

REPORT No. 73

The  
Stratigraphy of the Upper Devonian  
Saskatchewan Group  
of Southwestern Saskatchewan



by

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PROVINCE OF SASKATCHEWAN



## ABSTRACT

The stratigraphy of the Upper Devonian Saskatchewan Group of south-western Saskatchewan is presented. The Duperow Formation, the lowest unit of this group, is subdivided into an unnamed basal member—a carbonate-clastic sequence, a middle Wymark Member—a carbonate-evaporite sequence, and an upper Seward Member—a shale-evaporite-carbonate sequence. Three facies are outlined in the carbonates of the Wymark Member, including:

- (1) Carbonate ooze facies
- (2) Oolitic or pseudo-oolitic facies
- (3) Organic facies.

These are overlain by, and interfinger with, an evaporitic development made up of massive anhydrite layers. The oolitic and organic facies are thought to represent deposits laid down under high energy conditions, and often form banks of organic skeletal debris or oolites. The Seward Member is typified by a number of depositional rhythms of bioclastic limestones, argillaceous dolomites, anhydrites (which are sometimes absent), and shales or mudstones.

The Birdbear Formation which forms the upper unit of the Saskatchewan Group directly overlies the Duperow Formation. Dolomitization processes have done much to mask the primary features of this unit and little attempt is made at this time to outline facies as has been done for the Wymark Member of the Duperow Formation.

Four zones of the sporomorphs *Tasmanites* and *Leiosphaeridia* are outlined, and these are used to substantiate correlations throughout the region of study. No attempt is made to apply specific names to any of the specimens collected; however, some are found to be similar in morphology to those described by Sommer (1956a, 1956b) except that they are smaller.

The oil and gas prospects of each unit are evaluated. Conditions are considered to be favourable for the accumulation of oil and natural gas, including helium, in the porous organic facies, which are capped by anhydrites and form stratigraphic and structural-stratigraphic traps.

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## INTRODUCTION

Since the discovery of oil in Mesozoic rocks in western Saskatchewan in 1944 and in rocks of Mississippian age in southeastern Saskatchewan in 1953, petroleum exploration in Saskatchewan has been mainly confined to extending the boundaries of the older fields and finding new reserves in rocks of the aforementioned ages. The growing list of oilfields producing from Upper Devonian and upper Middle Devonian strata in Alberta since the discovery of oil in Devonian rocks at Leduc in 1947, and the recent discoveries of Devonian oil in Montana within a few miles of the Saskatchewan-Montana boundary, has created interest in the economic prospects of rocks of the same age in Saskatchewan. Most of the oil found in the Devonian strata of Alberta has accumulated in reef struc-

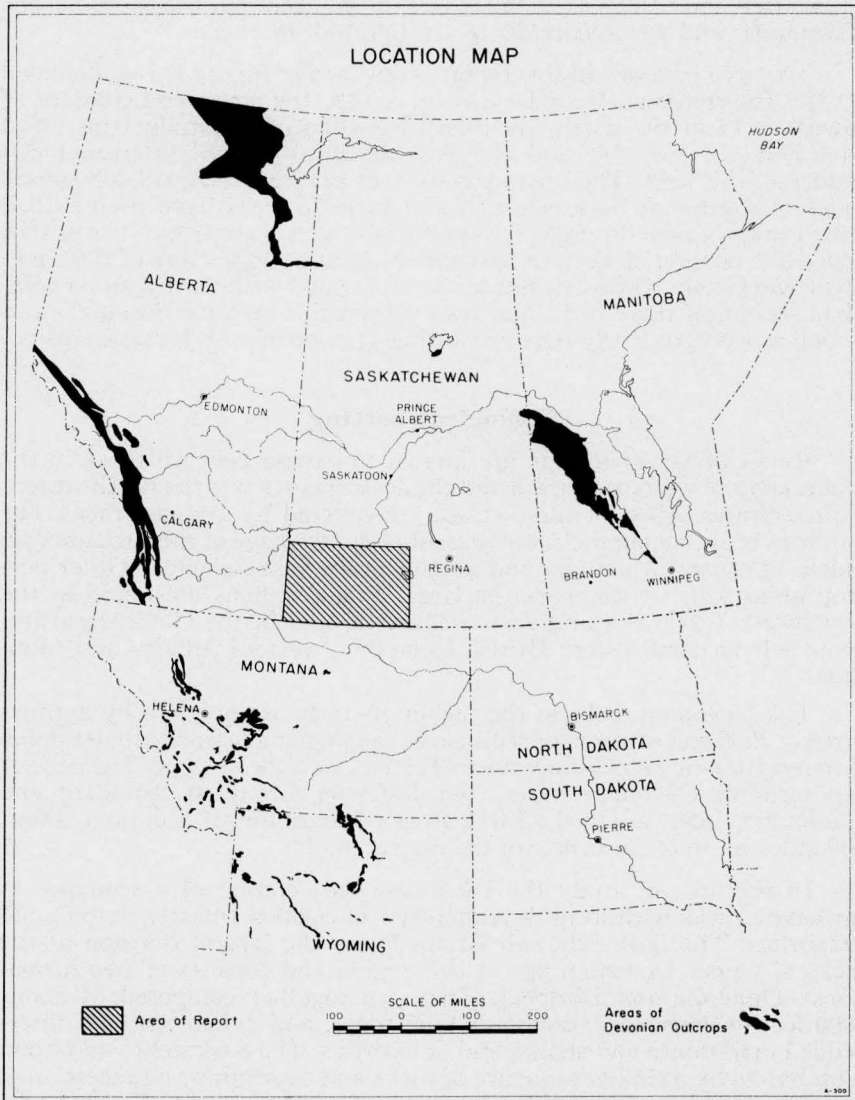


Figure 1—Location Map.

tures; it was with this in mind that attempts were first made to locate similar oil-bearing structures in the Devonian deposits of southern Saskatchewan. The structures were outlined by seismic surveys and tested with boreholes but the results were disappointingly unsuccessful. From these negative results, then, it would appear that any hydrocarbons to be found in these strata are probably enclosed in stratigraphic or structural-stratigraphic traps. Detailed regional stratigraphic and sedimentation studies will be required to find traps of these types. This paper is a preliminary report on a more detailed study of the Saskatchewan Group, and it is hoped that it will assist the discovery of oil and gas reservoirs in these Upper Devonian strata.

The purpose of this preliminary report is twofold: first, to discuss the stratigraphic subdivisions of the Saskatchewan Group with as little subjective interpretation as is possible; and second, to examine the application and utility of certain zones of occurrence of the sporomorphs *Tasmanites* and *Leiosphaeridia* as stratigraphic markers.

The area included in this report is outlined in Figure 1. It is bounded by the International Boundary in the south, the northern boundary of township 19 in the north, the 106th meridian of longitude (the Third Meridian) in the east and the Saskatchewan-Alberta interprovincial border in the west. The area extends over approximately 19,400 square miles of southwest Saskatchewan and in it 76 wells have been drilled which enter or pass through rocks of the Saskatchewan Group. The author chose this portion of western Saskatchewan to begin a study of the Saskatchewan Group because it has moderately good well control and a complete section of these beds. Northward from this area the Saskatchewan Group was progressively removed during a period of post-Jurassic erosion.

### Geological Setting

Rocks of Devonian age are known to extend beneath most of the plains areas of western Canada and the central portion of the northwestern United States. Most of these strata are covered by younger rocks, but outcrops of Devonian rocks are present along the edge of the Precambrian Shield in central Manitoba and northwestern Saskatchewan. Other outcrop areas which encompass the Great Plains regions are found in the Northwest Territories and eastern Alberta, and in the Cordilleran orogenic belt in northeastern British Columbia, western Alberta and Montana.

The Devonian rocks in the region of study are overlain by approximately 2000 feet of younger sediments, ranging in age from Mississippian through Jurassic and Cretaceous to Tertiary and Pleistocene. The nearest exposures of Devonian rocks (the Jefferson Group of Sandberg and Hammond, 1958) are in the Little Rocky Mountains of Montana, about 200 miles south of the centre of the map area.

