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CORRELATION OF DEVONIAN SUBSURFACE FORMATIONS, SOUTHERN ALBERTA

By
Helen R. Belyea

OTTAWA
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INTRODUCTION

A notable characteristic of the Upper Devonian rocks of Alberta is their rapid lateral variation in lithology. The present paper shows these lithologic variations, and correlates the Upper Devonian stratigraphic units from the central Alberta Plains across southern Alberta and into the Front Ranges of the Rocky Mountains.

The deposits of Upper Devonian age in southern Alberta were laid down in an epeiric sea that covered a vast shelf and in which conditions of depth, temperature, and salinity permitted, at times, local prolific growth of reef-building organisms. By partly impeding free circulation of sea water, the reefs were also a controlling factor in the distribution of other sediments; argillaceous clastics formed the chief deposits of the open sea; dark, fine-grained clastics and carbonates were deposited, probably, where reducing conditions prevailed; where protected by reef-like barriers from free circulation of sea water and the influx of clastics, carbonates and sulphates were precipitated from highly saline waters. The interrelation of these deposits in southern Alberta presents a complicated picture. In addition, gentle epeirogenic movements during Upper Devonian time caused shifts in the geographic position and shape of shelf and basin areas and, hence, in locale of reef growth. The interrelated deposits vary accordingly. The accompanying sections and maps illustrate the facies developed and their spatial relations.

This study is based entirely on lithologic data, as the cores of wells from which fossils might be obtained are few and the fossils are largely replaced by dolomite or anhydrite. When faunal data are available further studies may lead to revision of some of the conclusions drawn herein, but the interpretation presented seems to be the most satisfactory at present.

ACKNOWLEDGMENTS

The writer wishes to thank the Alberta Petroleum and Natural Gas Conservation Board for making cores and samples available for examination, and the Canadian Stratigraphic Service Limited for the privilege of examining some of their descriptive logs. Data from wells drilled by the following companies were used in the preparation of this report: Bailey Selburn Oil and Gas Limited, California Standard Company, Canadian Superior Oil of California Limited, Canadian Gulf Oil Company, Hudson's Bay Oil and Gas Company Limited, Husky Oil and Refining Limited, Imperial Oil Limited, International Petroleum Corporation, McColl-Frontenac Oil Company Limited, Phillips Petroleum Company, Shell Oil Company, Socony-Vacuum Oil Company of Canada, Sun Oil Company.

The Devonian section at the southeast end of the Rundle Range near Canmore was measured in collaboration with W. M. Tovell of the University of Toronto and the writer wishes to offer particular thanks to him.

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STRATIGRAPHY

POST-CAMBRIAN, PRE-UPPER DEVONIAN

Pre-Upper Devonian Unit A

Immediately overlying the Cambrian in southeastern Alberta, is a sequence of extremely finely crystalline, even-textured, pale coloured dolomites. These were penetrated in California Standard C.P.R. No. 1, Imperial Grassy Lake No. 3, Socony Wildhorse No. 1, Commonwealth Milk River No. 1 and Sunderland Warner No. 1 wells. They vary in thickness from 150 feet in Socony Wildhorse No. 1 well to 30 feet in Sunderland Warner No. 1 well and are not present in wells drilled to the west of the Princess field. They are lithologically similar to strata belonging to the Ordovician and Silurian systems in Saskatchewan and Montana[1]. The age of these beds has been discussed

[1] Price, L. L.: Personal communication.

by McGehee (12, p. 139)[2], but they cannot yet be assigned definitely

[2] Numbers in parentheses are those of references listed.

to either the Ordovician or Silurian systems and both are probably present.

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Unit FhB1, shale and dense limestone</td><td>Duvernay formation (off-reef)</td></tr>
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Pre-Upper Devonian Unit A</td><td colspan="3">Elk Point group</td></tr>
</table>

Seventy feet of pale, crypto-grained, dolomitic, limestone overlies Cambrian sandstones and shales in the International Blood No. 1 well. These beds bear some lithological resemblance to strata of Unit A in southeastern Alberta and may be correlative, or, more probably, they may be of Cambrian age.

