feldspar, mica, apatite, chlorite, zircon, rutile, and common siderite and pyrite. The sand is very fine-grained and massive at the base of the unit. Planar bedding and low angle cross-laminations were observed in the upper part of the unit. A chert pebble conglomerate overlies the sand.

There has been some controversy over determination of the depositional environment of the Cardium sandstone. The Cardium sand has all the characteristics listed by Davies _et al_ (1971) for dominantly regressive barrier sedimentation. This author believes it represents an offshore shoal deposit that is underlain by the Blackstone shale and overlain by the Wapiabi shale. It was deposited at the seaward migrating edge of the Turonian seaway.

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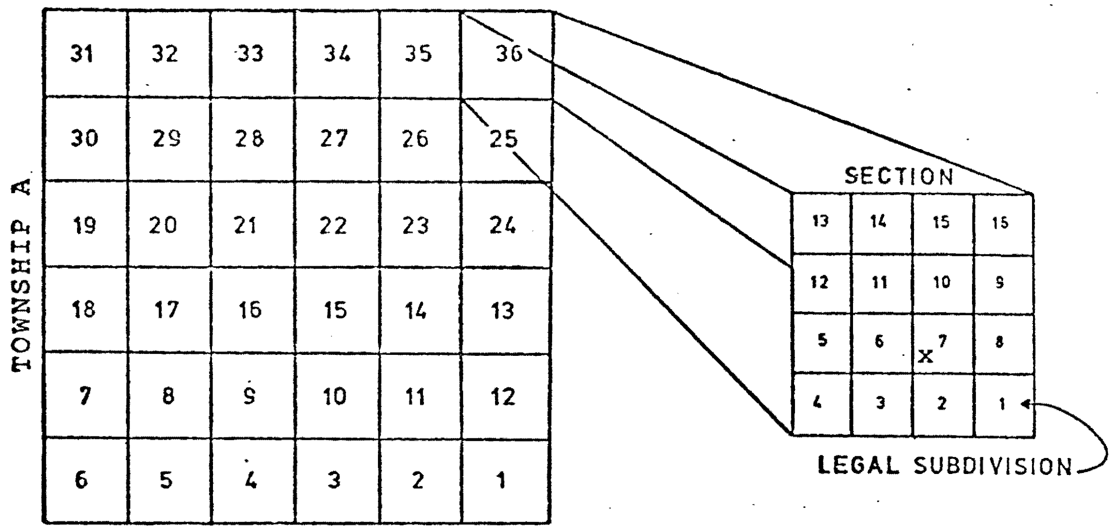
APPENDIX A

TOWNSHIP MAPPING SYSTEM



RANGE P

Alberta is divided into townships which run across the width of the province from east to west. Each township measures 6 miles from south to north. Divisions called ranges are made vertically to divide the province into 6 mile squares as shown above. Each of these is divided into 36 1 mile x 1 mile sections and each section is divided into 16 legal subdivisions (abbr. L.S.D.). A well marked "X" above would be labelled L.S.D. 7, Section 36, Township A, Range P, west of some meridian, for example the 5th. In abbreviated form, this well would simply be 7-36-A-P W5.

WELL NAME	LOCATION	K.B.	TOP OF CARDIUM (Well Depth)	BASE OF CARDIUM (Well Depth)	ISO-PACH	STRUC. ON CARDIUM B.S.L.	WELL DEPTH TO -3700 FT. B.S.L.
CROSS-SECTION A-A'							
Supertest Alminex Med Ferrier	08-09-39-9	3787	8175	8196	21	-4388	7487
Husky et al Ferrier	06-14-39-9	3520	7716	7741	25	-4196	7220
Oriole Ferrier	06-24-39-9	3416	7538	7563	25	-4122	7116
Sinclair et al Ferrier	10-30-39-8	3410	7396	7418	22	-3986	7110
Hunt Ferrier	06-28-39-8	3414	7320	7335	15	-3905	7114
Sinclair Pacific Ferrier	08-28-39-8	3408	7244	7259	15	-3836	7108
Southern Production Atlantic Ferrier	14-27-39-8	3347	7193	7207	14	-3846	7047
Seafort et al Ferrier	10-36-39-8	3278	6921	6941	20	-3643	6978
Amerada CR GM Ferrier	10-06-40-7	3212	6777	6800	23	-3565	6912
Dekalb Crimson	04-08-40-7	3188	6715	6735	20	-3527	6888
Quasar et al Ferrier	06-15-40-7	3225	6652	6667	15	-3427	6925
CROSS-SECTION B-B'							
Sinclair et al Cow Creek	09-28-38-8	3391	7445	7470	25	-4054	7091
Pacific et al Ferrier	11-35-38-8	3438	7350	7370	20	-3912	7138