In the area of study the Devonian beds consist of a sequence of carbonate rocks with local developments of clastics (mostly shales) and evaporites. The Saskatchewan Group forms the largest division of the rocks of Upper Devonian age in this region and consists of two formations—Duperow and Birdbear. They are together composed of about 1000 feet of limestones, dolomitic limestones, and dolomites, with interbedded marlstones and shales, and anhydrites. The Saskatchewan Group is underlain by a similar sequence of rocks and overlain by a succession of shales, evaporites and minor dolomites constituting the Three Forks Group (Christopher, 1961).

## GENERAL STRATIGRAPHY

### Origin of Stratigraphic Nomenclature

The nomenclature of the Devonian System in Saskatchewan and the rest of the Williston Basin area has undergone various alterations since the beginning of active oil exploration in these regions. Subsequent to the discovery of oil in Upper Devonian strata at Leduc and other locations in Alberta, attempts were made to apply the Alberta nomenclature to the subsurface strata in Saskatchewan and the Williston Basin. Other terminology that has commonly been applied to the Devonian rocks of these regions was derived from the outcrops in the Three Forks area of Montana.

In 1951 Andrichuk published a regional stratigraphic analysis of the Devonian rocks in a region including Montana and parts of Wyoming, Alberta and Saskatchewan. He subdivided the strata into four units which were suitable for his analysis of the succession, and added much to the knowledge of the regional stratigraphy and sedimentation of the area. However, these units were found to be difficult to correlate and Andrichuk's subdivisions did not attain widespread acceptance. Powley (1951) attempted a subdivision of the Devonian strata of central Saskatchewan, where he found he could delineate a number of major subdivisions of which his Duperow Formation and Moose Jaw Group together comprised the upper half of the Devonian succession in his area. The subdivision of these upper beds was based on the cored intervals from the Tidewater Duperow Crown No. 1 well, (Lsd 4-9-35-16w3) and the Tidewater Duperow Crown No. 2 well, (Lsd 4-22-34-16w3), in which Powley outlined 21 lithologic units, 15 of them in his Duperow Formation and 6 in his Moose Jaw Group. The Duperow and Birdbear Formations of present usage are equivalent to parts of Powley's Duperow Formation and Moose Jaw Group. (Figure 2).

Baillie (1953, 1955) demonstrated the general relationship between the Devonian sediments of the Williston Basin area and those of the southern Alberta plains. He further suggested that the nomenclature applied to the Upper Devonian rocks in the Three Forks area of Montana, *i.e.*, Jefferson limestone and Three Forks Formation, was not applicable to rocks of the same age in the Williston Basin area. He was of the opinion that the rocks of the Three Forks region belonged to an independent sedimentary province separated from the Williston Basin by a positive tectonic axis. Baillie proposed a four-fold subdivision of the Devonian strata of the Williston Basin area, including the Middle Devonian Elk Point Group, the Manitoba Group of Middle and Upper Devonian age, and the Saskatchewan and Qu'Appelle Groups of Upper Devonian age. Figure 2 illustrates the correlation between Baillie's Saskatchewan and Qu'Appelle Groups and Powley's subdivisions.

With the discovery of oil in the Mississippian in 1951, interest in the Williston Basin as an oil province increased rapidly, and the attempts to standardize the nomenclature of the area finally resulted in the establishment in 1954 of the Williston Basin Nomenclature Committee organized under the Palaeozoic subcommittee of the A.A.P.G. Geologic Names and Correlation Committee. While the findings of this group have never been published, many of the names which were proposed are now commonly used. Among definitions in use is that of the Duperow Formation which name was applied to Baillie's unnamed unit in his Saskatchewan

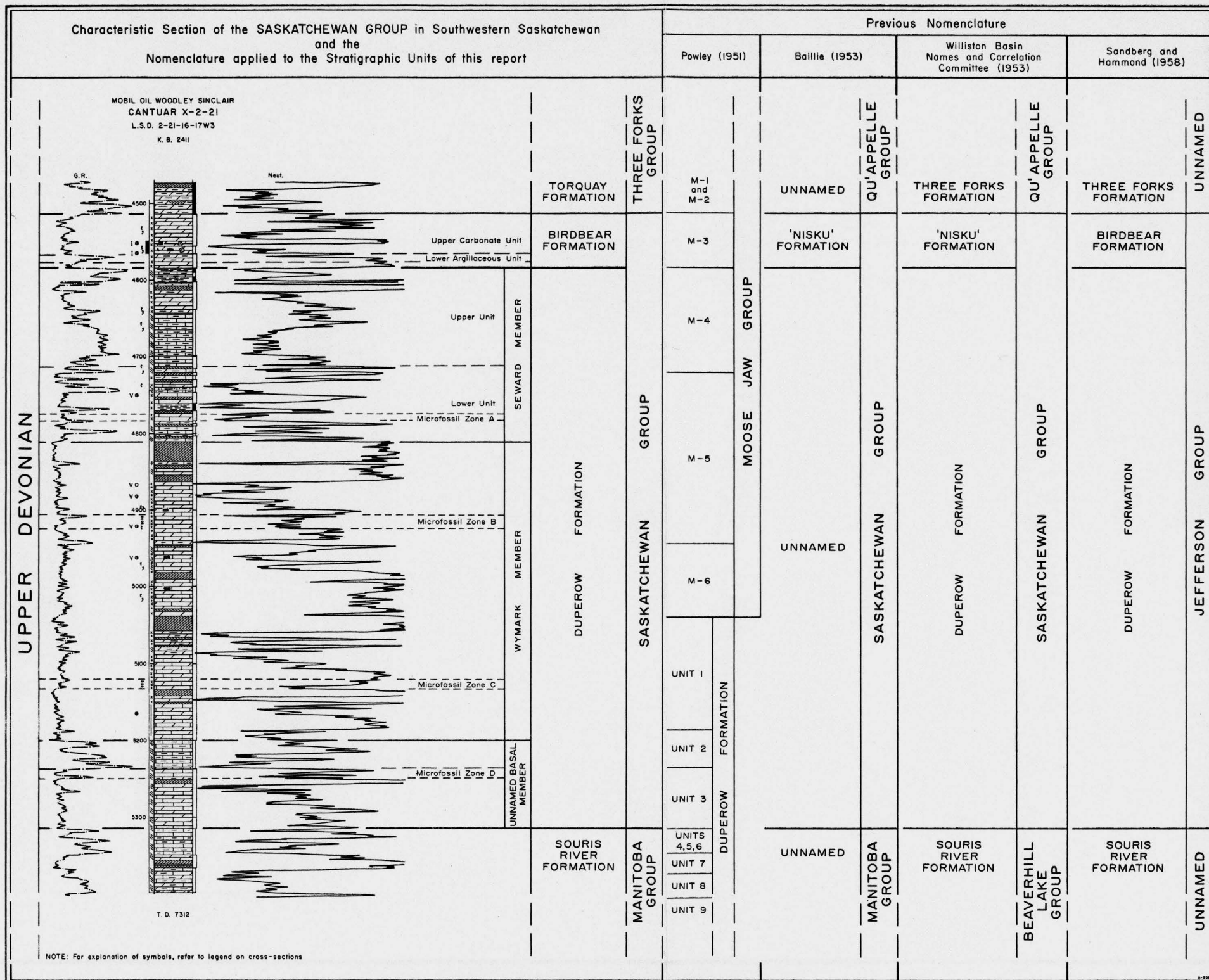
Group (Figure 2). This name was an unfortunate choice, the result of misunderstanding of Powley's (1951) definition, since the Duperow Formation of the committee includes only the uppermost six units of Powley's (op. cit.) Duperow Formation. Stanton (1953) introduced some of the names proposed by the Williston Basin Nomenclature Committee, but the only formal introduction of most of the proposed names was in a brochure published in 1954 by the North Dakota Geological Society. In this each stratigraphic unit of the Williston Basin area was described, and in many cases standard subsurface reference sections were proposed for units for which none previously existed.