Pre-Upper Devonian Unit B

Under this heading are described the beds of variable lithology and thickness present over most of southern Alberta, underlying the Upper Devonian Beaverhill formation and resting on Cambrian or Unit A strata, where the latter are present. This sequence has been penetrated by only a few wells and each well shows a somewhat different sequence. As a result, complete understanding of the unit and correlation of minor units within the major unit have not yet been established.

In almost all occurrences the unit consists of green shale, brown extremely fine-grained, dolomitic mudstones, and evaporite beds. Sandstones, sandy shales and gypsiferous red beds are prominent in the wells in southwestern Alberta, and a conglomerate composed of pebbles of the underlying dolomitic limestones forms the base of the section in International Blood No. 1 well. Marine limestones occur with the above strata in the wells in south central Alberta, for example in the Socony Tudor C.P.R. No. 1 and Socony Entice No. 1 wells.

The thickness of this unit is irregular; only 10 or less feet are present in Bailey Olds No. 1 well and 180 feet in Socony Tudor No. 1. Other wells that penetrate the whole of this unit show intermediate thicknesses. In general Unit B is thin in wells in which beds of Unit A are present.

The age of these beds has not been established. They occur in an approximately similar stratigraphic position to that of the Ghost River formation of the Front Ranges of the Rocky Mountains (see Harker, Hutchinson, and McLaren (10)) and are probably in part equivalent to the Middle Devonian Elk Point group described by McGehee (12).

UPPER DEVONIAN

Beaverhill Formation

The Beaverhill formation forms the lowest part of the Upper Devonian in both the central and southern Alberta Plains. The type section was designated in the Anglo-Canadian Beaverhill Lake No. 2 well (l.s. 11, sec. 11, tp. 50, rge. 17, W. 4th mer.) in the central Alberta Plains by the geological staff of Imperial Oil Limited (9).

It overlies the Elk Point group and underlies the Woodbend group. The type section is 722 feet thick, but only 530 feet of Beaverhill beds are present in Bailey Olds No. 1 well, 350 feet in International Blood No. 1 well, and 170 feet in McColl Frontenac Moose Mountain No. 1 well. Where the Bow Valley cuts through the Front Ranges of the Rocky Mountains the Beaverhill formation cannot be identified as a separate unit although it may be represented by the basal Fairholme beds.

In central Alberta, the Beaverhill formation consists of three major cyclical alternations, each composed of an upper shale and a basal carbonate, the latter including reefs or organic masses and evaporites. These stratigraphic subdivisions, indicated by Imperial Oil Limited (9) are herein shown as members of the Beaverhill formation and designated by numbers, consecutively from the base, as Bh1 to Bh6. In the southern Plains, the Beaverhill formation is thinner and consists of carbonates and associated evaporites, only the uppermost of the shaly members, Bh6, persisting over the whole area. The relationship of the individual cycles developed in the central Plains to the carbonate-evaporite beds of the southern Plains cannot be established with present well control, but the transition from one type of deposition to the other seems to occur between townships 30 and 35 north.

A stromatoporoid limestone rests on pre-Upper Devonian Unit B in Shell Westerdale No. 1, Socony Tudor C.P.R. No. 1, Bailey Olds No. 1 and Smith C.P.R. No. 1 wells. No definite evidence as to the age of this stromatoporoid limestone has been obtained and it is here included with the carbonates of the Beaverhill formation from which it cannot be readily separated. Crystalline, vuggy dolomites in Socony Entice No. 1, Socony Carbon No. 1, Socony Rockyford No. 1, and California Standard Princess C.P.R. No. 1 wells seem to be its dolomitized equivalent. Southeast, south, and southwest of these wells the stromatoporoid limestone and dolomite beds cannot be separated from the dolomites and evaporites that form most of the Beaverhill formation, and, indeed, they may not be present in the more southerly part of Alberta. The distribution of the stromatoporoid limestone, dolomite, and evaporite facies may parallel the trends indicated by the isopachs in Figure 4A.

