Eug. Poitevin

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

PAPER 55-3

CROSS-SECTIONS THROUGH THE DEVONIAN SYSTEM OF THE ALBERTA PLAINS

(Report and Five Figures)

By
Helen R. Belyea

OTTAWA
1955

Price, 50 cents

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
Paper 55-3

CROSS-SECTIONS THROUGH THE DEVONIAN SYSTEM OF THE ALBERTA PLAINS

By

Helen R. Belyea

OTTAWA
1955

Price, 50 cents

CONTENTS

Illustrations

CROSS-SECTIONS THROUGH THE DEVONIAN SYSTEM OF THE ALBERTA PLAINS

INTRODUCTION

The accompanying columnar sections illustrate the stratigraphy and proposed correlations for subdivisions of the Woodbend, Winterburn, and Wabamun groups of the Upper Devonian System of Alberta. Section A-A' (See Figure 2) crosses the central and east-central Alberta Plains from Imperial Paddle River No. 1 well in tp. 56, rge. 8, W. 5th mer., to the Alberta-Saskatchewan boundary at Widney Ward No. 1 well in tp. 33, rge. 2, W. 4th meridian. Section B-B' (See Figure 3) extends northward from Imperial Labyrinth Lake No. 15-14 well in tp. 48, rge. 23, W. 4th mer. (also included in Figure 2), to Imperial Caslan No. 1 well in tp. 63, rge. 17, W. 4th meridian. These sections are based on studies of cores and samples, supplemented by electric and radioactivity logs from many wells. Each well shown may be considered as representative of the facies developed in a considerable area.

Many of the proposed correlations are tentative, depending for proof or disproof on drilling of additional wells. In some cases alternative correlations are mentioned in the text. Assuming the correlation shown in the figures to be the most acceptable, an attempt has been made to show the relationship between the various facies and to interpret therefrom the history of the depositional basin.

ACKNOWLEDGMENTS

All fossil identifications were made by D. J. McLaren of the Stratigraphic Palaeontology Division of the Geological Survey of Canada. Dr. McLaren has also contributed information on faunal zones in the Rocky Mountains for correlation with the Plains region.

The writer wishes to thank the Alberta Petroleum and Natural Gas Conservation Board for providing facilities for the examination of cores; British American Oil Company Limited, California Standard Company, Canadian Gulf Oil Company, Canadian Superior Oil of California, Imperial Oil Limited, Shell Oil Company, Socony-Vacuum Exploration, and Texaco Exploration Company for permission to examine the cores of their wells and for courtesies shown during this work; and the Canadian Stratigraphic Services for making their material available. The writer also thanks the following companies whose cores were examined at the Petroleum and Natural Gas Conservation Board: Anglo Canadian Oil Company Limited, Bailey Selburn Oil and Gas Limited, Federated Petroleums Limited, Great Plains Development Company of Canada Limited, Hanna Petroleums Limited, Hudson's Bay Oil and Gas Company Limited, and New Superior Oils of Canada Limited.

REFERENCES

(1) Andrichuk, J. M.: Regional Stratigraphic Analysis of Devonian System in Wyoming, Montana, Southern Saskatchewan and Alberta; Amer. Assoc. Pet. Geol., Bull. 35, pp. 2,368-2,409 (1951).

(2) Andrichuk, J. M., and Wonfor, J. S.: Late Devonian Geologic History in Stettler Area, Alberta, Canada; Alberta Soc. Pet. Geol., Bull. 1, 1953.

(3) Belyea, H. R.: Further Discussion on the Use of the Term Nisku; Alberta Soc. Pet. Geol., Bull. 2, 1954.

(4) ———Notes on the Devonian System of the North-central Plains of Alberta; Geol. Surv., Canada, Paper 52-27, 1952.

(5) Crickmay, C. H.: New Spiriferidae from the Devonian of Western Canada; Imperial Oil Limited, 1953.

(6) Geological Staff, Imperial Oil Limited, Western Division: Devonian Nomenclature in Edmonton Area, Alberta, Canada; Amer. Assoc. Pet. Geol., Bull. 34, pp. 1,807-1,825 (1950).

(7) Laurence, R. H.: Discussion on the Term "Upper Nisku"; Alberta Soc. Pet. Geol., Bull. 1, 1953.

(8) Layer, D. B., et al.: Leduc Oil Field, Alberta, a Devonian Coral-Reef Discovery; Amer. Assoc. Pet. Geol., Bull. 33, pp. 572-602 (1949).

(9) Link, T. A.: Leduc Oil Field; Bull. Geol. Soc. Am., vol. 60, pp. 381-402 (1949).

(10) Lockwood, R. P., and Erdman, O. A.: Stettler Oil Field, Alberta, Canada; Amer. Assoc. Pet. Geol., Bull. 35, pp. 865-884 (1951).

(11) McLaren, D. J.: Reef Development in the Devonian of the Canadian Rocky Mountains; Can. Min. and Met. Bull., vol. 46, No. 499, pp. 706-710 (1953).

(12) Perry, E. S.: Oil and Gas in Montana; Montana Bureau of Mines and Geology, Mem. 35, 1953.

(13) Storey, T. P.: Some Regional Devonian Correlation in Alberta, Canada; Alberta Soc. Pet. Geol., Bull. 1, 1953.

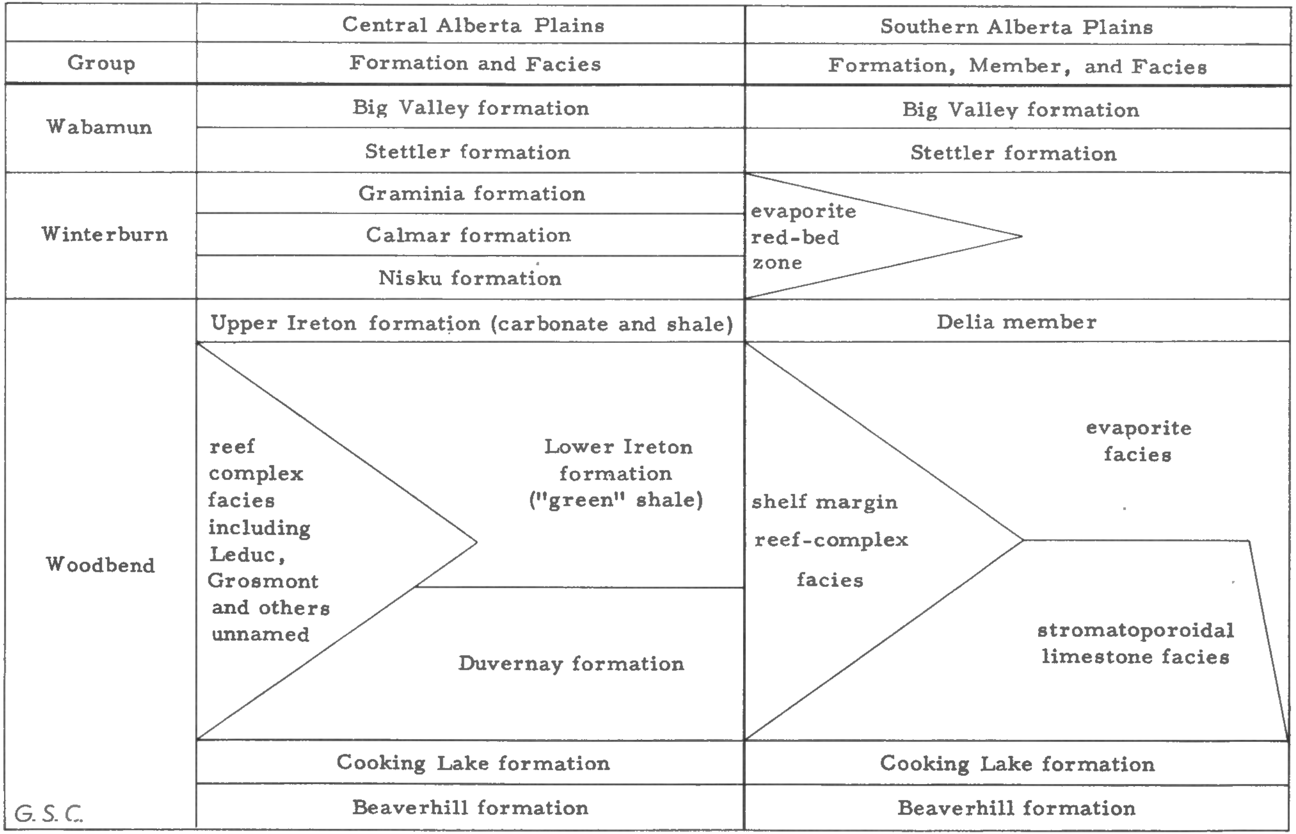
(14) Waring, W. W., and Layer, D. B.: Devonian Dolomitized Reef, D3 Reservoir, Leduc Field, Alberta, Canada; Amer. Assoc. Pet. Geol., Bull. 34, pp. 295-312 (1950).