Sandberg and Hammond (1958) investigated the Devonian System of Central Montana and that part of the Williston Basin south of the International Boundary. In their paper the subsurface rocks were correlated with the surface exposures of the Devonian in the Little Rocky Mountains and at Logan, Montana, and a standard subsurface reference section for the Upper Devonian rocks of the Williston Basin area was proposed. This reference section is in Mobil Oil Producing Co. No. 1, Birdbear well (C.SE  $\frac{1}{4}$  NW  $\frac{1}{4}$ -22-149N-91W) in Dunn Co., North Dakota. They felt that the term Jefferson Group was more appropriate for the interval previously called the Saskatchewan Group. They also proposed the name Birdbear Formation for the carbonate rocks overlying the Duperow Formation which previously were called 'Nisku' Formation. Sandberg and Hammond felt that this unit was not correlative with the Nisku Formation of the Edmonton, Alberta area (Geological Staff, Imperial Oil Ltd., 1950). This was in accord with Belyea (1955, 1957) who has also suggested that the 'Nisku' Formation of the Williston Basin area was not correlative with the Nisku Formation of Alberta. The term Birdbear was introduced into the Saskatchewan nomenclature by Kents (1959) who agreed with Belyea (op. cit.) and Sandberg and Hammond (ibid.).

The nomenclature employed in this report (Figure 2) is that which is generally accepted with the exception of the names of the members of the Duperow Formation. The writer has retained the term Saskatchewan Group for this interval of rocks in lieu of the term Jefferson Group as proposed by Sandberg and Hammond (op. cit.), because the author is of the opinion that there is still some doubt as to the applicability of the term Jefferson in the Williston Basin. However, the Saskatchewan Group probably correlates with the Jefferson Group of the standard subsurface reference section of Sandberg and Hammond (op. cit.).

### **Underlying Beds**

The Saskatchewan group of this report area is underlain by an average thickness of approximately 2300 feet of sediments composed of about 400 feet of shales and sandstones of Cambrian and Ordovician age and about 1900 feet of Ordovician, Silurian and Devonian (mostly Middle Devonian) carbonate rocks with varying amounts of shales and evaporites. Within the region of study the carbonate rocks of the Ordovician and Silurian Systems can only be subdivided with some difficulty and for this reason they have been placed into two groups—the Bighorn Group of Ordovician age and the Interlake Group of Silurian age (Porter and Fuller, 1959).



**Figure 2—Characteristic Section of the Saskatchewan Group in  
Southwestern Saskatchewan and Table of Nomenclature.**

## SUBDIVISIONS OF THE DEVONIAN SYSTEM

The Devonian rocks of southern Saskatchewan have been divided into four major stratigraphic units which are in descending order:

Three Forks Group  
Saskatchewan Group  
Manitoba Group  
Elk Point Group

The more detailed subdivisions of the lower three groups have been broadly based on the rhythmic patterns of sedimentation, as evidenced by the lithologies. These rhythmic patterns are best illustrated by the Elk Point Group, by the Dawson Bay Formation and by the Lower Souris River Formation of Walker (1957). In the Dawson Bay Formation, Lane (1959) outlined six well defined units of a sedimentation cycle, beginning with a red and/or green shale, passing upward into four successive carbonates and terminating in evaporites.

The cycles in the upper part of the Souris River Formation become thinner and hence more numerous. They are usually less perfectly developed than the underlying ones, in that the shale phases are very often absent. Further carbonate-evaporite cycles occur in the Duperow Formation of the Saskatchewan Group, and as in the Souris River Formation, the shale phases are very often missing in these cycles.

### **Souris River Formation**

The name Souris River Formation was first applied by the Williston Basin Nomenclature committee in 1954 to the unnamed beds overlying the Dawson Bay formation in Baillie's (1953, 1955) Manitoba Group. However, it was not until 1958 that a standard subsurface reference section was established for this formation by Sandberg and Hammond (op. cit.). They defined this section as the rocks extending from 10,743 feet to 11,046 feet in the Mobil Producing Co. No. 1 Birdbear well in (C.SE $\frac{1}{4}$ .NW $\frac{1}{4}$ -22-149N-91W) Dunn Co., North Dakota. The Souris River Formation as presently defined in the subsurface of Saskatchewan correlates with the standard reference section.

The Souris River Formation has a fairly uniform thickness over most of the area of study. It ranges between 580 feet and 610 feet for the most part, but has been observed to thin to about 440 feet along the International Boundary in the southwest part of the map area. As was previously suggested the lithologies of the Souris River Formation are indicative of a number of sedimentary rhythms or cycles. These rhythms or cycles are often imperfect as in many instances one of the lithologies of the cycle is absent within the map area, usually either the basal shale or the evaporite. A complete cycle consists of red and/or green and some gray shales and argillaceous limestones overlain by a sequence of sucrosic dolomites interbedded with thick-bedded, light colored, fine-grained limestone (called "standard carbonates" by Walker, 1957). When present the evaporite at the top of the cycle is usually anhydrite.

The lower contact of the Souris River Formation was placed at the base of a thin but persistent red shale horizon often called the First Red Beds. These red shales are an extremely good stratigraphic marker and can be traced over most of the Williston Basin. The top of the Souris River Formation is at the top of a gray argillaceous limestone or marl-

stone and is coincident with the base of the Duperow Formation. This argillaceous marker is also very persistent and is readily observed on the gamma ray-neutron logs and in well cuttings and cores.

The Souris River Formation has been tentatively correlated with the Beaverhill Lake Group of Alberta by D. M. Lane (Personal Communication). It is also thought to be correlative with the Maywood Formation of the Little Rocky Mountains area, Montana (Sandberg and Hammond, 1958).

### **Saskatchewan Group**

The name Saskatchewan Group was first proposed by Baillie (1953, reprinted with additions 1955) for the sequence of rocks subjacent to the Qu'Appelle Group. The Saskatchewan Group correlates with the Jefferson Group of Sandberg and Hammond (1958), and is represented by the rocks in the interval between 4518 feet and 5315 feet in the Mobil Oil Woodley Sinclair (hereinafter abbreviated to M.O.W.S.) Cantuar X-2-21 well, (Lsd 2-21-16-17w3). This interval in this well is here termed the characteristic section of the Saskatchewan Group in Southwestern Saskatchewan (Figure 2).

The Saskatchewan Group is composed of two main stratigraphic units—the Duperow Formation and Birdbear Formation. These units, although lithologically similar are easily delineated using marker beds. Both formations underlie and extend in all directions much beyond the boundaries of the area of study. The erosional edges of the Birdbear and the Duperow Formations lie north of the area of study. These two formations of the Saskatchewan Group are mainly composed of carbonate rocks, but thin argillaceous and evaporitic horizons are also present. Besides being the stratigraphic equivalents of the Jefferson Group (Sandberg and Hammond, 1958) of Montana, the Saskatchewan Group is probably coeval with the Woodbend Group of Central Alberta and with the Fairholme Group of Southern Alberta (Belyea, 1955, 1957).

#### **DUPEROW FORMATION**

The characteristic section of the Duperow Formation southwestern Saskatchewan has been established by the present author as the interval between 4584 feet and 5315 feet in the M.O.W.S. Cantuar X-2-21 well, (Lsd 2-21-16-17w3) (Figure 2). This formation underlies the entire map area and extends beyond its limits in all directions. The Duperow Formation attains a maximum thickness of 800 feet along the northwestern edge of this area as illustrated in the Mobil Oil North Richmond 31-1 well, (Lsd 1-31-18-28w3) (Figure 3). The effects of depositional thinning on this formation are minor within the area under consideration, and the thickness was found to be in the order of 700 feet along the southern and eastern borders of the study area (Figure 4 and 5).

The author has divided the Duperow Formation of this region into three stratigraphic units of varied lithologic character. The lowest unit, here termed the basal member, was distinguished from the rest of the formation on the basis of its lithologic similarity to and apparent correlation with the upper part of the Cooking Lake Formation of Alberta. It is composed of a relatively thin sequence of "clean"<sup>1</sup> carbonates overlain by marlstones and very argillaceous li nestones. The middle member

<sup>1</sup> Relatively free from argillaceous material

to which the name Wymark is here applied is a succession of relatively "clean" carbonates with thin evaporites and argillaceous beds. This is overlain by the Seward Member, a highly argillaceous sequence with thin anhydrite and carbonate layers.

Four zones of the sporomorphs *Tasmanites* and *Leiosphaeridia* have been found in the Duperow Formation. They have been designated the A, B, C, and D microfossil zones, in descending order; one such zone (A zone) is located in the Seward Member, two (B and C zones) in the Wymark Member, and one (D zone) in the basal member (Figure 2). These zones are thought to be time-marker horizons (Jodry and Campau, 1961); the application of them to the elucidation of the stratigraphy of the area under study, is discussed in a later section.