The basal stromatoporoid limestone of the Beaverhill formation passes upward into a sequence of carbonates and evaporites that seem to be continuous with the upper limestone member, Bh5, of the Beaverhill formation of the central Plains, stromatoporoid limestones of Bh5 being well developed as far to the south as Dome Socony Michichi No. 11-5 and Shell Olds No. 1 wells. Farther south and southeast Bh5 grades into pelletoid and dense limestones with interbedded evaporites. As the Beaverhill formation decreases in thickness, marginal to the basin (see Figure 4A) evaporites, evaporitic dolomites, and dense limestones form most of the sequence; for example, in Socony Wildhorse No. 1, International Blood No. 1, and McColl Frontenac Moose Mountain No. 1 wells (Figures 2 and 3).

The uppermost shaly limestone and shale member (Bh6) of the type section in the central Alberta Plains is recognizable over most of the southern Plains and forms an excellent marker separating the Beaverhill from the overlying Fairholme group.

The progressive thinning of the Beaverhill formation westward as well as southward (see Figures 2 and 3) and the transition from the shale-carbonate lithology of the central Plains to the carbonate and carbonate-evaporite lithology of the southern Plains (see Figure 5A) suggests a shoreline not only to the south, as indicated by Andrichuk (1), but also to the southwest and west. The basal dolomite is interpreted as organic reefs, biostromes or organoclastic bars, or beaches marginal to a landmass.

Fairholme Group[1]

[1] D. J. McLaren in a report in preparation for publication raises the Fairholme from formation to group status.

The Fairholme group may be traced from outcrop sections of the Front Ranges of the Rocky Mountains below the surface across the southern Alberta Plains (see Figure 2). One of the objects of this paper is to illustrate the correlation of the Fairholme over this area and to show the lithologic changes that occur in it.

The term Fairholme formation was introduced by Beach (3), "for the succession of strata overlying formation D and underlying the Palliser formation in the Moose Mountain and Bow River regions". Later, de Wit and McLaren (7) restricted the Fairholme, excluding the silty strata at the top which they termed the Alexo formation and placing the top of the Fairholme at the top of the light grey, crystalline dolomite succession. Beach (3), in his description of the wells in the Moose Mountain area, also used the "highest horizon at which the coarse-grained light-grey dolomite occurs" as the top of the Fairholme.

The base of the Fairholme in the Front Ranges rests unconformably on pre-Upper Devonian beds without apparent discordance. The age of these beds and the relationship of the Fairholme to them has been discussed by Harker, Hutchinson, and McLaren (10). Eastward from the Front Ranges in Bow Valley, the Beaverhill formation wedges in at the base of the Upper Devonian, the Fairholme resting on the shaly uppermost member (Bh6) of this formation.

The top of the Fairholme, as in the mountain sections, is placed at the top of the massive, crystalline dolomite on which, in the Plains and Foothills, rest the dolomites, siltstones, shales, and evaporites of the Winterburn group. It ranges from about 900 to 1,100 feet in thickness in the southern Plains.

The Fairholme group is correlative with the Woodbend group of the central Alberta Plains, described by the geological staff of Imperial Oil Limited (9). The Fairholme appears to represent the deposits of a stable shelf area whereas the Woodbend largely represents reef masses and shales deposited in a subsiding basin. The boundary between the two is defined as the basinward edge of the shelf margin reef complex. This margin has been described both by Downing and Cooke (8) and by Belyea (5). The Fairholme group is also correlative with part of the Jefferson formation of central Montana, although exact correlation between the two cannot be established with present well control.

Four subdivisions are at present distinguishable in the Fairholme group. For convenience in description these are herein designated consecutively from the bottom FhA to FhD. FhA is the Cooking Lake formation; FhB and FhC are units of variable lithology, unnamed until future drilling elucidates problems of facies relationship and permits correlation with named outcrop units; FhD is the Delia formation.