(15) Warren, P. S.: Fossil Zones of Devonian of Alberta; Amer. Assoc. Pet. Geol., Bull. 33, pp. 564-571 (1949).

(16) Warren, P. S., and Stelck, C. R.: Succession of Devonian Faunas in Western Canada; Roy. Soc., Canada, Trans., vol. 44, 3rd ser., sec. 4, pp. 61-78 (1950).

(17) Webb, J. B.: Geological History of Plains of Western Canada; Amer. Assoc. Pet. Geol., Bull. 35, pp. 2,291-2,315 (1951).

(18) Wonfor, J. S., and Andrichuk, J. M.: Upper Devonian in the Stettler Area, Alberta, Canada; Alberta Soc. Pet. Geol., Bull. 1, 1953.



Tentative Correlation Chart of Upper Devonian

WOODBEND GROUP

The name Woodbend was introduced by the geological staff of Imperial Oil (6)[1] for a formation that included several litho-

[1]Numbers in parentheses refer to References on page 2.

logically different but interrelated units distinguished as members. These comprised the Cooking Lake at the bottom, the Duvernay and overlying Ireton as the off-reef facies, and the Leduc[2] as the reef

[2]The term Leduc is here restricted to the Rimbey-Meadowbrook reef chain as there is no way of determining its relationship to limestones and dolomites of other reef chains from which it is completely separated by shale. It has been adequately described (6, 8, 9, 14) and further comment is not within the scope of this paper.

facies. As work since that time has shown that the members of the Woodbend are clearly mappable units they are here treated as formations and the name Woodbend is used as a group to include these formations and their equivalent facies in adjoining areas.

COOKING LAKE FORMATION

The Cooking Lake formation was described by the geological staff of Imperial Oil Limited (6, pp. 1,819-1,820, 1,823), and the description was later extended to cover the north-central Plains of Alberta (3, pp. 15-18). Only a few additional comments are needed here. In general, the Cooking Lake consists of fine- to medium-grained, organic, detrital limestones, stromatoporoidal 'build-ups', and interfingering dense limestone and pelletoid zones. Maximum stromatoporoidal development is in a broad belt extending east and southeast from a line trending roughly northeast, immediately west of the Rimbey-Meadowbrook reef chain (See Figure 1). The eastern limit is approximately range 18, west 4th meridian as far south as Stettler, from where it seems to veer westward. This 250- to 300-foot zone of maximum stromatoporoidal development probably indicates the growth of banks and shoals. An upper stromatoporoid limestone member separated by shale from the main body of the Cooking Lake seems to be a transition zone to the Duvernay. As it is reefoid in character and encloses a brachiopod fauna allied to that of the Cooking Lake it is included with that formation rather than with the Duvernay. The following fauna[3] were collected from this

[3]Identified by D. J. McLaren.

zone in various wells.

Alveolites sp.
Favosites sp.
Thamnopora sp.
Schizophoria sp.
"*Leptostrophia*" sp.
Schuchertella ? sp.
Productella sp.
Atrypa sp.
Eleutherokomma jasperensis (Warren)
E. cf. *killeri* Crickmay
E. leducensis Crickmay
Tylothyris ? cf. *subattenuatus* (Hall)

To the south and southeast of the belt characterized by abundant organic growth the Cooking Lake is about 200 feet thick. Dense limestones and thin evaporite zones interfingering with stromatoporoid and organoclastic limestones indicate restricted circulation of sea water. Anhydritic carbonates and anhydrite occur in wells southeast of a line approximately from Imperial Plain Lake No. 1 well, tp. 53, rge. 12, W. 4th mer., to Husky-Phillips Pine Lake No. 1 well in tp. 35, rge. 25, W. 4th mer., and three anhydrite bands are found in wells south and east from Socony Entice No. 1 and Socony Craigmyle No. 1 wells. A shaly limestone and grey shale zone enclosing a brachiopod-crinoid fauna separates the upper and lower limestone members of the Cooking Lake in areas where reef growth is poorly developed.

To the north, the upper part of the Cooking Lake interfingers with greenish grey and brown shales, gradually becoming indistinguishable lithologically from the Duvernay. The approximate position of the northern margin of the upper part of the Cooking Lake is indicated in Figure 1, and the facies change is shown in Figure 3 from Great Plains Seaboard Smoky Lake No. 2 to Imperial Figure Lake No. 1. Thin shale bands occur in the Cooking Lake as far south as Socony Vegreville No. 1 well in tp. 51, rge. 15, W. 4th mer., and also around the Vermilion area. West of the Rimbey-Meadowbrook reef chain the Cooking Lake thins abruptly to about 30 feet (See Figure 2) between Ponder Leduc No. 1 and Imperial Golden Spike No. 3 wells, and most of its stratigraphic position is occupied by greenish grey and brownish grey shales. The age relationships between the Cooking Lake limestone and the greenish grey shales has not been determined with certainty. Possibly they interfinger but more probably the entire period of stromatoporoidal growth of the Cooking Lake, in the Golden Spike and Leduc field wells, may equal in time the thin Cooking Lake limestone in Imperial Golden Spike No. 3 well. The occurrence of a faunal assemblage characteristic of the top of the Cooking Lake limestone, in the thin limestone below this greenish grey shale in Imperial Westlock 14-24-59-26 well, lends some support to the latter interpretation. If this interpretation is true the greenish grey shales may have been deposited during an hiatus in reef growth in the reef chains and may be equivalent to a black shale in the basin area to the northwest, at the base of the Woodbend. Because it is a shale facies, this unit is, however, included with the Duvernay.

The Cooking Lake is a widespread deposit traceable eastward across Saskatchewan and westward to the Rocky Mountains, where it may be equivalent to part, if not all, of the Flume formation. It seems to represent turbulent shallow-water deposits in a stable shelf type of environment, at the front or seaward margin of which grew shoal reefs and banks composed largely of stromatoporoids and syngenetic forms. Rate of subsidence and depth of water was such that growth tended to spread horizontally rather than to form vertical mounds. These reefs and bars were probably the important factor contributing to the deposition of evaporites to the southeast. Interfingering of the shales and limestones to the northeast in the upper member of the Cooking Lake suggests increased subsidence and transgression of deeper water conditions from the north and northeast, as well as an increase in the amount of argillaceous and silty material supplied to the area. These conditions seem to have killed most of the reef forming organisms of the Cooking Lake.

The following fauna[1] from the upper part of the Cooking

---

[1]All forms were identified by D. J. McLaren of the Stratigraphic Palaeontology Division of the Geological Survey of Canada.

Lake of various wells is similar to the fauna of the upper Flume formation of the Rocky Mountains[2].

---

[2]D. J. McLaren: personal communication.