### Basal Member

The basal member occupies the interval between 5199 feet and 5315 feet in the characteristic well, M.O.W.S. Cantuar X-2-21 (Figure 2). It extends beyond the boundaries of the map area, and in most places within the region it is a good cartographic unit, due to the distinctive argillaceous beds which mark its upper and lower boundaries. Both argillaceous zones appear as well marked mechanical log deflections, being particularly distinctive on the gamma ray curves where they produce the usual increase in radio-active counts characteristic of argillaceous beds. The boundaries of the basal member have been established by the author at the tops of both the above mentioned argillaceous zones (Figure 2). Towards the southeast the upper argillaceous unit which marks the top of the basal member becomes less distinctive as a result of a lateral facies change to "clean" carbonate.

Along the eastern edge of the map area the basal member has a remarkably constant thickness varying only slightly between 70 feet and 85 feet. As the member is traced westward toward the Alberta boundary the thickness increases to about 135 feet, although it is slightly thinner in the southwest corner and a little thicker in the northwest corner of the report area.

Two lithologic units characterize the basal member of the Duperow Formation. They are a lower carbonate unit and an upper argillaceous unit. The lower carbonate unit appears to have been laid down under conditions similar to those proposed for the Cooking Lake Formation of Alberta (Andrichuk, 1958). The carbonates of this unit are quite variable and include pale yellowish brown<sup>1</sup> to yellowish brown<sup>1</sup>, microcrystalline<sup>2</sup> limestones, dolomitic limestones and dolomites. Ovoid to irregularly-shaped oolites and/or pseudo-oolites ranging in size from 0.1 mm. to 0.6 mm. are common, particularly along the eastern side of the map area. The oolites or pseudo-oolites appear to be built up in isolated banks (Figure 5) the inter-bank areas being composed of fine-grained limestones

<sup>1</sup> The colour classification used throughout this report is that of the Geological Society of America Rock Color Chart.

<sup>2</sup> In the sense of Williams, Turner and Gilbert (1955, pp. 276-277). Their classification of non-clastic textures and grain sizes is as follows:

Crystalline Granular	—Coarse, greater than 5 mm.
	—Medium, 1-5 mm.
	—Fine, less than 1 mm.
Microcrystalline	0.01 mm.-0.2 mm.
Cryptocrystalline	less than 0.01 mm.

or dolomitic limestones. Westward the oolite banks pass laterally into fine-grained limestones which become increasingly more dolomitic in a northwesterly direction (Figure 3 and 4). Fragmented brachiopod remains and crinoid ossicles are occasionally intermixed with the oolites or pseudo-oolites.

Along the western margin of the study area a thin anhydrite bed extends into the carbonate unit from the west. It occurs as far east as the M.O. W.S. Cantuar X-2-21 well (Lsd 2-21-16-17w3) (Figure 3). Beyond this well the anhydrite either thins out or passes laterally into carbonate. Near the top of the carbonate unit there are thin beds of yellowish-gray to pale yellowish brown, very fine-grained argillaceous limestone or dolomites interbedded with the "clean" carbonate. The microfossil zone D is found in these beds at the top of the carbonate unit. It is a thin persistent zone observed in a large proportion of the sample cuttings of this interval taken from the wells of the area of study. The stratigraphic position and extent of this zone are illustrated in Figures 3, 4 and 5 where it is seen to have the same distribution as the overlying argillaceous unit.

The upper argillaceous unit also has a varied composition, which embraces very fine-grained, yellowish gray to greenish and light gray marlstones and very argillaceous limestones. Brachiopods, corals, crinoid ossicles and charophyte remains are plentiful within certain beds. The marlstones and argillaceous limestones are sometimes interbedded with limestone of a less argillaceous nature. Toward the southeast corner of the area there is a facies change and the argillaceous unit passes laterally into "clean" carbonate (Figure 5).

The basal member of the Duperow Formation has been variously correlated with the Beaverhill Lake Group and/or the Cooking Lake Formation of Alberta. Powley (1951) obtained fossils from this unit in the Tidewater Duperow Cr. No. 1 well (Lsd 4-9-35-16w3) which are similar to ones obtained from the Cooking Lake Formation of Alberta. The author is of the opinion that the basal member of the Duperow Formation is equivalent to the upper part of the Cooking Lake Formation of Alberta (Figure 4).

### **Wymark Member**

The Wymark Member lies conformably on the upper argillaceous unit of the basal member. It is here defined as that sequence of rocks occupying the interval between 5423 feet and 5827 feet in the Tidewater Wymark Crown No. 1 well, (Lsd 3-10-14-14w3). This well was chosen as the type well for two reasons: first, about 50 per cent of the member has been cored in it, and second, the section in this well illustrates all the lithologic aspects of the member (Figure 6).

Type Section: Wymark Member

Tidewater Wymark Crown No. 1

Lsd 3-10-14-14w3

Name derived from Town of Wymark 5.4 miles south-east of the type well.

Interval: 5423.5 feet-5826 feet.