Cooking Lake Formation, Unit FhA

The Cooking Lake formation was originally described for the Edmonton area by the geological staff of Imperial Oil Limited (9) and further description of the various facies developed and their distribution in central and southeastern Alberta has been given by Belyea (5). The Cooking Lake in southern and southwestern Alberta consists of alternations of fine-grained tightly cemented limestones, finely pelletoid or pseudo-oolitic beds, stromatoporoid limestones, and thin evaporites. Beds of grey shale and shaly limestone occur everywhere in the middle of the formation. The fine-grained limestones, suggestive of chemical precipitation under quiet water conditions, predominate. Stromatoporoid limestones and dolomites occur in the outcrop sections of the Front Ranges of the Rocky Mountains, and also to the east under the Plains, for example in Bailey Olds No. 1 well. Crystalline, vuggy dolomites probably represent the stromatoporoid facies in Shell Jumpingpound Unit 4 and Shell Crossfield No. 1 wells. One to three thin evaporite zones, each consisting of dense limestones, finely saccharoidal and earthy, evaporitic dolomites, and anhydrite, occur southeast and east of the crystalline dolomite facies and in general increase in thickness to the southeast. The lowest evaporite beds may be represented in the section on the southeast end of Mt. Rundle by cherty beds and finely saccharoidal limestone and dolomite. Figure 4B shows the distribution of facies in the Cooking Lake formation in southern Alberta.

The Cooking Lake rests on the Bh6 member of the Beaverhill formation and is overlain by a grey shaly limestone and shale zone, up to 20 feet thick. The base of this shale is taken as the top of the Cooking Lake formation as it forms the most persistent marker in the area. The Cooking Lake formation is about 200 to 220 feet thick in the southern Plains.

No fossils were collected from the Cooking Lake formation in the southern Alberta Plains, but in the central Plains it carries a Flume fauna (McLaren, 13).

Post-Cooking Lake Facies Distribution

The beds immediately overlying the Cooking Lake must be separated, for convenience of discussion, into the southern Alberta shelf deposits and the central Alberta basin deposits.

The shelf deposits consist of the upper three subdivisions of the Fairholme group; Unit FhB, Unit FhC, and the Delia formation (FhD). These subdivisions are described below.

In the central Alberta basin the post-Cooking Lake deposits are separated into off-reef and reef facies. The off-reef deposits consist of the shales and limestones of the Duvernay formation which are overlain by the shales of the Ireton formation; the reef deposits consist of the limestones and dolomites of the Leduc formation and similar reef complexes, all of which are included in the Woodbend group. These deposits have been described by the geological staff of Imperial Oil Limited (9), Andrichuk and Wonfor (2), and Belyea (5). The boundary between the two areas is drawn at the basinward edge of the shelf margin reef complex (*see* Figure 1).

Unit FhB, Stromatoporoid Limestone and Dolomite

The stromatoporoid limestone and dolomite sequence, Unit FhB, may be subdivided, except in areas of continuous reef growth, into a lower shale and dense limestone (Unit FhB1) and an upper predominantly reef unit (FhB2).

Unit FhB1, Shale and Dense Limestone

The shale and dense limestone unit (FhB1) is a persistent marker over central and southern Alberta, except for local areas where reef growth was continuous from the Cooking Lake. It is characterized by thin limestone bands or nodules in a grey or greenish grey shale and by low self potential and resistivity curves in electrologs of wells. In the central Plains it carries an Upper Flume fauna and is included in the Cooking Lake - Duvernay transition beds. In the southern Plains brachiopod fragments are common in drill cuttings but no cores are yet available to supply identifiable forms. In the southern Plains it is generally less than 20 feet thick.

Unit FhB2, Stromatoporoid Limestone, Dolomite, and Equivalent Beds

The shale unit (FhB1) is overlain by about 300 to 400 feet of strata herein designated Unit FhB2, consisting of stromatoporoid limestone and dolomite but including beds of other rock types believed to be equivalent.