<u>Amphipora</u> sp.
stromatoporoids
<u>Thamnopora</u> cf. <u>cervicornis</u> (de Blainville)
<u>Pachyphyllum</u> aff. <u>woodmani</u> (White)
<u>Tabulophyllum</u> sp.
<u>Stropheodonta</u> sp.
<u>Nudirostra</u> <u>athabascensis</u> (Kindle)
<u>Atrypa</u> spp.
<u>Allanaria</u> <u>minutilla</u> Crickmay
<u>Eleutherokomma</u> cf. <u>killeri</u> Crickmay
<u>E.</u> <u>cf.</u> <u>leducensis</u> Crickmay
<u>Tylothyris</u> ? sp.
<u>Tentaculites</u> sp.
gastropods
crinoid fragments

The following were obtained from the shale break and lower part of the Cooking Lake:

stromatoporoids
Alveolites sp.
Spongophyllum sp.
Synaptophyllum sp.
Zaphrentids
Schizophoria sp.
Productella sp.
Spinatrypa albertensis (Warren)
Eleutherokomma cf. hamiltoni Crickmay
E. cf. killeri Crickmay
E. cf. leducensis Crickmay

POST-COOKING LAKE MIDDLE WOODBEND FACIES DISTRIBUTION

Discussion of post-Cooking Lake stratigraphy is complicated by the development of a predominantly carbonate facies in southern Alberta and a predominantly shale facies surrounding reef complexes in central Alberta. The line separating the two facies is roughly the latitude of Drumheller, although east of Drumheller it trends in a northeasterly direction so that part of eastern Alberta is included with the southern Plains carbonate development (See Figure 1). The carbonate facies of the southern Alberta Plains seems to be largely biostromal with associated evaporites suggestive of a stable shelf environment. In contrast, in central Alberta, the thick carbonate accumulations forming reefs and reef complexes surrounded by shales indicate a more rapidly subsiding area, here referred to as a basin. The difference in elevation between shelf and basin at any one time may not, however, have been great. This pattern of shelf and basin, exaggerated by compaction of the shale, had a strong influence on later Devonian sedimentation although the locus of shale deposition showed a progressive shift, with minor fluctuations, in a westerly to northwesterly direction. For simplication of discussion of the post-Cooking Lake Woodbend the deposits of the southern Alberta or shelf area and the central Alberta or basin area are considered separately.

SOUTHERN ALBERTA PLAINS

Post-Cooking Lake deposits in the southern Alberta Plains may be resolved into a crystalline dolomite zone, interpreted as reef complex at the boundary between stable shelf and basin, and the predominantly flat-lying stable shelf deposits. One facies interfingers with the other so that no sharp line can be drawn to separate them.

Shelf Margin Reef Complex

The southern Alberta shelf deposits overlying the Cooking Lake are separated from the basin deposits by a zone of crystalline dolomite with vuggy porosity, presumably recrystallized organic limestone. This dolomite has been penetrated by a series of wells from the Olds area in the southwest to the Vermilion area in the northeast, suggesting a chain of reefoid complexes or masses, as illustrated in Figure 1. Drilling has been insufficient to determine the internal organization of the vuggy dolomites and whether they form separate reefoid bodies or are continuous throughout, or at any horizon, is open to speculation. For convenience, the dolomite is referred to as the Middle Woodbend shelf margin reef complex[1] and is illustrated in Figure 2 by Western Byemoor 34-8 well.

[1]The term complex is used in a non-technical sense to indicate the highly complicated structures composed of reefs and associated carbonate rocks that have not yet been subdivided into their constituent parts.

Stable Shelf Deposits

Behind the reef complex described above and striking roughly parallel with it, the broad regional picture suggests belts grading from dolomitized limestone at the shelf margin eastward and southeastward through limestones to evaporitic deposits and finally to shale and siltstones. The spacial position of these belts changed with time. Figure 2 from Western Byemoor 34-8 well to Widney Ward No. 1 well illustrates all these facies changes in the middle part of the Woodbend. Similar changes in the lower part of the Woodbend may be expected farther to the south and southeast, beyond the Alberta boundary.

The shelf deposits proper are subdivided vertically into the separate lithologic units described below. As these deposits include the Cooking Lake as the basal unit and the probable equivalent of the upper part of the Ireton as the top unit they are referred to as the Woodbend group equivalent. They are probably equivalent to the Fairholme of the Rocky Mountains.

Stromatoporoidal Limestone Facies

Overlying the Cooking Lake is a zone about 250 to 300 feet thick composed largely of stromatoporoidal limestones with interbedded fine-grained and pelletoid limestones (See Figure 2, Widney Ward No. 1 and Princess C.P.R. 16-22A wells). Thin, dark brown shale stringers are commonly intercalated. Towards the shelf margin brown, vuggy, crystalline dolomite replaces the limestone (Figure 2, Imperial Golden Hill 12-2-30-16 and Socony Craigmyle No. 1 wells) and Imperial Golden Hill 12-2-30-16 well illustrates a zone in which these dolomitized limestones reach a thickness of approximately 450 feet, suggesting reef conditions. Finer grained limestones and some anhydrite stringers in Widney Ward No. 1 well indicate the beginning of a facies change to the east. These beds are similar to, and with the Cooking Lake probably are the equivalent of, the Lower Fairholme.

A narrow zone, represented in Figure 2 by Amerada Stanolind Crown BF21A-23 well, is of interest in that anhydrite and salt have been deposited presumably as a 'back-reef' facies to the vuggy dolomites illustrated by Imperial Golden Hill 12-2-30-16 well. The salt in Amerada Stanolind Crown well rests on dark brown shales suggestive of a Duvernay embayment, but, as the well bottoms in these shales, the exact correlation is not certain. This salt-anhydrite zone probably extends from this well northeastward to Brooks Stanmore No. 1 well in tp. 30, rge. 11, W. 4th meridian.

Evaporite Facies

A zone of interbedded, vuggy, crystalline dolomites, saccharoidal and dense, evaporitic dolomites, cryptocrystalline limestones, primary anhydrites, and shales overlies the zone of stromatoporoidal limestone and equivalent dolomitized limestone. The alternation of rock types is shown in a generalized form in Figure 2, Socony Craigmyle No. 1 well to Widney Ward No. 1 well. The alternation of beds suggests rhythmic or cyclical deposition, an idea already put forward by Andrichuk for equivalent deposits in Saskatchewan (1, p. 2,378). Work in the future with more closely spaced well control should show the exact relationships. This evaporitic zone ranges from 250 feet over the thick reefoid dolomites in Imperial Golden Hill 12-2-30-16 well to 450 feet in other wells. Eastward, as illustrated by Hudson's Bay Sparky No. 1 well, and northeast, for example in Imperial Provost No. 2 (tp. 37, rge. 3, W. 4th mer.) and Imperial Eyehill No. 1 wells (tp. 35, rge. 2, W. 4th mer.), argillaceous and silty beds become more prominent, suggesting rejuvenation of a source of sediment to the east. In eastern Alberta, where the marginal reef complex makes a northeasterly swing from about tp. 41, rge. 14, W. 4th mer., to about tp. 50, rge. 5, W. 4th mer., cryptocrystalline limestones and interbedded dolomites form the back-reef or shelf deposits, and grade into the evaporites and silty beds to the south and southeast. The approximate position of the transition zone from limestones to evaporites is indicated on Figure 1.

Delia Member

The evaporite zone is overlain by a succession of shales, shaly dolomites, and reefoid dolomites for which the term Delia is here proposed. The following section is from the cores of the Imperial Golden Hill 12-2-30-16 well between depths of 5,203 and 5,327 feet. The well is in l. s. 12, sec. 2, tp. 30, rge. 16, W., 4th mer. [1], about 11 miles southeast of the town of Delia, from which the name of the member is derived. The radioactivity and electric log curves are illustrated in Figure 5.

[1]The elevation of the kelly bushing of the well is 3,049 feet. The cores are stored with Imperial Oil Limited in Edmonton.