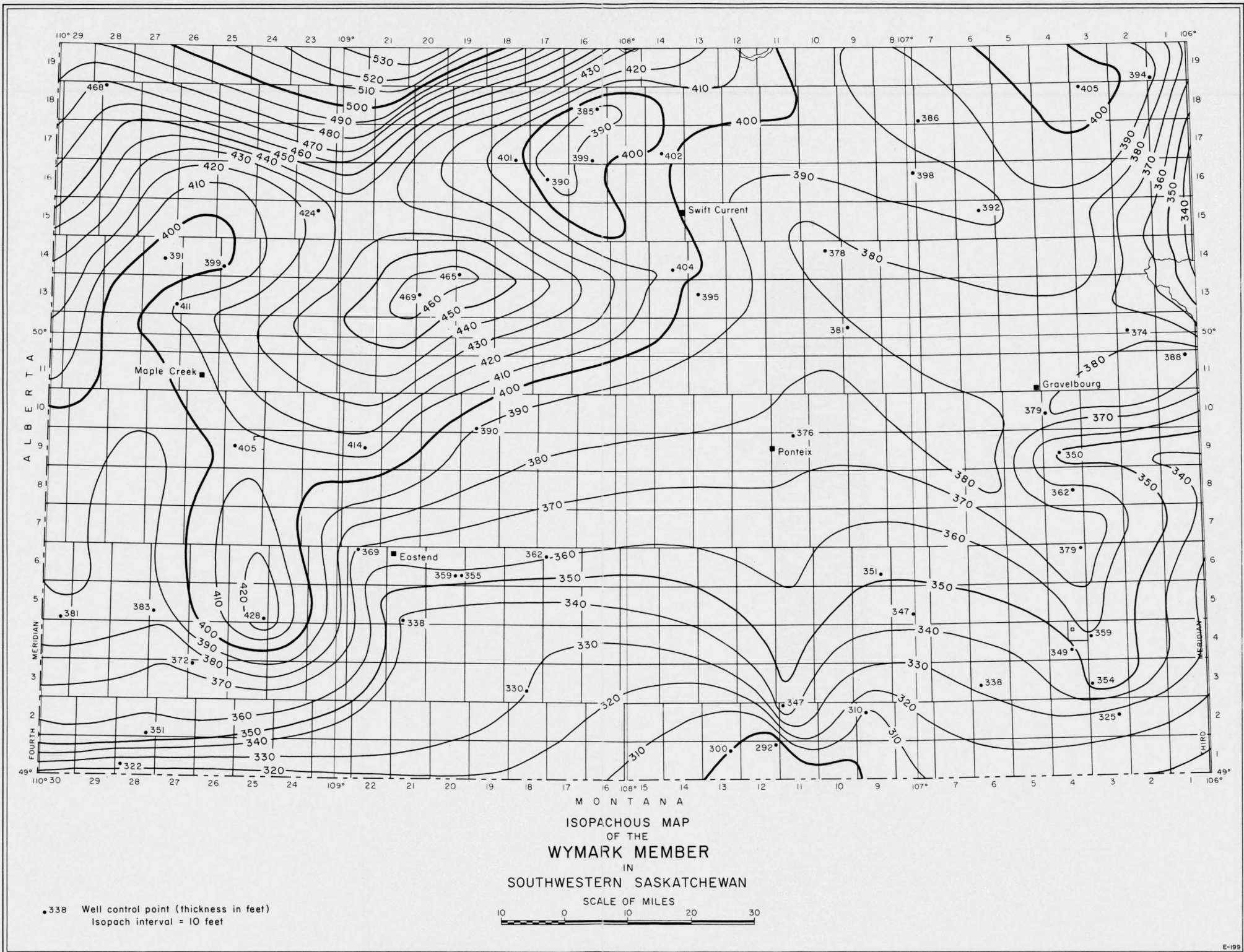


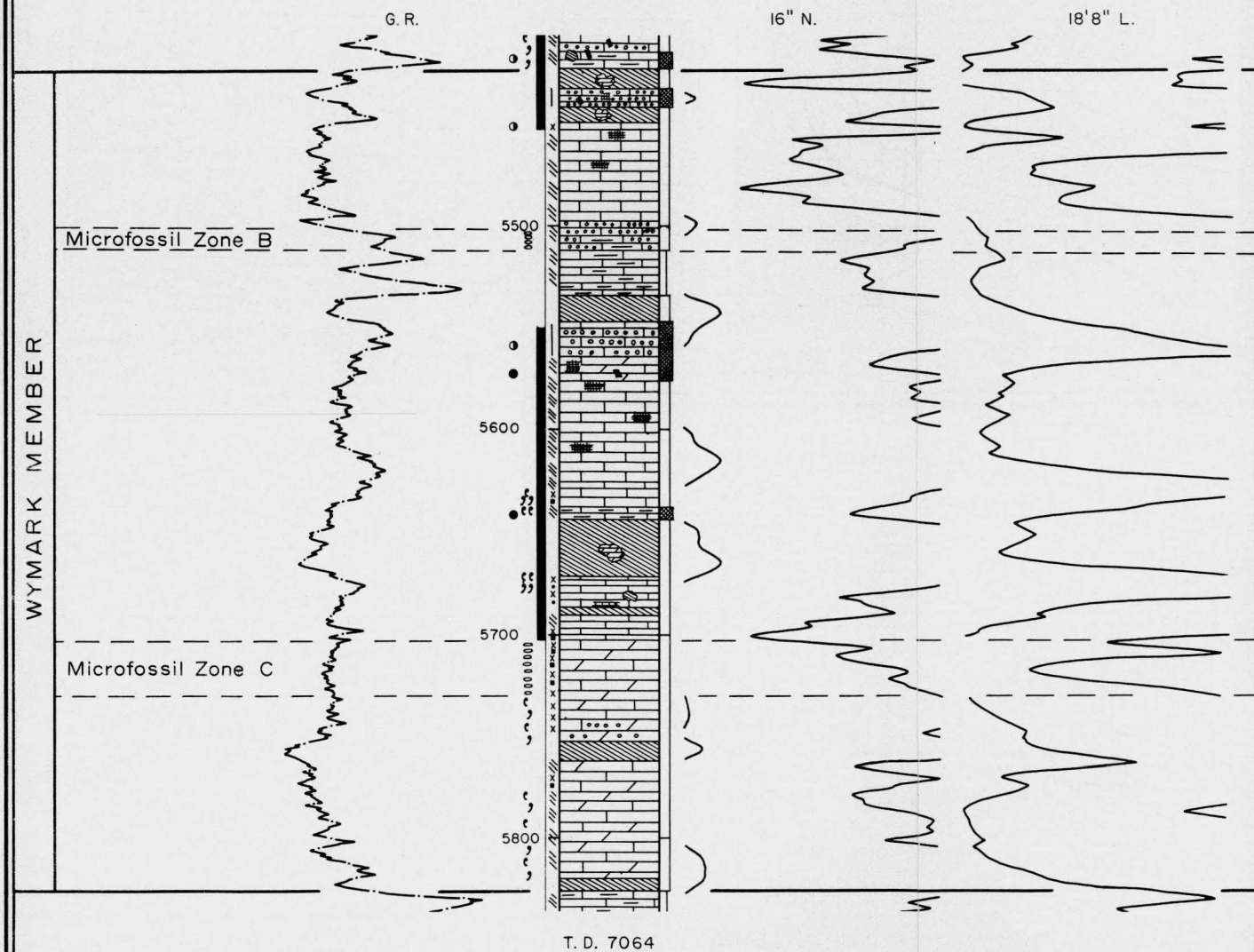
Figure 7—Isopachous Map of the Wymark Member.

TYPE SECTION  
OF THE  
WYMARK MEMBER

TIDE WATER  
WYMARK CROWN I

L.S.D. 3-10-14-14W3

K.B. 2788



T. D. 7064

NOTE: For explanation of symbols, refer to legend on cross-sections.

Figure 6—Type Section of the Wymark Member.

## Lithology

Drilled Depth in feet	Overlying beds—Seward Member
5423.5-5432	(Core) Anhydrite—dark yellowish brown; granular; massive to poorly bedded with thin (1 inch to 1½ inches) dark brown dolomite layers, sparsely distributed through upper portion of anhydrite becoming more common toward the base.
5432-5441	(Core) Limestone—very pale orange; cryptocrystalline to microcrystalline; oolitic and fossiliferous; argillaceous in part; has porphyroblasts of dark brown anhydrite disseminated through the interval.
5441-5447	(Core) Anhydrite—pale yellowish brown to light olive gray; cryptocrystalline to microcrystalline; massive to poorly laminated.
5447-5452	(Core) Limestone—very pale orange; microcrystalline; thin black carbonaceous shale streaks; some clear to white anhydrite crystals, in the limestone.
5452-5500	(Cuttings) Limestone—medium yellowish brown; microcrystalline; thin brown carbonaceous shale streaks.
5500-5515	(Cuttings) Limestone—pale yellowish brown; oolitic; massive; contains sporomorphs (zone B).
5515-5525	(Cuttings) Limestone—light gray; microcrystalline; massive; argillaceous.
5525-5530	(Cuttings) Limestone—pale yellowish brown; microcrystalline; fossil fragments (mainly crinoid ossicles).
5530-5540	Missing.
5540-5550	Cavings. (Core from this depth to 5703)
5550-5564	Limestone—yellowish gray; microcrystalline to cryptocrystalline, recrystallized oolites and fragmental material ranging from .23 mm. to 1.19 mm. ovoid to irregularly shaped and lathe-shaped, massive, with good vuggy porosity, some thin (1 mm.-3 mm.) medium gray shale partings.
5564-5576	Limestone—very pale orange; microcrystalline; thin black carbonaceous shale streaks; slightly argillaceous; some white calcitic crystalline anhydrite near base of interval.
5576-5629	Limestone—very pale orange to pale yellowish brown; cryptocrystalline; poorly to thinly laminated; thin black carbonaceous shale streaks; slightly argillaceous.
5629-5638	Limestone—pale yellowish brown; microcrystalline; fossil debris and oolites; thin black carbonaceous shale streaks; argillaceous in part.
5638-5644	Limestone—pale orange brown; microcrystalline (euhedral); dolomitic; poorly bedded.