The lower part of this unit is significantly different in character from place to place. In the reef chains and reef complexes, reefs beginning in the Cooking Lake seem to have continued to grow throughout the time this unit was being deposited, thus forming thick dolomite masses; a short distance from the reef chains, for example, in the Carbon-Entice-Olds area, the lower beds are predominantly limestone, in contrast with the main body of the unit which is dolomite; in other places, for example in the area represented by the wells between Socony Entice No. 1 and Husky Phillips Pine Lake No. 1 wells (see Figure 2) and in the McColl Frontenac Moose Mountain No. 1 well (see Figure 3), stromatoporoid limestones are interbedded with dark brown shales and shaly limestones to form a transition zone between the shale of Unit FhB1 at the base and the stromatoporoid limestone or dolomite of Unit FhB2 above. Elsewhere, alternating fine-grained carbonates and dark brown shales form equivalent transition beds. This transition zone, with its lateral and vertical gradation into reef deposits seems to be similar to the relationship of reef and off-reef deposits at Wapiabi Creek in the Bighorn Range in the central Foothills noted by Belyea(4).

The main body of Unit FhB2 is composed of dark, vuggy, crystalline dolomite that contains abundant stromatoporoids, corals, and Amphipora. These strata, described from exposures in the Front Ranges of the Rocky Mountains, may be recognized in cores from well sections all across the southern Alberta Plains (see Figures 2 and 3). The unit has been described for southeastern Alberta in a previous report by Belyea (5), but whether it is continuous from the mountains across the southern Plains is not certain, indeed embayments into the reef areas are suggested by the presence of dark brown, shaly limestones in the Roxana No. 1 well in the Moose Mountain area and in the bottom of the Amerada Stanolind Crown B.F. 21-A23 well in tp. 26, rge. 14, W. 4th meridian.

The stromatoporoid beds seem to be in the form of reefs or biostromes. Where they form part of the shelf margin reef complex they have been completely dolomitized; behind this feature they have remained predominantly limestone. The limestones in places contain abundant stromatoporoids and, in southern Alberta, are generally tightly cemented. Extremely fine-grained, chemically precipitated limestone and pelletoid beds are intercalated with them and anhydrite commonly fills voids and pore spaces. Anhydrite has also been deposited in thin beds from the area of Shell Little Bow River No. 1 well to the Princess Field in tp. 19, rge. 12, W. 4th meridian. From there the anhydrite content seems to increase generally southward towards an assumed shoreline in Wyoming. The distribution of these strata is illustrated in Figure 4C.

The basal transition zone of this unit suggests the mode of origin of the whole unit. As described above, stromatoporoid limestones and dolomites, in places, rest directly on the Cooking Lake formation and, in other places, are separated from it by shales and limestones. This suggests that reef growth started at favourable nuclei on the Cooking Lake surface while shales were deposited in the surrounding sea. Reef-building organisms built masses upwards and outwards over the off-reef deposits of earlier stages, until vast areas were finally covered with actively growing reefs.

The stromatoporoid limestone unit and its associated facies correspond to the early reef-growing phase in the Stettler area, described by Andrichuk and Wonfor (2), and to the upper part of the "black-reef" of the Rocky Mountains, described by McLaren (13). It appears to be the equivalent of at least part of the Duvernay formation of the central Alberta Plains, although no faunal evidence has as yet been obtained to support this hypothesis. Facies changes in this unit and suggested correlations are illustrated in Figures 2 and 3.

Unit FhC, Dolomite-Evaporite

Unit FhB is overlain by a sequence described by Belyea (5) as the dolomite-evaporite unit (FhC). The dolomite facies forms the shelf margin reef complex that separates the shelf deposits of southern Alberta from the basin deposits and reefs of central Alberta. This reef complex seems to extend as a distinct belt from the Vermilion area in northeastern Alberta to the Front Ranges of the Rocky Mountains (see Figure 1). Whether or not the belt is uninterrupted is not known, but the beds are similar throughout its length. To the south and southeast of the shelf margin reef complex lies the evaporite facies.