Depth	Lithology
Feet	
	Overlying beds: post-Woodbend evaporite-red bed zone
	Delia Member
5,203-5,214	Dolomite, buff to light brown, fine grained, crystalline; good intercrystalline and small vuggy porosity, mostly of organic origin; scattered dark brown shale laminae and partings; large irregular inclusions of white crystalline anhydrite
5,214-5,220	Dolomite, brown, finely crystalline; abundant small vugs; at top is 1 inch of small dolomite nodules enclosed in black shale
5,220-5,224	Argillaceous dolomite, grey; greenish grey shale laminae and partings making beds 0.1 inch to 6 inches thick; sharp break
5,224-5,226	Dolomite, brown, finely crystalline; small vugs; organic remains replaced by white anhydrite; dark brown shale laminae; sharp break
5,226-5,235	Argillaceous dolomite and shale; dolomite, light brown, argillaceous, fine grained; shale, dark brown; occurs as partings and irregular, in places wavy, inclusions in dolomite

Depth	Lithology
Feet	
5,235-5,240	Shale, greenish grey, dolomitic, massive; light grey shaly dolomite bands up to 1 inch thick; abundant finely disseminated pyrite; small brown carbonaceous specks
5,240-5,264	Dolomite, with irregular, in places, wavy, shale inclusions and partings; dolomite, light yellowish brown, dense, argillaceous; containing small brown carbonaceous plant fragments; shale, dark brown in laminae up to 1/8 inch thick; in places suggest ripple-mark; scattered inclusions of white anhydrite
5,264-5,270	Shale, greenish grey, dolomitic, massive; banded and mixed with grey, argillaceous dolomite; shell fragments and small pyrite (?) - stained pebbles at base
5,270-5,294	Argillaceous dolomite, light yellowish brown, fine grained, tight; interbedded and intermixed brown dolomitic shale in part suggesting ripple-marks; small carbonaceous specks and pyrite
5,294-5,302	Dolomite, yellowish brown, finely crystalline; scattered small vugs, some filled with white anhydrite; dark brown shale intermixed and interbanded, shale bands becoming more prominent downwards
5,302-5,319	Shale, greenish grey, dolomitic, massive scattered crinoid and brachiopod fragments in bottom 5 feet
5,319-5,327	Dolomite, grey, argillaceous; fossiliferous, abundant brachiopods and crinoids; greenish grey shale intermixed
	Underlying beds: Evaporite facies of Middle Woodbend

Depth	Lithology
Feet	
5,327-5,333	Dolomite, greyish buff, finely to coarsely crystalline; some brecciation in upper 2 feet with black shale between fragments; thin bedded; flat-lying shale partings at 1/2-inch to 3-inch intervals; abundant spore-like matter at contact with Delia member
5,333-5,351	Anhydrite and dolomite interbedded

In order to give a more complete description of this member a section composed largely of reef dolomite is described from the cores[1] of the Hudson's Bay West Drumheller 2-1 well in

[1]The cores of this well are stored in the Alberta Petroleum and Natural Gas Conservation Board core house in Calgary.

l. s. 1, sec. 2, tp. 30, rge. 21, W. 4th meridian.

5,493-5,494	Anhydrite: white, crystalline; scattered pyrite; shale, dark green, waxy, with mixed dolomite and anhydrite; abundant pyrite; sharp break
	Delia Member
5,494-5,503	Dolomite and shale: dolomite, grey and buff, fine to medium crystalline; banded with bright green, waxy, pyritic shale and greenish grey, argillaceous, fine-grained dolomite; inclusions of white anhydrite in dolomite
5,503-5,518	Dolomite: grey and buff, fine to medium crystalline; bands with good vuggy porosity replacing organisms and bands with scattered small vugs

Depth	Lithology
Feet	
5,518-5,535	Dolomite: light grey, fine to medium crystalline, tight; large, irregularly shaped inclusions of white anhydrite, many surrounded by green argillaceous material; 1 inch at base of light green argillaceous dolomite banded with bright green pyritic shale
5,535-5,542	Dolomite and shale: dolomite, buff and grey, fine to medium crystalline; thin, irregular bands of bright green shale; scattered inclusions of white anhydrite
5,542-5,550	Dolomite: buff, fine to medium crystalline; scattered small vugs and some inter-crystalline porosity; some vugs partly filled with white anhydrite
5,550-5,555	Dolomite: buff and grey, finely crystalline, tight, brittle; light green argillaceous dolomite inclusions
5,555-5,558	Dolomite breccia: light brown, finely crystalline, tight, brittle, cemented with white crystalline anhydrite
5,558-5,590	Dolomite: buff, fine to medium crystalline; vuggy porosity and, in places, good inter-crystalline porosity; some infilling of vugs with white anhydrite
5,590-5,595	Argillaceous dolomite: light greenish grey; irregular and wavy greenish grey shale laminae
5,595-5,606	Dolomite: light yellowish brown, finely crystalline; scattered small vugs; brachiopod; stylolites
5,606-5,614	Argillaceous dolomite and shale: dolomite, argillaceous, grey; irregular partings and inclusions of dark greenish grey shale
5,614-5,622	Dolomite: dark brown, finely crystalline; vuggy porosity; inclusions of white anhydrite

Depth	Lithology
Feet	
5,622-5,636	Dolomite and shale: dolomite, brown and grey, granular, argillaceous; irregular inclusions and partings of dark grey shale, in part may be ripple-mark; scattered pyrite
5,636-5,643	Shaly dolomite and shale: greenish grey; irregular layers and inclusions of greenish grey shale; sharp break
	Middle Woodbend shelf margin reef complex
5,643-	Dolomite: light grey, fine to medium crystalline; vuggy porosity; some vugs filled with pyrobitumin

The shale break at the base may be traced across most of the southern Plains. The dolomite and shaly dolomite above varies from the off-reef sequence described from the Imperial Golden Hill well to massive, clean, reef dolomites. In some places as, for example, in the Princess field, argillaceous dolomites and anhydrite are interbedded with clean porous dolomites that probably represent small, low reefs. The zone of small reefs grades, in turn, to massive reefs, as illustrated in Figure 2 by Anglo-Heathdale No. 1, Gulf Gridley No. 6, and Hudson's Bay West Drumheller 2-1 wells. An analogous transition is apparent in the 'white reef' -coral bed relationship in the upper part of the Mount Hawk formation in the Rocky Mountains (11). In other places, such as near Swalwell in tp. 30, rge. 25, W. 4th mer., and in a number of places over the Bashaw complex, anhydrite represents a back or inter-reef facies. One of the large reef masses of the Delia member extends outward from the shelf margin reef complex over the shale basin and interfingers with the upper Ireton. The relationship of this mass to the upper Ireton and to the Nisku is illustrated in some detail in Figure 4.

This zone of interbedded dolomites and shales is here correlated with the upper Ireton. Its relation to the Winterburn will be discussed later. Previously, it has been referred loosely to the Jefferson and the overlying anhydrite to the Potlatch. The difficulties involved in making this correlation are apparent from an examination of Figure 2, Western Byemoor No. 34-8 well to Widney Ward No. 1 well, where the Delia dolomite facies is both underlain by, overlain by, and interfingers with, anhydrite. Just where the Jefferson of central Montana fits into this section is impossible to determine with present well control. This difficulty is recognized in northeastern Montana, where, according to Perry (12), the Canadian nomenclature is found more satisfactory than central Montana terms.

CENTRAL ALBERTA PLAINS

The Woodbend of the central Alberta Plains following deposition of the Cooking Lake is clearly differentiated into shale and reef facies. Reef growth and shale deposition must have been to some extent simultaneous, but it seems more convenient to describe first the reef complexes and then the off-reef shale facies.