Drilled Depth in feet	
5644-5646	Limestone—pale yellowish brown; microcrystalline; massive; dolomitic with white lathe-shaped anhydrite crystals ranging in size from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch long and $\frac{1}{4}$ inch wide.
5646-5646.4	Limestone—light olive gray to olive gray; cryptocrystalline; argillaceous.
5646.4-5674.3	Anhydrite—pale yellowish brown; cryptocrystalline; massive to poorly bedded, with thin irregularly-shaped patches of yellowish gray earthy dolomitic limestone disseminated through the anhydrite.
5674.3-5682	Limestone—pale yellowish brown; cryptocrystalline to microcrystalline; some pseudo-oolites and fossil fragments; thin black carbonaceous shale streaks; dolomitic in part, with large (1 inch to 3 inches) irregularly shaped blebs of white granular anhydrite.
5682-5688.7	Limestone—dark yellowish brown; microcrystalline; brecciated with angular limestone fragments, recrystallized algal remains and solution vugs, some infilled with white sugary anhydrite; good to fair vuggy porosity.
5688.7-5692.4	Anhydrite—very pale orange to pale yellowish brown; cryptocrystalline; massive; considerable dolomite in the form of thin stringers and thin beds intermixed with the anhydrite.
5692.4-5693.1	Limestone—pale yellowish brown to dark yellowish brown; microcrystalline; thinly bedded with carbonaceous shale streaks in part.
5693.1-5703	Limestone—pale yellowish brown; microcrystalline (euhedral) about .1 mm. to .17 mm.; some thin carbonaceous shale streaks. (Cuttings from this depth to end of log)
5703-5735	Limestone—pale yellowish brown; microcrystalline; euhedral grains; dolomitic in part; contains sporomorphs (zone C).
5735-5750	Limestone—pale yellowish brown; cryptocrystalline; dolomitic; fossil fragments and pellets.
5750-5810	Limestone — pale yellowish brown; cryptocrystalline, chalky with euhedral grains; dolomitic.
5810-5820	Anhydrite—dark yellowish brown; microcrystalline; dense.
5820-5826	Limestone—medium yellowish brown; microcrystalline; fossil fragments (brachiopods). Underlying beds—Basal Member.

Except for a few isolated areas of anomalous thickness (Isopachous map, Figure 7) the regional thickening of the Wymark Member seems to be fairly regular in a northwesterly direction. The maximum thickness attained by the unit is 570 feet in the northwest corner of the map area. It is thinnest along the southern margin where the thickness ranges from 290 feet to 300 feet.

The Wymark Member is traceable beyond the western, northern and southern boundaries of the area of study. In the southeastern part of the area of study the upper argillaceous unit of the basal member, the top of which represents the base of the Wymark Member, undergoes a gradual change of facies to "clean" carbonate with the result that the Wymark Member becomes indistinguishable from the underlying basal member. The combined units however can be traced eastward into Manitoba. In the northeastern part of the region the upper argillaceous unit is still a prominent marker, consequently, both the Wymark and the basal member are recognizable as separate units for some distance east of the area of study. The upper boundary of the Wymark Member was established by the author at the base of the lowest argillaceous bed in the Seward Member. This bed usually overlies an anhydrite bed of variable thickness and fairly widespread distribution. Wherever it is present the anhydrite may be used as a marker for establishing the top of the Wymark Member, which is coincident with the top of the anhydrite.

The Wymark Member consists of a series of alternations of carbonates and evaporites. It is possible to divide the carbonate rocks into a number of different types based on differences in the manner of deposition under various environmental conditions. The author recognized three facies in the carbonate rocks. These are listed below in order of their relative abundance:

- (1) Carbonate ooze facies.
- (2) Oolitic or pseudo-oolitic facies
- (3) Organic facies.

#### *Carbonate Ooze Facies*

This facies is the predominant rock type of the Wymark Member, having a wide range of grain sizes varying from microcrystalline to lithographic the former predominating. The rocks are mostly pale yellowish brown to yellowish brown and yellowish gray limestones, dolomitic limestones and dolomites with the dolomites the most abundant. Fossils are plentiful throughout the deposits, but do not form the framework of the rock, as they do in the organic facies. They include brachiopods, gastropods, bryozoa and some crinoid ossicles. The state of preservation varies, ranging from well preserved to fragmented in the limestones, to poorly preserved in the dolomites and dolomitic limestones. Considerable amounts of anhydrite are present in the form of dusky brown porphyroblasts<sup>1</sup> disseminated through the rock, or as white to very pale gray dense material infilling the void spaces in the dolomitized portions of the rock. Thin streaks of carbonaceous shale were observed occasionally but these are not as prominent as in some of the other carbonate facies.

The finer grained deposits (cryptocrystalline to lithographic) of this facies are most often found in close association with the primary anhydrite beds present in the Wymark Member. For the most part they are thin beds which usually overlie and underlie the anhydrites, but are occasionally interbedded with them. They possess slightly different coloration from the coarser grained rocks of this facies usually being very pale orange, but they may also be pale yellowish brown and yellowish gray. The finer grained deposits usually consist of slightly argillaceous limestones or dolomitic limestones. Fossils are rare or absent, and the

<sup>1</sup> In the sense of Pettijohn, (1957), p. 92.

rocks probably represent an environment intermediate between less restricted conditions and a restricted phase where anhydrites were laid down.

The carbonate ooze facies is thought to represent sediments laid down under relatively quiet water conditions, as in a protected region of the basin.

#### *Oolitic and Pseudo-oolitic Facies*

The rocks making up this facies consist of pale yellowish brown to dark yellowish brown limestones and dolomites composed principally of oolites and/or pseudo-oolites having a size range between 0.0625 mm. and 1.67 mm., the average being about 0.3 mm. The oolites or pseudo-oolites range from spherical to ovoid in shape, the latter being more common. The matrix or cement is usually microcrystalline to cryptocrystalline calcareous material. Dolomitization in these rocks has often advanced to the stage that the oolites and pseudo-oolites are only relic forms faintly visible in the matrix material; however, where the recrystallization processes have not reached such an extreme degree only the concentric structure of the oolites has been erased.

The oolites or pseudo-oolites may grade laterally into rocks of the bahamite variety as described by Beales (1958), since limestones with a brecciated appearance have been found associated with oolites and pseudo-oolites in some wells. The bahamite material is included with the oolites and pseudo-oolites on the facies distribution map (Figure 8).

This facies is thought to represent an environment of deposition with a relatively high energy level. The distribution of this facies, as illustrated by Figure 8, appears to support this theory, since the facies is developed largely in the interbank areas where current action might have been generally high.

#### *Organic Facies*

The sediments forming this facies are the third most abundant rock type in the Wymark Member. These limestones are composed of calcareous fossil fragments including brachiopod, gastropod and bryozoan remains and crinoid ossicles. The facies has also been extended to include the remains of colonial organisms such as algal nodules and colonies, stromatoporoid colonies, bryozoa and branching corals.

These rocks are microcrystalline to cryptocrystalline, pale yellowish brown to dark yellowish brown limestones and dolomitic limestones. The highly dolomitized forms of these rocks are microcrystalline textured rocks with euhedral to subhedral rhombs of dolomite cemented together along their edges or at their corners, thus imparting a spongy appearance to the rock. Sometimes a chalky, calcareous material infills the areas between the rhombs, otherwise the original void spaces are infilled to varying degrees by clear crystals of anhydrite or by milky dense anhydrite. This infilling tends to lower the overall porosity and permeability of these potential reservoir rocks.

Both the fragmental fossil material and the remains of colonial organisms seem to have accumulated in isolated areas, and in relatively thick deposits. Calcispheres are a prominent minor constituent in intervals in which algal colonies predominate.

Algal colonies and nodules and stromatoporoid colonies are the dominant rock builders among the colonial organisms. Examples from