WELL NAME	LOCATION	K.B.	TOP OF CARDIUM (Well Depth)	BASE OF CARDIUM (Well Depth)	ISO-PACH	STRUC. ON CARDIUM B.S.L.	WELL DEPTH TO -3700 FT. B.S.L.
Pure TPC & O Baysel Ferrier	02-17-39-7	3271	6919	6941	22	-3651	6971
Seafort et al Ferrier	10-16-39-7	3165	6765	6786	21	-3600	6865
Seafort et al Ferrier	04-22-39-7	3256	6810	6822	12	-3554	6956
Seafort et al Ferrier	08-27-39-7	3250	6743	6754	11	-3485	6950
Seafort et al Ferrier	06-24-39-7	3289	6735	6750	15	-3446	6989
Union Codner	10-32-39-6	3271	6494	6502	08	-3222	6971
CROSS-SECTION C-C'							
Sinclair Pacific Cow Lake	11-14-38-8	3425	7450	7475	25	-4026	7125
Home Pembina Ferrier	11-18-38-7	3467	7395	7417	22	-3928	7167
Home Pembina IOE Ferrier	11-20-38-7	3440	7250	7270	20	-3810	7140
Gridoil Ferrier	10-26-38-7	3319	6875	6899	24	-3556	7019
Gridoil Ferrier	03-35-38-7	3297	6868	6890	22	-3568	6997
Cox SE Ferrier	10-36-38-7	3348	6840	6864	24	-3492	7048
Seafort et al Ferrier	06-05-39-6	3331	6721	6745	24	-3391	7030
Mobil HB Codner	10-08-39-6	3304	6661	6671	10	-3357	7004

WELL NAME	LOCATION	K.B.	TOP OF CARDIUM (Well Depth)	BASE OF CARDIUM (Well Depth)	ISO-PACH	STRUC. ON CARDIUM B.S.L.	WELL DEPTH TO -3700 FT. B.S.L.
CROSS-SECTION D-D'							
Pinn Chedderville	16-19-37-7	3471	7500	7515	15	-4029	7141
Imperial Chedderville	10-29-37-7	3485	7445	7460	15	-3960	7185
Seafort et al Ferrier	12-04-38-7	3403	7328	7348	20	-3928	7103
Chevron IOE Dovercourt	10-02-38-7	3359	7091	7114	23	-3732	7059
Amerada CR FA Horseguard	04-24-38-7	3295	6890	6910	20	-3595	6995
Gridoil Ferrier	09-18-38-6	3294	6809	6825	16	-3515	6997
CROSS-SECTION E-E'							
Petromark et al Chedderville	07-22-37-7	3434	7342	7364	22	-3909	7134
Imperial Chedderville	10-25-37-7	3400	7155	7164	09	-3755	7100
Imperial Dovercourt	12-30-37-6	3381	7090	7104	14	-3709	7081
Home et al Alhambra	06-10-38-6	3297	6706	6718	12	-3409	6997

APPENDIX C - SAMPLE DESCRIPTIONS

CROSS-SECTION A-A'

Husky et al Ferrier 06-14-39-9W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
		SHALE -dark grey, hard, silty lenses indicate planar bedding
7721.5 - 7722.5	7721.5	CONGLOMERATE -rounded pebbles, generally about 3 mm but some exceed 10 mm -imbricated, fissile -sandy matrix
7722.5 - 7724.5		SHALE -bioturbated, dark grey, hard
7724.5 - 7741.5	7725.5 7728.5 7734.0 7737.5 7740.5	SANDSTONE -pyritic -subangular quartz grains (80%) -thin ironstone layer near top (massive and fine-grained) -grain size 3.5 phi -finer towards base -some planar bedding and cross-bedding at top - more massive at base -silty lenses and shale breaks -relatively coarse and "clean" -carbonate material in fractures
7741.5 -		SHALE -bioturbated, silty, mottled -pyritic