Reef Complexes

The major period of reef growth in the Upper Devonian of Alberta followed the Cooking Lake and is referred to in this paper as middle Woodbend. At this time, patterns of reef growth developed definite linear tendencies, probably related to banks and shoals in the Cooking Lake and, more fundamentally, to lines of tectonic weakness in the Precambrian basement. The distribution of the reef chains at the close of the period of major reef-building is shown roughly in Figure 1, and cross-sections through them are illustrated in Figure 2, with the vertical scale greatly exaggerated. This major period of reef growth may be subdivided into an earlier and later part. In the earlier, or lower, period the reefs and closely associated carbonate deposits referred to here as the reef complex are dark in colour and contain a considerable amount of brown argillaceous and bituminous material. Stromatoporoids, many of them large, are, probably, the most abundant single organism. The dark reefs and associated carbonate deposits, consisting of reef-derived detritus, pelletoid and other carbonate beds, are loosely referred to as 'black reef'. The distribution of the 'black reefs' and associated deposits is, to a certain extent, the same as that for the later 'reefs' shown in Figure 1, but the earlier 'reefs' spread out to cover a much wider area. The 'black reef' section is probably the reef equivalent of the Duvernay. The dark stromatoporoidal limestones and dolomitized limestones extending from the shelf margin over southeastern Alberta are probably equivalent to the 'black reef' of the reef chains. Beds or masses of weathered, black debris along the edges of the reef chains at the top of the 'black reef' suggest that these reefs have been subjected to severe erosion and may once have had considerably greater elevation than they now have.

On this 'black reef' base has grown the upper or 'white reef' zone. Study of the limestone 'white reefs', namely Redwater, Golden Spike, and Duhamel, shows that these are not simple reefs but contain a varied carbonate lithology. Stromatoporoids are less abundant than in the 'black reef', and much of the reef mass is fine-grained, comminuted, organic debris and much of it is white, dense limestone, probably formed largely by lime-trapping algae. White dolomites also occur in the upper part of the reef complexes along the southern Alberta shelf and in the Bashaw complex[1]. To the north,

---

[1] The term Bashaw reefoid area was used by Storey (13) presumably to refer to the complicated area of reefoid dolomites, back-reef evaporites, and dense limestones that occupy a large region between the towns of Red Deer and Stettler. This complex has been only indefinitely outlined by drilling and is roughly indicated on Figure 1.

---

the Grosmont reef complex is composed entirely of dolomitized 'white reef'. It seems to represent a shelf margin reef complex in the middle or late Woodbend, the Hondo[2] evaporites, and sugary, silty

---

[2] The Hondo occurs only on the northern margin of the area discussed (See Imperial Caslan No. 1 well, Figure 3). As it has been discussed in detail (3) no further reference is made to it here.

---

dolomites representing the shelf deposits. Whether or not the 'white reef' zones of the shelf margins, Grosmont and Bashaw complexes, and of the reef chains are the same age is still a matter for speculation.

The reef chains are surrounded and covered by shales. Towards the base the reefs pass into the Duvernay black shales and limestones, and above they are surrounded and overlain by the green Ireton shale. The relative age of the reef masses and the enclosing shale forms an interesting subject for speculation. Several possibilities are presented briefly below, although no proof or strong evidence can be presented for any one hypothesis. The Duvernay dark brown shales and limestones, which by their nature suggest a 'starved basin', may, for instance, be the time equivalent of the whole period of reef growth, or they may represent only the brown, highly stromatoporoidal limestones and dolomitized limestones overlying the Cooking Lake in the reef complexes. In the latter case, the 'white reef' zone overlying the 'black reef' may be considered to be equivalent to the basal Ireton limestone member and, in the centre of the basin, to the thin, black, basal Ireton shale. Or, again, the upper or 'white reef' zone may have grown by pulsations, the rate of subsidence of the basin permitting vertical growth to a relief of, perhaps, from 50 to 150 feet. This hypothesis gains some support from the occurrence of massive-bedded dolomites in the Upper Fairholme of the Rocky Mountains and from breaks in reef growth in the Rimbey-Meadowbrook and Redwater reefs marked by brecciation and infilling of light green shale. Thin limy shales and fossil beds in the off-reef Ireton may correspond to the periods of reef growth and the shales may be considered as filling in the surrounding basin during periods of relative quiescence in reef growth resulting from drowning, exposure, or changes of salinity. Still another hypothesis assumes that reef and shales accumulated contemporaneously, there being little difference in relief between the two at the time of deposition. The apparent transition zone from shale through shaly limestone and dolomite to the clean dolomites of the shelf margin reef complex gives some support to this idea.

Off-Reef Shale Facies

Duvernay Formation

In the embayment referred to as the shale basin, as contrasted with the shelf area (See Figure 1), the Woodbend group above the Cooking Lake formation is divided into the Duvernay and Ireton formations (6). The Duvernay overlies the Cooking Lake formation. It consists of interbedded, dense to fine-grained, brown limestones, dark brown to black, bituminous shales, and, less common, light greenish and brownish grey shales and shaly limestones. Throughout the area under discussion the strata are lithologically similar to those of the type section (6, pp. 1,817-1,819). Cores from wells between the Rimbey-Meadowbrook reef chain and the shelf margin show evidence of numerous small breaks in deposition, such evidence, for example, as small-scale erosion and filling in of cracks, thin quartz sandstones, pebble beds, thin layers of pyrite, and fish remains. Shales and shaly limestones contain an abundance of black carbonaceous material, probably of plant origin, and plant spores are common. The general character of the Duvernay suggests deposition under conditions of restricted circulation. Whether it indicates deep water or a putrid shallow basin protected by bars, banks, or reefs from the open sea is still a question. Fluctuation in subsidence and water level permitted alternation of euxinic and open water conditions.

In the basin east of the Rimbey-Meadowbrook chain and south of the Redwater field the Duvernay formation is generally about 150 to 180 feet thick, thinning locally, as in the Camrose-Duhamel area, to 70 or 80 feet. West of the Rimbey-Meadowbrook reef chain, greenish and brownish grey shales stratigraphically equivalent to the Cooking Lake formation are included with the Duvernay, giving a thickness varying from 240 feet in Imperial Paddle River No. 1 well to about 400 feet in Imperial Westlock and Imperial Dapp No. 1 wells for the total section (See Figure 2). The age of this greenish grey shale section relative to the Cooking Lake has been discussed on page 6. North and northeast from the Redwater field (See Figure 3) the Duvernay thickens gradually to 535 feet in the Imperial Caslan No. 1 well. The lower part of the Duvernay in this part of the basin seems to be transitional to the upper part of the Cooking Lake. Transgression of the Duvernay over the Cooking Lake from a shale basin to the north or northeast is indicated.

In the vicinity of the reef masses, both in the reef chains and about the margin of the shelf, dark stromatoporoidal limestones become more abundant in the Duvernay formation and the Duvernay section thickens. This suggests that reef growth in Duvernay time may have spread out more extensively than later reef growth. The writer prefers to restrict the term Duvernay to the interbedded limestone and shale facies of the basin, cutting it off at the shelf margin where dolomitization of the limestones indicates a change in conditions, possibly biohermal reef growth along the shelf margin.

The significance of the rapid variation in thickness and lithology of the Duvernay requires consideration. To the northeast, thickening seems to represent an approach to open-water conditions. Thickening of the Duvernay in the vicinity of the shelf margin reef complex, on the other hand, is largely due to the intercalation of limestones in the shales. These limestones may be represented by only a thin shale layer in basin deposition. Hence, the 60 to 80 feet of Duvernay in the Stettler-Duhamel area may represent a true starved basin deposit. On the other hand, there is evidence of accumulation of reef detritus at the close of the Duvernay period of reef growth in, for example, Texaco Wizard Lake B9 well in l. s. 3, sec. 22, tp. 48, rge. 27, W. 4th mer., Okalta Leduc No. 1 well in l. s. 13, sec. 7, tp. 50, rge. 25, W. 4th mer., California Standard Narrow Lake well in l. s. 5, sec. 19, tp. 65, rge. 24, W. 4th mer., and Sharples Stanolind Superior Tawatinaw well in l. s. 8, sec. 5, tp. 62, rge. 23, W. 4th meridian. Sharp breaks near the top of the Duvernay shale have been observed in the cores of Imperial Labyrinth Lake in 15-14-48-23 well, Imperial Westlock 14-24-59-26 well, and Gulf Gridley No. 6 well in l. s. 6, sec. 14, tp. 34, rge. 20, W. 4th meridian. These facts and the rapid change of lithology from the Duvernay to the Ireton, and from the stromatoporoidal Duvernay equivalent of the shelf area to the overlying evaporitic facies, suggest that an interval of non-deposition or even erosion may have occurred at the close of Duvernay time.