Unit FhC, where it forms the shelf margin reef complex, consists of massive, crystalline, vuggy dolomites which probably represent reefs, biostromes, banks, shoals, reef-derived clastics, and precipitated limestones. Carbonate clastics seem to form an important part. Dolomitization has destroyed the original nature of the rocks but their complete dolomitization and porosity suggest that they were open-textured. Typical sections of this massive dolomite are illustrated in Figures 2 and 3 by Bailey Olds No. 1 well and the section at the southeast end of Mt. Rundle.

Behind the shelf margin reef complex the dolomites are less coarsely crystalline and vugs and pore spaces are, to some extent, filled with white, crystalline anhydrite. Comparison with sections in the Front Ranges suggest that, in places, the deposits are bedded, and the organic deposits biostromal. The dolomite facies is of variable extent as illustrated in Figure 4D and is succeeded southwards by alternating deposits of crystalline dolomites and microsaccharoidal dolomites, anhydritic dolomites, and primary anhydrites. This predominantly evaporitic sequence is illustrated by Socony Tudor No. 1, Shell C. and E. Little Bow River No. 1, and International Blood No. 1 wells in Figure 2, and may be found in this unit in all wells of the southern Alberta Plains. Thin shaly dolomite and shale beds are common in some areas and may lead to more detailed correlations at a future date after more wells have been drilled giving better control from point to point.

The dolomite-evaporite unit (FhC) varies considerably in thickness. Along the shelf margin reef complex, where it is largely composed of crystalline dolomites, it is difficult to separate from underlying beds of similar lithology, but seems to be about 200 to 300 feet thick. A similar thickness holds for wells to the south where evaporites form the chief deposits. Westward, the unit thickens to about 300 feet in Moose Mountain area and to about 400 feet in the Front Ranges.

Unit FhC is probably the equivalent of the upper part of the Leduc formation of the Rimbey-Meadowbrook reef chain and the medial reef-growing phase of Andrichuk and Wonfor (2). The correlations with the central Plains suggested herein are shown in Figure 2, in which the formations of the Woodbend group are illustrated by Phillips Double A Mintlaw No. 1-A and Husky Phillips Pine Lake No. 1 wells. Close to the shelf, probably in deep embayments where free circulation of sea water was to some extent impeded, the normal green shale facies of the Ireton formation is replaced by dark brown limy shales and limestones, for example in the Westerdale-West Olds area, tps. 33, 34, rges. 3 and 4, W. 5th mer., and in the Sunnyslope area in tp. 31, rge. 27, W. 4th meridian. As pointed out by Andrichuk and Wonfor (2, p. 2,524) there seems to be little evidence in these embayments of outwash from the destruction of the reef. It seems to the writer, however, that debris formed from the destruction of reefs as they grew would accumulate close to the reef, especially on the seaward or steeper sides. The reef debris, being porous would be dolomitized along with the reef and the deposits immediately behind the reef barrier and, accordingly, would be included as part of the reef complex.

Delia Formation, (FhD)

The Delia formation, which forms the uppermost part of the Fairholme group, overlies the dolomite-evaporite unit (FhC) and extends from eastern Alberta to the Front Range of the Rocky Mountains (see Figure 5). It has been described by Belyea(5) in southeastern Alberta, Imperial Golden Hill 2-12 being the type well.

The lower 10 to 20 feet of the Delia formation generally consist of a greenish grey, shaly dolomite or dolomitic shale but, locally, the shale may be poorly developed or missing, for example in the Socony Carbon No. 1 and Bailey Olds No. 1 wells. In other places most of the lower 100 to 150 feet of the formation consist of brown, slightly argillaceous dolomites with irregular dark brown shale stringers and inclusions that may represent ripple marks. The dolomite-shale sequence commonly contains poorly preserved Amphipora, corals, bryozoans, crinoids, and brachiopods, which suggests that they correlate with the coral beds of the mountain sections described by McLaren (13). This dolomite-shale sequence may change at various horizons throughout the section to massive, vuggy dolomites, probably of organic origin, in the form of low reefs or biostromes.