Southern Production Atlantic Ferrier 14-27-39-8W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 7189.0		SHALE -dark grey, hard, silty lenses indicate planar bedding
7189.0 - 7189.5	7189.5	CONGLOMERATE -rounded pebbles, generally 4 to 5 mm, fair sorting

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
7189.5 - 7203.0	7193.0 7198.0	SANDSTONE -subangular quartz grains (85%) -some planar bedding towards top -fairly massive towards base -silty lenses with a high percentage of opaques
7203.0 -		SHALE -bioturbated, silty, mottled

Amerada CR GM Ferrier 10-06-40-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
6775.0 - 6777.5	6777.5	SHALE -dark grey, hard, sandy lenses with subangular quartz (4 phi) -planar bedding
6777.5 - 6779.6	6778.8	CONGLOMERATE -rounded pebbles, generally 2 to 5 mm -imbricated -sandy matrix
6779.6 - 6786.2	6780.2 6781.8 6782.8 6786.0	CONGLOMERATE -rounded pebbles -shaly matrix, matrix increases with depth -fissile -siderite present
6786.2 - 6786.9	6786.9	SANDSTONE -shaly, mud support -subangular quartz grains -massive, limy
6786.9 - 6797.2	6788.0 6790.5 6793.0 6795.5 6796.6	SANDSTONE -subangular quartz grains (85-90%) -grain size 3.5 - 4 phi -planar bedding at top - more massive at base -some shale lenses and silt breaks -some carbonate cement -relatively fine and "dirty"
6799.2 -		SHALE -bioturbated, silty, mottled

CROSS-SECTION B-B'

Seafort et al Ferrier 10-16-39-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 6754.5		SHALE -hard, dark grey, massive -pyritic
6754.5 - 6755.0		IRONSTONE -very fine-grained, massive, limy
6755.0 - 6763.0		CONGLOMERATE -rounded pebbles -silty matrix
6763.0 - 6776.5	6765.7 6776.5	SANDSTONE -subangular quartz grains (60%) -chert quite abundant -poor to fair sorting -some silty and shaly lenses -planar bedding -bioturbated in shaly zones -occasional carbonate patches
6776.5 -		SHALE -dense, quite massive -pyritic

Seafort et al Ferrier 08-27-39-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 6743.0	6730.0	SHALE -dark grey, hard, sandy lenses -some carbonate patches
6743.0 - 6743.5		CONGLOMERATE -rounded pebbles, pebble support -shale matrix
6743.5 - 6752.0	6743.5 6744.0 6745.8 6748.5 6750.0 6751.5	SANDSTONE -subangular quartz grains (75%) -grain size 3 - 3.5 phi -fair to good sorting, "clean" -shaly and silty lenses -carbonate material in fractures
6752.0 - 6755.0	6753.0 6754.5	SANDSTONE -pyritic -subangular quartz -relatively coarse "clean" sand
6755.0 -	6755.8	SHALE -bioturbated, silty, mottled

CROSS-SECTION C-C'

Home Pembina Ferrier 11-18-38-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 7396.2	7393.0	SHALE -hard, sandy and silty layers indicate planar bedding -burrowed slightly -pyritic -conglomerate towards base
7396.2 - 7397.0	7397.0	CONGLOMERATE -rounded pebbles -silty matrix
7397.0 - 7416.2	7399.5 7403.5 7408.0 7412.0 7415.0	SANDSTONE -subangular quartz grains (85%) -grain size 3.5 - 4 phi -plagioclase, apatite and siderite present -shaly and silty layers at top and base -cross-bedding and planar bedding towards top, massive at base -relatively coarse "clean" sand at top and finer "dirty" sand at base
7416.2 -		SHALE -bioturbated, silty, mottled

Gridoil Ferrier 10-26-38-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
6880.0 - 6885.0		CONGLOMERATE -rounded pebbles -silty matrix
6885.0 - 6886.0	6885.5	SANDSTONE -silty, sucrosic, massive -subrounded grains, well sorted
6886.0 - 6897.0	6891.0 6894.2 6896.5	SANDSTONE -plagioclase present -subangular quartz (80-90%) -grain size 3.5 - 4 phi -good sorting -shale breaks, planar bedding -relatively coarse "clean" sand
6897.0 -		SHALE -bioturbated, dense, mottled