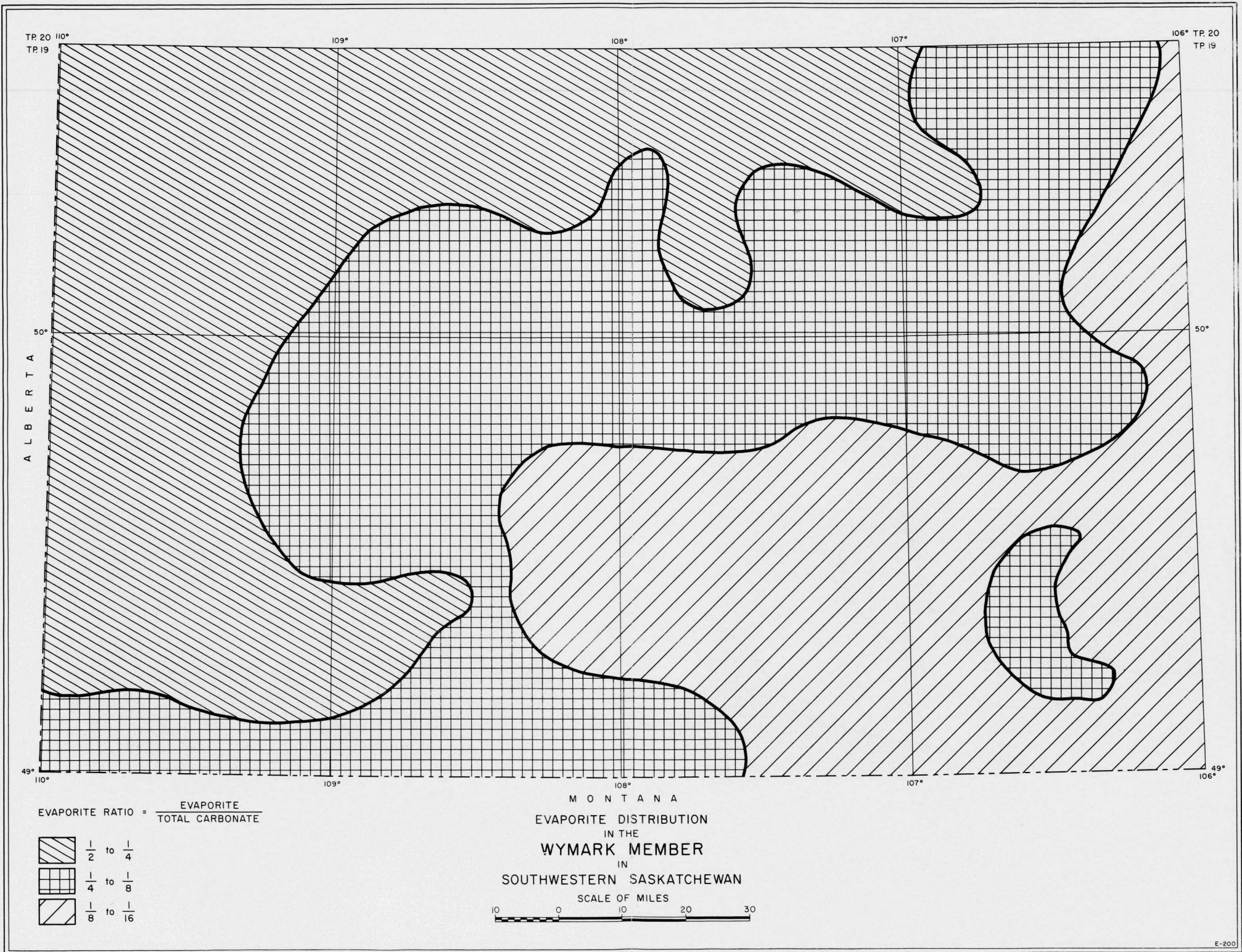


Figure 9—Evaporite Distribution Map of the Wymark Member.

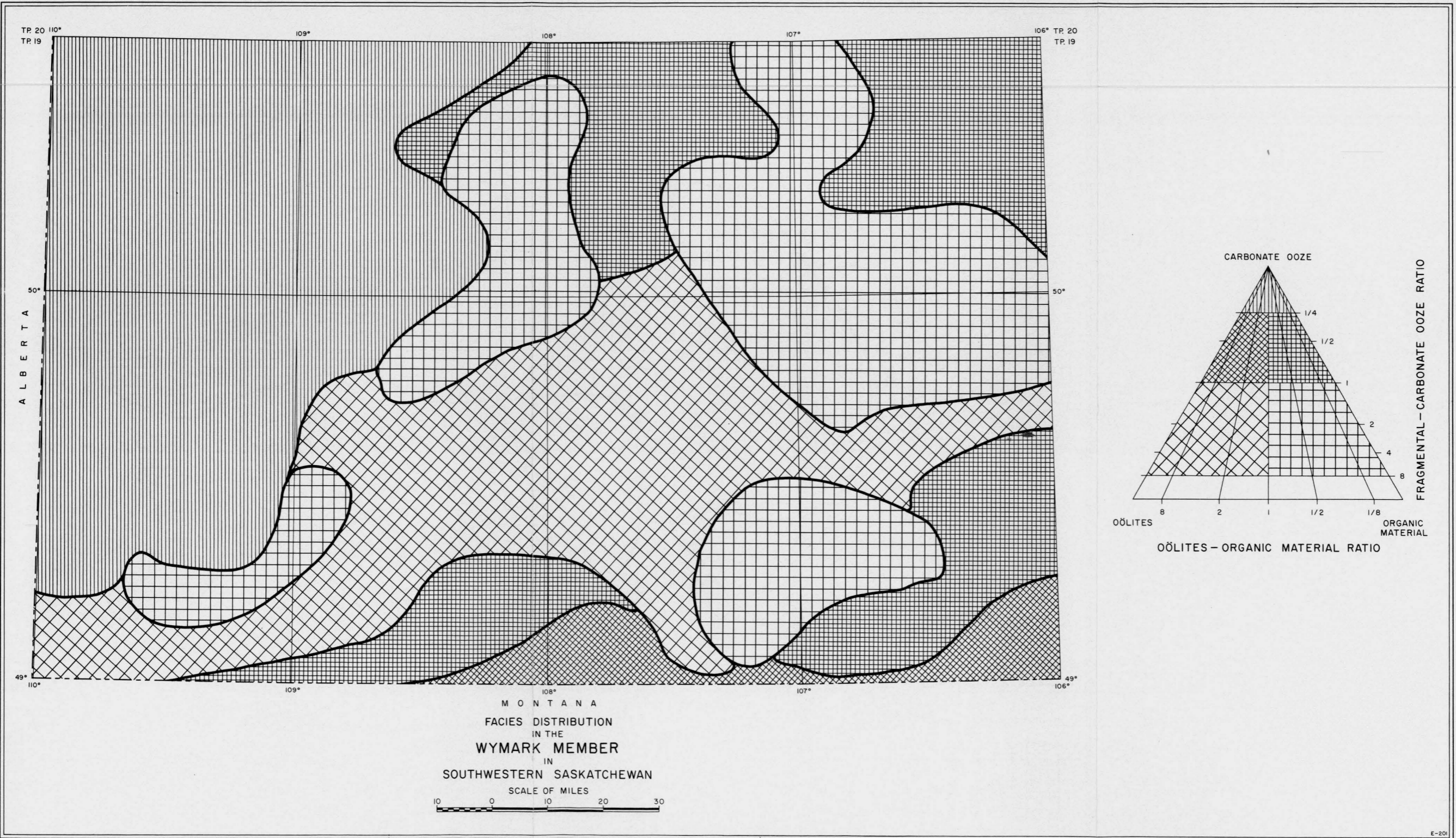


Figure 8—Wymark Member Facies Distribution Map.

core range in size from  $\frac{3}{4}$  inch for the nodules to 4 inches and larger for the colonies. Bryozoa and corals are present in lesser amounts, but locally they are the dominant rock building constituent.

The rocks of this facies are thought to have been formed under high energy conditions, and appear to be in the form of bank deposits.

#### *Minor Constituents and Other Features*

There are a number of minor constituents which are common to rocks of all the carbonate facies. These include blebs of white to very light gray, translucent anhydrite, granular to cryptocrystalline in texture, and ranging from  $\frac{1}{4}$  inch to  $3\frac{1}{2}$  inches in diameter. Pyrite is present in all facies as small grains in association with fossil remains, with anhydrite which fills void spaces and with vug-infilling calcite. It has also been observed as cubic crystals scattered through the body of the carbonate rocks. Stylolites both as incipient and well-developed forms are also prominent in most facies. Thin greenish-gray to grayish-green and light gray, calcareous shale beds are interbedded in the sequence, and become especially important near the top of the Wymark Member.