Massive, crystalline vuggy dolomites form the upper part of the Delia formation in the Plains from a short distance west of the Duhamel reef chain southeast and south over most of south and south-central Alberta (see Figure 1). This dolomite is probably biostromal. Correlation with the mountain section is not certain, but the massive dolomite may be equivalent to the upper grey dolomite visible at the southeast end of Mt. Rundle (see Figure 3).

Evaporites are present in the upper part of the Delia formation in many places. In Socony Swalwell No. 1 well, tp. 30, rge. 25, W. 4th mer., Shell Crossfield No. 1 well, and other wells in that area the evaporites may form a single basin enclosed by the thick reef masses penetrated by Socony Carbon No. 1, Shell Jumpingpound Unit 4, Shell Anglo Canadian Pine Creek No. 1, and Canadian Superior Robertson 9-26 wells.

Dolomite stringers in the Delia formation, possibly representing biostromes or beds of reef detritus, extend into the shale basin where they form part of the Upper Ireton formation. The uppermost of these may include basal beds of the overlying Nisku formation. However, cores from the Husky Phillips Pine Lake No. 1 well, Husky Bargrave No. 1 well in tp. 26, rge. 30, W. 4th mer. and Socony Entice No. 1 well establish the stratigraphic position of the dolomite stringer of the Delia formation in relation to the base of the Nisku formation (see Belyea (5) for a more detailed account).

The Delia formation ranges from about 130 to 250 feet thick in central southern Alberta. In general it thins to the south, as shown by Socony Tudor C.P.R. No. 1, Shell C. and E. Little Bow River No. 1, and International Blood No. 1 wells (see Figure 2).

Winterburn Group

The Winterburn group, in the central Alberta Plains where it overlies the green shales of the Ireton formation, includes, from base to top, the Nisku, Calmar, and Graminia formations, all of which have been described by the geological staff of Imperial Oil Limited (9) from the British American Pyrcz No. 1 well. To the south, where it overlies the Fairholme group, it consists of a variable sequence of siltstones, shales, and anhydrite described below under the heading siltstone-evaporite facies.

Nisku Formation

The Nisku formation, which in the type well consists of 156 feet of finely crystalline dolomite, interfingers with anhydrite to the southeast and east. It becomes thinner and, in places, pinches out, as it approaches the areas underlain by the shelf margin reef complex of the Fairholme group. Thus, for example, as shown in Figure 2, the Nisku formation, which in Phillips Double A Mintlaw No. 1A well consists of about 160 feet of dolomite and anhydrite, thins to about 100 feet in Husky Phillips Pine Lake No. 1 well and to about 50 feet of anhydrite and anhydritic dolomite in the Socony Wimborne 15-11 well. A similar, though less rapid, thinning of the Nisku formation and gradation to anhydritic dolomite, anhydrite, siltstone, and shales, commonly red in colour, occurs southeast of a line from the Mintlaw well to the Duhamel area, (see Belyea (5) for a more complete discussion).

Calmar and Graminia Formations

The Calmar formation consists of 44 feet of green and red mottled dolomitic, argillaceous siltstone in the type well, B.A. Pyrcz No. 1. It is overlain by the Graminia formation, consisting of 50 feet of siltstone and dolomite. Both of these formations thin to the southeast and south and cannot readily be separated one from the other. Where they approach the shelf margin reef complex they become a part of the siltstone-evaporite facies.

Siltstone-Evaporite Facies

The siltstone-evaporite facies rests, commonly with sharply defined contact, on the Fairholme group of the southern Alberta Plains. The sequence is by no means homogeneous, but varies throughout its extent both in character and thickness. It ranges in thickness from a few inches in the Princess area to about 130 feet in Shell Jumpingpound Unit 4 well.