The following fauna has been obtained from the Duvernay well sections[1]:

---

[1] Identifications made by D. J. McLaren.

<u>Calvinaria</u> ? <u>inelegans</u> McLaren
<u>Nudirostra</u> <u>insculpta</u> McLaren
<u>Atrypa</u> spp.
<u>Eleutherokomma</u> cf. <u>jasperensis</u> (Warren)
<u>Warrenella</u> <u>nevadensis</u> (Walcott)
    (= <u>W.</u> <u>eclectea</u> Crickmay)
<u>Tentaculites</u> sp.
cf. <u>Leptodesma</u> sp.

goniatite fragments
<u>Echinocaris</u> ? sp.
ostracods
fish fragments
conodonts

This fauna is similar to that of the Perdrix formation of the Rocky Mountains[1].

[1]D. J. McLaren: personal communication.

Ireton Formation

The Ireton was originally described by the geological staff, Imperial Oil Limited (6, pp. 1,816-1,817). Over most of the basin it may be separated into a lower, predominantly shale, member, and an upper, interbedded limestone and shale, member referred to hereafter as the Lower Ireton and Upper Ireton, respectively. The lower part of the Lower Ireton, throughout most of the basin consists of interbedded limestone and shale gradational downwards to a black shale and upward to the green calcareous shale member. The Lower Ireton rests on the Duvernay formation. In cores of several wells the uppermost break in deposition in the Duvernay was seen to occur 3 to 10 feet below the top of the black shale. Probably, the upper part of the black shale, commonly included with the Duvernay, belongs properly with the Ireton, but, as this break cannot be determined with accuracy unless cores are available, for practical purposes all the black shales are placed in the Duvernay. The limestones and shaly limestones in the basal Ireton are ribbon-banded or nodular; in the latter case, the shale layers ripple over and under the more limy nodules. The limestones become thicker and cleaner in the approaches to the shelf margin and reef chains (<u>See</u> Figures 2 and 3). Possibly in the more central parts of the basin the black shale may be the equivalent of the basal limestone-shale member. The basal limestone and shale member grades upwards to greenish grey calcareous shales that carry a sparse fauna of <u>Tentaculites</u>, <u>Lingulas</u>, and ostracods. Along a narrow belt following the margin of the shelf the green shales grade to argillaceous limestones and dolomites with thin shale partings. These are included with the Ireton to avoid unnecessary complication of the nomenclature. The Lower Ireton ranges from approximately 300 to 500 feet in thickness east of the Rimbey-Meadowbrook reef chain and up to 600 feet west of the Rimbey-Meadowbrook reef chain. The Lower Ireton shale facies is gradational upward to the Upper Ireton, or interbedded limestone and shale facies. The contact between the two parts of the Ireton is based on the appearance of shelly limestone beds in the shales and is not a time line over any extensive area. The relationship between the two is illustrated in Figures 2 and 3.

The interbedded shelly limestone and shales of the Upper Ireton cover the green shale facies of the Lower Ireton over most of the basin, the shell limestone beds becoming thicker and more abundant to the east and northeast, for example, in the Vegreville and Smoky Lake areas. The shelly limestone facies thickens in the proximity of the shelf margin reefs and thins west of the Rimbey-Meadowbrook reef chain, where conditions favourable for shale deposition, but excluding a shelly fauna, seem to have lasted for a longer time than in the basin east of the Rimbey-Meadowbrook reef chain. Dolomitization of the limestones and red colours in the shales are also notable in the northeast part of the basin, but the extent and full significance of these facts cannot be determined as post-Devonian erosion has cut into the Ireton. Probably these characteristics indicate approach to a shoreline. The shelly limestone and shale facies grades upwards into a lighter green, granular, argillaceous dolomite that on disintegration leaves a fine quartz grain residue commonly below silt size. Attention is called to these beds in Figures 2 and 3 as a valuable marker. Above this zone, interbedded argillaceous dolomites, dolomitic shale, and crystalline dolomites continue to the base of the Nisku. In the vicinity of the Duhamel reef chain the Upper Ireton predominantly shale facies passes laterally to the Delia. predominantly dolomite facies, described above.

The following fauna[1] has been collected from the Upper

---

[1]Identifications made by D. J. McLaren.

Ireton of various wells in the green shale basin:

<u>Thamnopora</u> sp.
<u>Hexagonaria</u> cf. <u>bassleri</u> (Webster and Fenton)
<u>Synaptophyllum</u> cf. <u>stramineum</u> (Billings)
<u>Lingula</u> sp.
<u>Orbiculoidea</u> sp.
<u>Schizophoria</u> cf. <u>iowensis</u> (Hall)
<u>Douvillina</u> cf. <u>arcuata</u> (Hall)
cf. <u>Douvillina</u> sp.
"<u>Leptostrophia</u>" sp.
<u>Nervostrophia</u> cf. <u>iowensis</u> (Fenton and Fenton)
<u>Schuchertella</u> cf. <u>prava</u> Hall
<u>Chonetes</u> sp.
<u>Atrypa</u> cf. <u>devoniana</u> Webster
<u>Cyrtospirifer</u> cf. <u>gradatus</u> (Fenton)
<u>Cyrtospirifer</u> sp.
<u>Indospirifer</u> ex gr. <u>I.</u> <u>orestes</u> (Hall and Whitfield)
<u>Tenticospirifer</u> cf. <u>cyrtiniformis</u> (Hall and Whitfield)
cf. <u>Theodossia</u> sp.
<u>Cyrtina</u> cf. <u>iowensis</u> Fenton and Fenton
<u>Platyostoma</u> sp.
fenestellid and trepostome bryozoans

This assemblage is similar to that carried by the middle and upper Mount Hawk formation of the Rocky Mountains (Nudirostra albertensis zone[1]).

---

[1] D. J. McLaren: personal communication.

WINTERBURN GROUP

The Winterburn was defined (6) as a formation in the Edmonton area and was divided into the Nisku, Calmar, and Graminia members. The members are here treated as formations and the Winterburn used as a group name. This terminology is used to apply throughout the area underlain by the Ireton shale basin as defined in this report and as illustrated in Figure 2.

Nisku Formation

The Nisku formation may be subdivided into three members referred to as A, B, and C, A being the lowest of the three. The A member is a grey and buff, finely crystalline dolomite that is particularly well developed immediately west of the Rimbey-Meadowbrook reef chain, and, though thinner, probably occurs off the Duhamel, Grosmont, and Redwater reef complexes (See Figures 2 and 3). The dark dolomite breccia that forms the bottom 20 feet of the type section in B. A. Pyrcz No. 1 well may be the equivalent of this member. Characteristics of this member where cored in Ponder Leduc No. 1 well suggest a similarity with the uppermost reef-type dolomite of the Ireton, but more control is necessary before this correlation can be made. Meanwhile, as a dolomite, not readily separated from the Nisku, it is included with the Nisku. To the west and northwest, for example in Imperial Dapp No. 1 well, it interfingers with fossiliferous limestones and shales.

The B member of the Nisku is a crystalline dolomite with an apparently irregular distribution of original porosity that suggests vuggy reef growth and fine-grained inter-reef dolomite, rather than a simple biostrome. Much work needs to be done to determine its actual character. Eastward, this member grades into anhydrite with thin silt beds, and this, in turn, seems to pass into an anhydrite-red bed zone east and southeast of the shelf margin (See Figure 2, Socony Flint No. 1 to Imperial Golden Hill No. 12-2-30-16 wells). Breccias and the thin Nisku section in Socony Flint No. 1 well probably represent leaching of the anhydrite, as the later Devonian cover has been largely eroded from that area. West of the Rimbey-Meadowbrook chain, between the Grosmont and Rimbey-Meadowbrook chains, and northeast of the Grosmont reef complex, quartz sands and silts form the off-reef facies of this member. The large amount of sand and silt in the Nisku equivalent and in the detritus derived from the Devonian in wells northeast of the Grosmont reef complex, coupled with the presence of tourmaline in the sands, suggests that the source of the sand is the Canadian Shield and the limitation of the dolomite facies in this direction. Deposition along the reef fronts was probably controlled directly by the presence of reefs acting as bars that caused a change in turbulence of the water with the consequent dropping of the sand load and winnowing of the argillaceous material. Superior Wabamun No. 1 well (See Figure 2) shows a thin sandstone stringer. West from Superior Wabamun No. 1 well the B member of the Nisku seems to grade to dull, greenish grey, splintery, calcareous shales.