Cox SE Ferrier 10-36-38-7W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 6851.5		SHALE -dark grey, hard, massive -conglomerate at base
6851.5 - 6860.0	6852.0	SANDSTONE -very fine-grained -generally massive with some planar bedding at top -some ripples -"dirty" sand
6860.0 -	6859.9 6861.5	SHALE -bioturbated, silty, sandy, mottled

Seafort et al Ferrier 06-05-39-6W5

WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
- 6715.0		SHALE -dark grey, hard, massive
6715.0 - 6715.2		CONGLOMERATE -rounded pebbles
6715.2 - 6742.8	6715.2 6722.0 6726.5 6730.5 6738.2 6741.8	SANDSTONE -angular quartz grains (80%) -grain size 3.5 - 4 phi -muscovite present -bioturbated shale layers at base -sandy and silty lenses in shale
6742.8 -	6748.2	SHALE -bioturbated, silty, mottled

CROSS-SECTION D-D'

Gridoil Ferrier 09-18-36-6W5

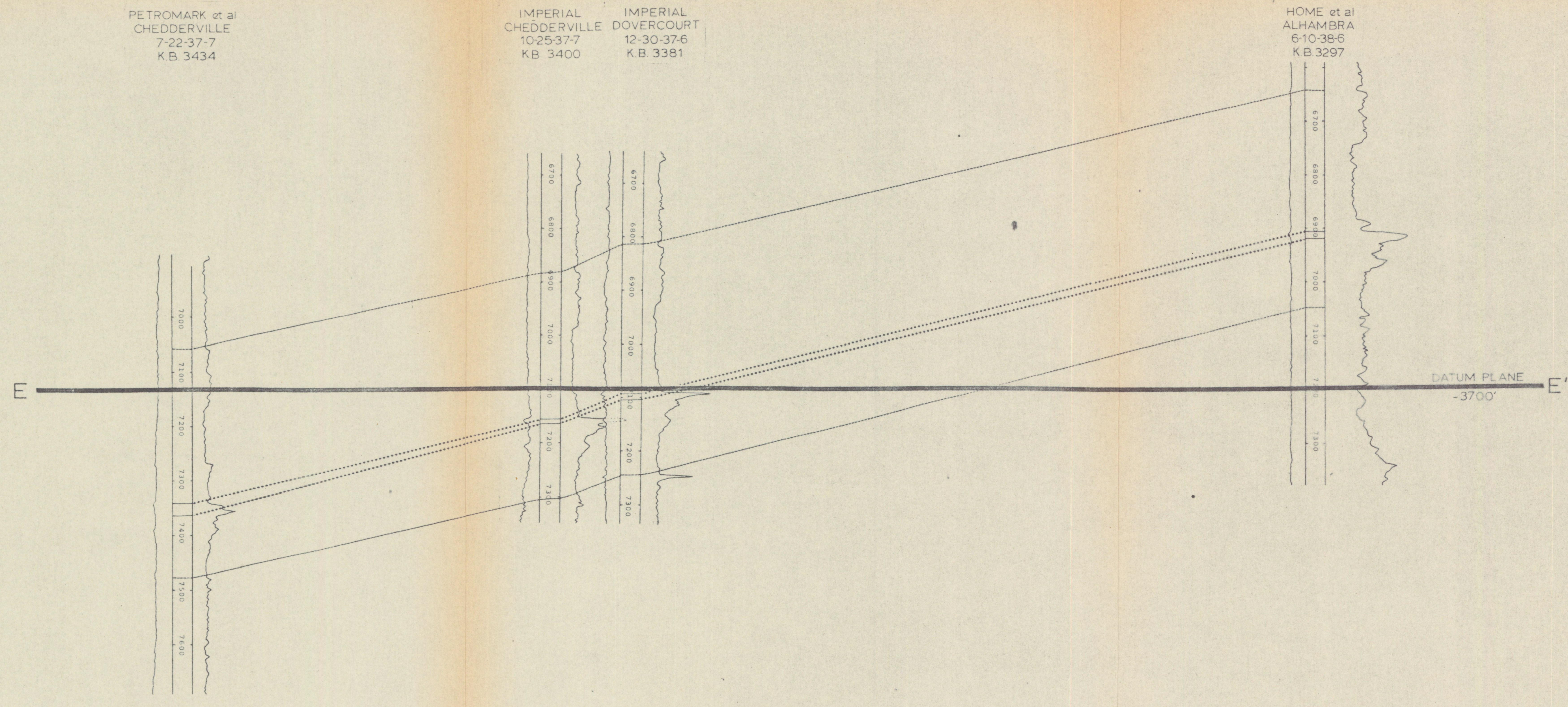
WELL DEPTH (FEET)	THIN SECTION DEPTHS	LITHOLOGY
-6819.5	6819.5	SHALE -dark grey, hard, massive -silty lenses indicate planar bedding -conglomerate at base
6819.5 - 6840.0	6823.5 6831.0 6835.2 6839.5	SANDSTONE -pyrite, muscovite, oligoclase, chlorite present -shaly and silty layers -"dirty" fine sand