This sequence may contain a considerable thickness of anhydrite and anhydritic dolomite that, in places, contain small scattered sand grains. Siltstones and fine-grained sandstones occur in lenses and layers, generally less than 2 inches thick, that alternate with bright green, waxy, shales. The siltstones and sandstones consist chiefly of quartz with rare, unidentified, coloured grains. Red colouration of both anhydrite and shale is common, particularly in southeastern Alberta.

The siltstone-evaporite facies is equivalent to part of the Alexo formation of the Bow Valley.

Wabamun Group

The Wabamun group as defined by the geological staff of Imperial Oil Limited (9) was subdivided by Andrichuk and Wonfor (2) into the Stettler and Big Valley formations.

Stettler Formation

The Stettler formation in the central Alberta Plains overlies the Winterburn group and may be transitional from the underlying Graminia. In southern Alberta it rests on the siltstone-evaporite facies of the Winterburn group.

Variations in lithofacies of the Stettler formation are illustrated in Figures 2 and 3. In the Stettler area the formation consists largely of evaporites, illustrated in Figure 3 by Socony Tudor C.P.R. No. 1, and Socony Entice No. 1 wells. Westward from Entice, for example in the Olds area, there is a gradual transition from anhydrite to dolomite. Four distinct members are recognizable there and can be traced at least as far west as the Moose Mountain area. These consist from the bottom up, of lower evaporite, lower dolomite, upper evaporite, and upper dolomite members.

The lower evaporite member consists of anhydrite, generally buff in colour, with local thin shale laminae. Salt is present in the Stettler area and as far southwest as Tudor. The lower evaporite member is present in the wells of the Moose Mountain area but cannot be identified in the outcrops in the Front Ranges. It may be represented by breccias in the upper part of the Alexo formation.

In the Olds area dolomite, termed the lower dolomite member, overlies the lower evaporite member. At Entice it includes anhydrite, anhydritic and evaporitic dolomite, and dolomite, but to the west and south, at Okotoks for example, it consists of crystalline, vuggy dolomites that locally form a reservoir for gas. Westward, in Moose Mountain area, a thick dolomite and dolomitic limestone sequence probably includes the equivalent of this member and parts of both the lower and upper evaporite members.

The overlying upper evaporite member consists of shaly, micro-saccharoidal dolomite, anhydritic dolomite, and anhydrite. The anhydrite seems to be largely secondary. The predominantly evaporitic beds in the Entice and Olds areas grade westward to finely crystalline anhydritic dolomite with small bands of white crystalline anhydrite in Moose Mountain area. The member, although present in adjacent wells, is absent in Shell C. and E. Little Bow River No. 1 well, where it may be represented by a brecciated zone, the anhydrite having been removed by solution.

The upper dolomite member consists of a yellowish brown, micro-saccharoidal, argillaceous dolomite varying from 30 feet to 10 feet or less in thickness. This member forms a persistent marker across southern Alberta from the Alberta-Saskatchewan boundary to Moose Mountain.

In eastern and southeastern Alberta, in the Princess area for example (*see* Figure 3), the Stettler formation is thin and consists almost entirely of anhydrite and greenish grey shale.

Big Valley Formation

The Big Valley formation, overlying the Stettler formation, consists of greenish grey shales and coarse-grained fossiliferous limestones containing abundant crinoids and brachiopods. It is variable in thickness, being about 60 feet in the Stettler area and thinning westward to about 5 feet in Jumpingpound area. It is missing in the wells of the Okotoks region and probably does not extend as far west as Moose Mountain.

DEVONIAN OR MISSISSIPPIAN

Exshaw Formation

The Exshaw formation overlies the Wabamun group over the southern Alberta Plains. As in the Front Ranges, it consists of a brownish black shale, commonly pyritic and carrying plant spores. It varies in thickness from 30 feet in the Moose Mountain area to between 5 and 20 feet over the Plains.

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