The upper or C member of the Nisku consists of interbedded dolomites and siltstones and seems to be gradational both laterally and vertically to the Calmar. Eastward it grades to anhydrite. This upper member is sharply separated from the B member by a thin bed of sandstone and bright green shale. Evidence of leaching of the underlying member is common. This member can be traced from Imperial Golden Spike No. 3 well eastward to Canadian Gulf W. E. Porter No. 16 well. West of Golden Spike No. 3 well it cannot be separated with certainty from the Calmar.

Calmar Formation

The Calmar formation in the type section (6, p. 1,814) consists of light green shale and argillaceous siltstone, in places spotted red. It is well developed in the Leduc area and westward but thins rapidly to the south and southeast and cannot be identified southeast of a line joining Gulf Gridley No. 6 well in tp. 34, rge. 20, W. 4th mer., to Gulf Porter No. 16 well in tp. 41, rge. 18, W. 4th meridian. The Calmar seems to show relatively high radioactivity as plotted on the gamma ray curve of radioactivity logs. This characteristic serves to distinguish it from the overlying Graminia sandstone and is of special value in places where only one sand is present.

Graminia Formation

The Graminia formation consists of white, quartzose, fine-grained sandstones or siltstones and interbedded dolomite. East and southeast of the type area (6, p. 1,814) the dolomites change to anhydrite and the section thins. In places, it consists only of thin lenses of fine-grained dolomitic quartz sandstone. Beyond the shelf margin it becomes part of the anhydrite-red bed-sandstone zone. West of the type area the dolomites thicken and probably form reefs. The major dolomite section in Imperial Paddle River No. 1 well and, by analogy, the dolomite in wells south and west of Lesser Slave Lake, are here correlated with the Graminia.

Problems of Correlation of Formations of the Winterburn Group

The correlation of the Nisku dolomite, both to the west and to the southeast, presents an interesting problem. The accompanying figures (Figures 2, 3, and 4) illustrate a theory of correlation that seems, at present, to be the most satisfactory. However, well control is inadequate to prove the correlations and they are presented largely to stimulate discussion that may lead in time to the solution of the history of the basin. The interpretation presented in the diagrams and alternate interpretations are discussed briefly below.

To the west and northwest of the Rimbey-Meadowbrook reef chain, the Nisku is illustrated as passing from dolomite through the reef-flanking sandstones to shale facies in Imperial Paddle River No. 1 well. North of the section illustrated, interfingering limestones and shales intervene between the dolomite and shale facies. An alternate correlation, which assumes greater subsidence in the Ireton shale basin west of the Rimbey-Meadowbrook chain, would place the total shale and shaly limestone section in the Ireton and the overlying dolomite in the Nisku. The sand at the top of the section in Imperial Paddle River No. 1 well would, then, correlate with the Calmar formation, the Graminia becoming indistinguishable from the Calmar. Following this correlation, the Graminia sandstone and dolomite become a purely local phenomenon in the vicinity of the Rimbey-Meadowbrook reef chain. The choice presented in Figure 2 is based partly on the presence of a granular, argillaceous, finely silty dolomite in Imperial Paddle River No. 1 well similar to that beneath the Nisku in the Edmonton area. Secondly, the thickening of the Graminia westward from Leduc to the Texaco British Dominion Carvel No. 1 well and other wells in that vicinity suggests that it will continue to thicken to Imperial Paddle River No. 1 well rather than disappear. Thirdly, build-up of sands in the Nisku suggests the western margin of a reef trend.

Another, and highly controversial, problem lies in the relation of the Nisku formation to the porous dolomites in the section above the middle Woodbend reefs in the Stettler-Drumheller embayment, over the southern Alberta shelf and the Bashaw complex. The massive oil-producing dolomite of the Stettler-Drumheller embayment is commonly correlated with the Nisku (2, 18). In this report, it is considered as a facies change from the shelly limestone and shale of the Upper Ireton, and hence below the Nisku. Figure 4 illustrates the relationship that, at present, seems to the writer to show the most probable correlation. This figure is based largely on wells in which the section in question is cored, and in which the entire section above the Beaverhill has been drilled. Some of the lines of evidence leading to this correlation may be noted. First to place these beds in the regional picture; a green shale zone with minor brachiopod-crinoid beds overlies the evaporites and shelf margin reefs of the middle Woodbend. This is similar to the shales of the lower part of the Upper Ireton and seems to be an extension of this shale over the shelf area, in the same manner as this shale extends over the Rimbey-Meadowbrook and Duhamel chains. Between this shale and a succession of sandstone beds are the reefoid dolomites, 'coral-beds', and shales of which the correlation is in question. If these beds are equivalent to the Nisku some 150 to 200 feet of Upper Ireton beds are missing, and there is little evidence for this other than minor breaks in deposition below the dolomite part of the section. On the other hand, there is abundant evidence for an unconformity at the top of the dolomite. (1) The dolomite is leached to a sugary texture and is mottled with black oil; (2) rounded pebbles of light brown dolomite occur in light green anhydritic shale in Western Dome Thelma well in l.s. 16, sec. 21, tp. 34, rge. 12, W. 4th mer., at 3,880-3,890 feet and strongly suggest erosion and re-working of upper Woodbend dolomite; (3) in the core of Bailey Chinook No. 1 well in l.s. 13, sec. 19, tp. 26, rge. 6, W. 4th mer., a weathered, porous, brecciated dolomite, stained with black oil and with the brecciated zone filled with bright green siltstone and shaly material, occurs at 3,650 feet; (4) bright green waxy shales and thin siltstone and sandstone layers rest in sharp contact on the reef dolomite in wells of the Princess field and the West Drumheller field; (5) the eastward transition of Nisku anhydrites to red beds, siltstones, sandstones, and red-mottled anhydrite suggests shoreline deposits that might be equivalent to a much thicker seaward section or they may represent a residual zone or a combination of both shoreline and residual zones; (6) the dolomite that is separated by a thin shale break from the Nisku in Socony Flint No. 1 well may be seen to grade rapidly westward to the greenish grey, shaly dolomite of the Upper Ireton (See Imperial Labyrinth Lake No. 15-14 well) and northeastward to become an easily recognizable member of the shelly limestone and shale beds under the Nisku in Socony Vegreville No. 1 well and all other wells in that area. It may also be traced southeastward to Socony Craigmyle No. 1 and Hanna Syndicate No. 4 wells, and southwest to Husky Phillips Pine Lake No. 1 well. It appears to be the seaward extension of more strongly reefoid facies over the shelf and the Bashaw complex. This facies change, namely, shelly limestone to massive reef, is illustrated in Figure 4. This pattern seems to be in accord with expected regional facies changes. The Nisku dolomite, on the other hand, is seen to grade southeastward to anhydrite. This anhydrite may represent the filling of a basin surrounded by Nisku reefs, as suggested by Laurence (7), but it seems more probable that the anhydrite is marginal to a shoreline where the red evaporites, shales, and sands were being deposited, and grades seaward to the Nisku dolomite.

The Calmar pinches out to the southeast and the Graminia probably becomes a part of the sandstone, red-bed, anhydrite zone between the Woodbend and the Wabamun. It is missing or very thin in many places, probably where reef masses formed local 'highs' that were later covered by anhydrite during Wabamun time, for example, in the Princess and West Olds areas.