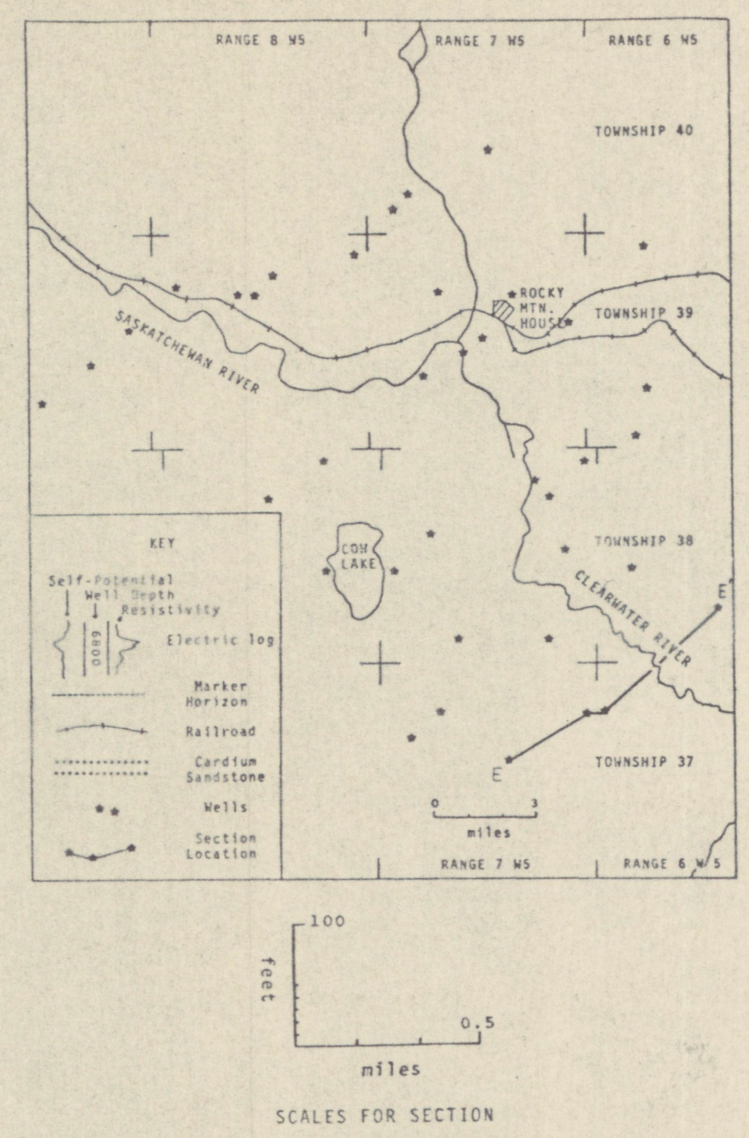
SUPTST ALMINEX
MED FERRIER
8-9-39-9
K.B. 3787
HUSKY
et al FERRIER
6-14-39-9
K.B. 3520
ORIOLE
FERRIER
6-24-39-9
K.B. 3416
SINCLAIR
et al FERRIER
10-30-39-8
K.B. 3410
HUNT
FERRIER
6-28-39-8
K.B. 3414
SINCLAIR PACIFIC
FERRIER
8-28-39-8
K.B. 3408
SOUTHERN PRODUCTION
ATLANTIC FERRIER
14-27-39-8
K.B. 3347
SEAFORT
et al FERRIER
10-36-39-8
K.B. 3236
AMERADA CR GM
FERRIER
10-6-40-7
K.B. 3212
DEKALB
CRIMSON
4-8-40-7
K.B. 3188
QUASAR
et al FERRIER
6-15-40-7
K.B. 3225
A
DATUM PLANE
-3700'
A'
RANGE 8 W5
RANGE 7 W5
RANGE 6 W5
TOWNSHIP 40
TOWNSHIP 39
TOWNSHIP 38
TOWNSHIP 37
SASKATCHEWAN RIVER
CLEARWATER RIVER
ROCKY MTN. HOUSE
COW LAKE
KEY
Self-Potential
Well Depth
Resistivity
Electric log
Marker Horizon
Railroad
Cardium Sandstone
Wells
Section Location
0
3
miles
100
feet
0.5
miles
SCALES FOR SECTION