WABAMUN GROUP

The Wabamun was described by the geological staff of Imperial Oil Limited in 1950 (6, pp. 1,810-1,813), the description applying to the limestone and dolomite beds that occur west of the Rimbey-Meadowbrook reef chain. Wonfor and Andrichuk (18), with reference to the Stettler area, divided it into an upper member, the Big Valley, and a lower member, the Stettler. These will be described in a forthcoming paper by J. S. Wonfor[1], as formations

[1] J. S. Wonfor; personal communication.

and the term Wabamun used as a group.

STETTLER FORMATION

The Stettler formation in the Stettler area is largely evaporitic in character but can be traced without break westwards to the dolomite and limestone facies of the type Wabamun area. The term Stettler is, therefore, extended to apply to the lower unit of the Wabamun, regardless of the facies developed. The Stettler formation consists of several distinct zones. The basal zone is of salt and primary anhydrite in the Stettler area and grades laterally to primary anhydrite. In many wells in the Edmonton area a brecciated zone and chert nodules may represent this basal anhydrite. This zone is overlain by anhydrite, and sugary, evaporitic dolomites that, westwards, interfinger with crystalline dolomites and change, farther west, to fine-grained limestones and dolomites. This transition is illustrated by Figure 2, although, in the line of section, the Wabamun is interrupted where it has been partly destroyed by post-Devonian erosion. Some of the dolomite zones seem to persist across most of Alberta.

To the southeast the Stettler formation thins and changes to shaly dolomite, green shale, and anhydrite, the latter being in part secondary. Thin siltstone and fine-grained quartz sandstone beds seem to come in from the east. This facies change is illustrated in Figure 2 from Home High Crest Steveville No. 1 to Widney Ward No. 1 wells. The top of the Stettler formation is marked by a zone of sugary dolomite and, commonly, breccia and black oil stain. This suggests a period of quiescence near sea-level and possible exposure before the deposition of the succeeding Big Valley formation. The Stettler ranges in thickness from 165 feet in Widney Ward No. 1 well to about 500 feet in the Stettler area and to 650 feet in Imperial Paddle River No. 1 well.

BIG VALLEY FORMATION

The Big Valley formation consists of 20 to 60 feet of grey-green shale, light grey, dense, argillaceous limestone, and crinoidal limestone. It seems to be more argillaceous to the south and southeast and more limy over the Woodbend shale basin. A thin crinoidal limestone may commonly be distinguished in the upper part. The Big Valley is traceable from the Saskatchewan boundary westward over the Devonian, at least as far as Imperial Paddle River No. 1 well and it probably extends into the Peace River country. In the past it has been loosely correlated with the Three Forks of Montana, but, as the exact correlation cannot be determined with present well control, the term Big Valley is preferred.

EXSHAW FORMATION

The Big Valley is sharply separated from the overlying black shale. This shale, because of its lithology and stratigraphic position, is referred to the Exshaw formation of the Rocky Mountains. Over the Plains it varies from 5 to 30 feet thick. No new information on it has been obtained during the compilation of this paper, and as, regardless of its age, it marks the beginning of the Mississippian cycle of sedimentation it is not discussed here in detail.

GEOLOGICAL HISTORY

Woodbend deposition in central and southern Alberta was initiated by the accumulation of the Cooking Lake limestones. These seem to indicate that a shallow water, slowly subsiding shelf, marginal to an extremely low land mass, covered this area and stretched eastward across Saskatchewan and westward to the Rocky Mountains. Shallow banks and shoal reefs formed the seaward front. The open sea, where free circulation of currents brought in mud, lay to the north and in an embayment to the west.

Following the Cooking Lake, the pattern of major Woodbend reef growth seems to have been established. This pattern is illustrated in Figure 1 and shows the differentiation of a broad shelf area in southern and southeastern Alberta separated from the Duvernay shale basin by a belt of stromatoporoid limestone and dolomitized limestone. Other reef belts show linear arrangement in the shale basin. Differential subsidence, probably controlled by lines of weakness in the basement complex, may have been the important factor in determining reef distribution. In embayments protected, probably by reef growth, from open circulation of sea water, the brown limestones and black shale of the Duvernay were deposited.

Subsidence continued through the middle Woodbend at a rate favourable for the growth of reef masses. The relative narrowness of the belts of reef growth as compared with the reef belts of Duvernay time suggests an increased rate of subsidence and a preference for vertical rather than lateral reef growth. Reefs developing marginal to the shelf area both in southeastern Alberta and in the Grosmont reef area of northeastern Alberta, by restricting circulation of sea water, must have played an important part in the development of vast evaporating pans marginal to a flat-lying land mass. The Grosmont reef complex and reef masses in wells in eastern Alberta show that the embayment was considerably smaller than earlier in the Woodbend.

Tectonic readjustments later in Woodbend time caused gradual decrease in the rate of subsidence of the basin concomitant with positive movements in neighbouring land masses. The result was a return to shallow water conditions in the Upper Ireton and some redistribution of conditions favourable for reef growth. Relatively small reefs and possibly biostromes developed over the Woodbend shelf and over the margin of pre-existing reefs. These reef masses tended to grow outward over the Ireton shale basin and to pass laterally to shelly limestones and shales, the outward growth probably being encouraged by compaction of the underlying Ireton shales and the shallow-water conditions.

Succeeding positive movements, emanating from a southeasterly direction, resulted in the withdrawal of the sea from southeastern Alberta and the northwestward migration of the axis of shale deposition. The Nisku dolomite with its small reefs formed the front of a large evaporite basin that thinned against a shoreline to the south and southeast, red beds and sands indicating the pinchout. This shoreline seems to have been largely controlled by the line of weakness that earlier in the Woodbend separated the shelf from the shale basin. The Nisku formation may represent the last phase of the progressive northwestward outgrowth of reef organisms from the middle Woodbend shelf, but, as it is separated areally from the other Upper Ireton reefs and has such an extent of evaporites behind it, it has been treated as a separate entity. The Nisku, like the lower reef masses, was flanked westwards by shale. Late in the Nisku and in the succeeding Calmar, as positive movements reached a maximum, retreat of the sea from central Alberta was almost complete.

To the northwest, over the shale facies of the Nisku, reefoid dolomites interbedded with sand accumulated during Graminia time. The upper part extended over the Leduc reef chain and clean white quartz sandstones, possibly in part reworked Calmar, extended at least as far southeast as the front of the middle Woodbend shelf. This formation probably indicates the beginning of a renewed marine cycle comprising the Graminia formation and Wabamun group. In this cycle the seas did not extend as far to the southeast as they had earlier in the Devonian and the locus of maximum subsidence was probably far to the northwest. The Wabamun evaporitic sequence was deposited over much of the Woodbend shale basin, Wabamun shales and sandstones forming in the south and east, while thick limestones accumulated to the west. The closing episode of the Wabamun was marked by a widespread return of the sea and the deposition of fossiliferous limestones and shales of the Big Valley formation. This, in turn, was succeeded by the complete change of conditions that resulted in the deposition of the Exshaw and similar shales in the Plains.

In summary, the Upper Devonian of central Alberta from the beginning of Woodbend time represented recurring cycles of positive and negative tectonic movements and resultant advances and regressions of sea-level. A cycle of subsidence beginning with the Woodbend resulted in the period of major reef growth. Regression during late Woodbend permitted the development of horizontal components in reef growth, shallow reefs, and shallow-water limestones and shales. General positive movements in the land masses and the basin resulted in floods of sand flanking the Nisku dolomites and, during the period of maximum regression, the accumulation of the bright green and red shaly siltstones of the Calmar. A second major marine cycle, not as extensive as the Woodbend-Winterburn cycle, was initiated with the Graminia and continued with the deposition of the Stettler limestones and evaporites. The Stettler was followed by another extremely widespread shallow-water marine cycle that resulted in the deposition of the Big Valley formation. This was followed by a change of conditions and the deposition of the black shales that marked the Devonian-Mississippian boundary.