SINCLAIR et al COW.CK 9-28-38-8 K.B. 3391
PACIFIC et al FERRIER 11-35-38-8 K.B. 3438
PURE TPC&O BAYSEL FERRIER 2-17-39-7 K.B. 3271
SEAFORT et al FERRIER 10-16-39-7 K.B. 3165
SEAFORT et al FERRIER 4-22-39-7 K.B. 3256
SEAFORT et al FERRIER 8-27-39-7 K.B. 3250
SEAFORT et al FERRIER 6-24-39-7 K.B. 3289
UNION CODNER 10-32-39-6 K.B. 3271
B
B'
DATUM PLANE -3700'
SCALES FOR SECTION

SINCLAIR
PACIFIC COW LK
11-14-38-8
K.B. 3425
HOME PEMBINA
FERRIER
11-18-38-7
K.B.3467
HOME PEMBINA
IOE FERRIER
11-20-38-7
K.B. 3440
GRIDOIL
FERRIER
10-26-38-7
K.B. 3319
GRIDOIL
FERRIER
3-35-38-7
K.B. 3297
COX SE
FERRIER
10-36-38-7
K.B. 3348
SEAFORT
et al FERRIER
6-5-39-6
K.B. 3331
MOBIL HB
CODNER
10-8-39-6
K.B.3304
C
C'
DATUM PLANE
-3700'
RANGE 8 W5
RANGE 7 W5
RANGE 6 W5
TOWNSHIP 40
TOWNSHIP 39
TOWNSHIP 38
TOWNSHIP 37
ROCKY
MTN.
HOUSE
SASKATCHEWAN RIVER
CLEARWATER RIVER
COW
LAKE
KEY
Self-Potential
Well Depth
Resistivity
Electric log
Marker Horizon
Railroad
Cardium Sandstone
Wells
Section Location
0
3
miles
100
feet
0.5
miles
SCALES FOR SECTION


PINN
CHEDDERVILLE
16-19-37-7
K.B. 3471
IMPERIAL
CHEDDERVILLE
10-29-37-7
K.B. 3485
SEAFORT
et al FERRIER
12-4-38-7
K.B. 3403
CHEVRON IOE
DOVERCOURT
10-2-38-7
K.B. 3359
AMERADA CR FA
HORSEGUARD
4-24-38-7
K.B. 3295
GRIDOIL
FERRIER
9-18-38-6
K.B. 3294
D
D'
DATUM PLANE
-3700'
RANGE 8 W5
RANGE 7 W5
RANGE 6 W5
TOWNSHIP 40
TOWNSHIP 39
TOWNSHIP 38
TOWNSHIP 37
ROCKY
MTN.
HOUSE
RIVER
COW
LAKE
CLEARWATER RIVER
Electric log
Marker
Horizon
Railroad
Cardium
Sandstone
Wells
Section
Location
0
3
miles
100
feet
0.5
miles
SCALES FOR SECTION


PETROMARK et al
CHEDDERVILLE
7-22-37-7
K.B. 3434
IMPERIAL
CHEDDERVILLE
10-25-37-7
K.B. 3400
IMPERIAL
DOVERCOURT
12-30-37-6
K.B. 3381
HOME et al
ALHAMBRA
6-10-38-6
K.B. 3297
E
DATUM PLANE
-3700'
E'


RANGE 8 W5
RANGE 7 W5
RANGE 6 W5
TOWNSHIP 40
TOWNSHIP 39
TOWNSHIP 38
TOWNSHIP 37
ROCKY
MTN.
HOUSE
SASKATCHEWAN RIVER
CLEARWATER RIVER
COW
LAKE
E
E'
KEY
Self-Potential
Well Depth
Resistivity
Electric log
Marker Horizon
Railroad
Cardium Sandstone
Wells
Section Location
0
3
miles
100
feet
0.5
miles
SCALES FOR SECTION