#### *Distribution of Carbonate Facies*

Figure 8 indicates the distribution of the various carbonate facies of the Wymark Member. In constructing this map the author has placed the various carbonate facies of the Wymark Member at the apices of triangular ratio diagrams similar to those employed by Sloss *et al.* (1949) in the construction of sand-shale and clastic ratio lithofacies maps. The writer feels that the environments of deposition represented by the lithologies employed by Sloss *et al.* are analogous to those environments represented by the facies involved in the construction of the carbonate facies distribution map presented herein. Because of this the same limiting ratios may be used and the same general method may be employed to establish the ratios. The author, therefore, concluded that the following two ratios would be the most applicable ones:

- (1) oolite-organic material ratio =  $\frac{\text{oolites}}{\text{organic material}}$
- (2) fragmental-carbonate ooze ratio =  $\frac{\text{oolite} + \text{organic material}}{\text{carbonate ooze}}$

The first ratio indicates the proportions of those materials formed under high-energy conditions, while the second ratio indicates the proportions of high-energy environment material and low-energy environment material. The method of obtaining these ratios is illustrated in the following example; consider a borehole which encounters 900 feet of Wymark Member of which 100 feet is mainly oolitic rock, 200 feet of carbonate rock composed of mainly organic material (bioclasts and colonial organisms) and 600 feet of carbonate ooze material, then the oolite-organic material ratio is  $\frac{100}{200}$  or  $\frac{1}{2}$  and the fragmental-carbonate ooze material ratio is

$$\frac{100 + 200}{600} \text{ or } \frac{1}{2}, \text{ also.}$$

The distribution of the various facies of the Wymark Member suggests deposition on a shallow platform. The platform was probably affected to some degree by wave and current action since most of the material on it is either bioclastic and biostromal or oolitic and pseudo-oolitic (Figure 8). The bioclastic and biostromal material appears to have been distributed as patches on the platform. Their position in section

(Figures 3 and 5) indicates that the bioclastic and biostromal materials may have been laid down as banks or bars of organic material. In most instances the oolitic and pseudo-oolitic material seems to form the inter-bank deposits. It can be seen from the facies distribution map that in no case is either one of these facies completely dominant, instead they are intermixed and interfinger with one another and with the carbonate ooze material and evaporites.

The platform appears to be flanked on the west, and possibly on the southeast beyond the map area, by the carbonate ooze facies, probably representing sediments deposited in quiet and protected waters. That ooze material is present to the southeast is only conjecture based on the fact that the amount of this material present in the Wymark Member seems to increase in that direction (Figure 8).

#### *Evaporite Phase*

The carbonate-evaporite rhythms of the Wymark Member are best illustrated in the region northwest of the shallow platform, where the evaporites become quite extensive and can be traced for considerable distances (Figure 3).

The evaporites within this area are cryptocrystalline to microcrystalline anhydrites, ranging in colour from pale yellowish brown to medium yellowish brown and sometimes light-gray. Dolomite stringers and lenses are common in the anhydrites and are often associated with carbonaceous or bituminous shale streaks, particularly in the vicinity of the contacts between carbonate and evaporite. Dolomite was also observed forming a thin outer layer surrounding blebs of anhydrite. Similar features were seen by the author in the evaporites of the Upper Ordovician (Kent, 1960) and were attributed to an origin involving gel-like balls of calcium sulphate formed on the floor of the evaporating basin and later enclosed by thin layers of marl.

The contacts of the anhydrites with the underlying and overlying beds vary from gradational with a strong intermixing of anhydrite and limestone or dolomitic limestone, to sharp with a very distinct break between the evaporite and the overlying or underlying lithologies. Pene-contemporaneously formed slump structures in the form of microfaults and microfolds are sometimes present along these contacts and within the anhydrites themselves.

The amount of evaporitic material increases greatly in the western portion of the area of study, as illustrated by Figure 9. This material has an areal distribution which compares for the most part with that of the carbonate ooze facies (Figure 8). It would seem therefore that these two deposits may be closely associated and laid down under similar environmental conditions. The high dolomite content of the carbonates attests to conditions of deposition similar to those described by Graf (1960, pp. 12-14), in which he attributes the increase of dolomite content in carbonates associated with anhydrites to an increase in salinity of the waters of the depositional area. In every case described by Graf, the dolomite and anhydrite is surrounded laterally by dolomitic limestone grading outward into limestone, a situation which appears to exist in this region. The anhydrites in the southeastern portion of the area become fewer in number and are less well developed with little lateral continuity (Figure 5). They are probably the result of the restriction of small evaporating basins by the organic banks built up on the platform.

There is a great diversity in the thickness of the anhydrite beds within the region. They range from less than a foot to about 40 feet in thickness; the thickest developments being in the vicinity of the Alberta-Saskatchewan boundary, thinning eastward. There appears to be a general stepped pattern to the anhydrites, in that, the higher the bed is stratigraphically the farther eastward it extends, indicating that as deposition continued in the area a progressively larger portion of the area of deposition came under evaporating conditions.

### Correlation

A detailed discussion of the correlation of the Wymark Member with other units in adjacent areas is beyond the scope of this paper and will be given greater consideration in the more detailed report soon to be published by the author. The Wymark Member probably correlates with the Cairn Formation and the lower part of the Southesk Formation of Belyea (1957, 1960) (Figure 4).

### Seward Member

The term Seward Member is here proposed for the widespread succession of alternating "clean" carbonates and argillaceous rocks which directly overlies the Wymark Member of the Duperow Formation and underlies the Birdbear Formation. The type section for this unit is designated as the interval between 4584 feet and 4810 feet in the M.O.W.S. Cantuar X-2-21 well (Figure 10).

Type Section: Seward Member

Mobil Oil Woodley Sinclair Cantuar No. X-2-21<sup>1</sup>

Lsd 2-21-16-17w3

Name derived from Seward Forest Reserve part of which lies about 5 miles south of the type well.

Interval: 4584 feet-4820 feet.

### LITHOLOGY

Drilled Depth in feet	Overlying beds—Birdbear Formation
4580-4590	Dolomite—dark yellowish brown; cryptocrystalline; poorly laminated in part. Shale—olive gray; fissile; waxy luster; calcareous.
4590-4610	Shale—olive gray; fissile; waxy luster; calcareous. Limestone—yellowish gray; microcrystalline; dense; very argillaceous.
4610-4620	Anhydrite—white; microcrystalline; sugary appearance; dense; intermixed with medium brown; microcrystalline, anhydritic dolomite.
4620-4640	Dolomite—yellowish gray; microcrystalline; dense; with growths of anhydrite crystals.

<sup>1</sup> This well was chosen for the type section of the Seward Member in preference to a well with a completely cored interval through the member, because of its well developed radioactive log characteristics. It was felt that the gross aspects of the lithology of this member were also well illustrated by the sample cuttings from this well, and that if a more detailed description of the lithology was required, it could be obtained from the cored interval between 4655-4814 feet in the Tidewater Parkbeg Crown No. 1 well (Lsd 10-32-18-8w3).

Drilled Depth  
in feet

- 4640-4650 Limestone—pale gray; cryptocrystalline; dense; dolomitic and argillaceous.
- 4650-4660 Limestone—pale yellowish brown; microcrystalline; dolomitic; fossiliferous-fragmental (mainly brachiopod remains).
- 4660-4700 Limestone—light gray; cryptocrystalline; dense; very argillaceous with disseminated pyrite crystals.
- 4700-4720 Limestone—medium yellowish brown; microcrystalline; dense; dolomitic; slightly argillaceous.
- 4720-4740 Limestone—pale yellowish brown; cryptocrystalline; dolomitic; fossiliferous, mainly brachiopods, a few ostracods. Some pale gray; microcrystalline; dense; argillaceous limestone and pale yellowish brown; cryptocrystalline; dense anhydrite.
- 4740-4750 Limestone—medium gray; microcrystalline; dense; very argillaceous; slightly silty with mica flakes and disseminated pyrite crystals.
- 4750-4760 Limestone—pale yellowish brown; sublithographic; dense; contains limestone fragments of a similar character; disseminated pyrite crystals and calcispheres.
- 4760-4770 Shale—olive gray to light gray; fissile; waxy luster; calcareous in part.
- 4770-4800 Dolomite—very pale orange; microcrystalline; dense; anhydritic. Some anhydrite appears in lower part of this interval.
- 4800-4810 Limestone—dark gray; cryptocrystalline; dense; argillaceous.

Underlying beds—Wymark Member.

The Seward Member is conformable with the underlying Wymark Member and with the superjacent Birdbear Formation. The base of this unit is marked by a thin argillaceous limestone or greenish-gray calcareous shale which represents the break between the argillaceous carbonates of the Seward Member and the cleaner carbonate deposits of the Wymark Member. The uppermost shale of this member also marks a change in depositional conditions between the Seward Member and the overlying Birdbear Formation. This upper shale is an extremely good correlation datum, and can be traced over most of southern Saskatchewan into Alberta and across the International Boundary into North Dakota and Montana.

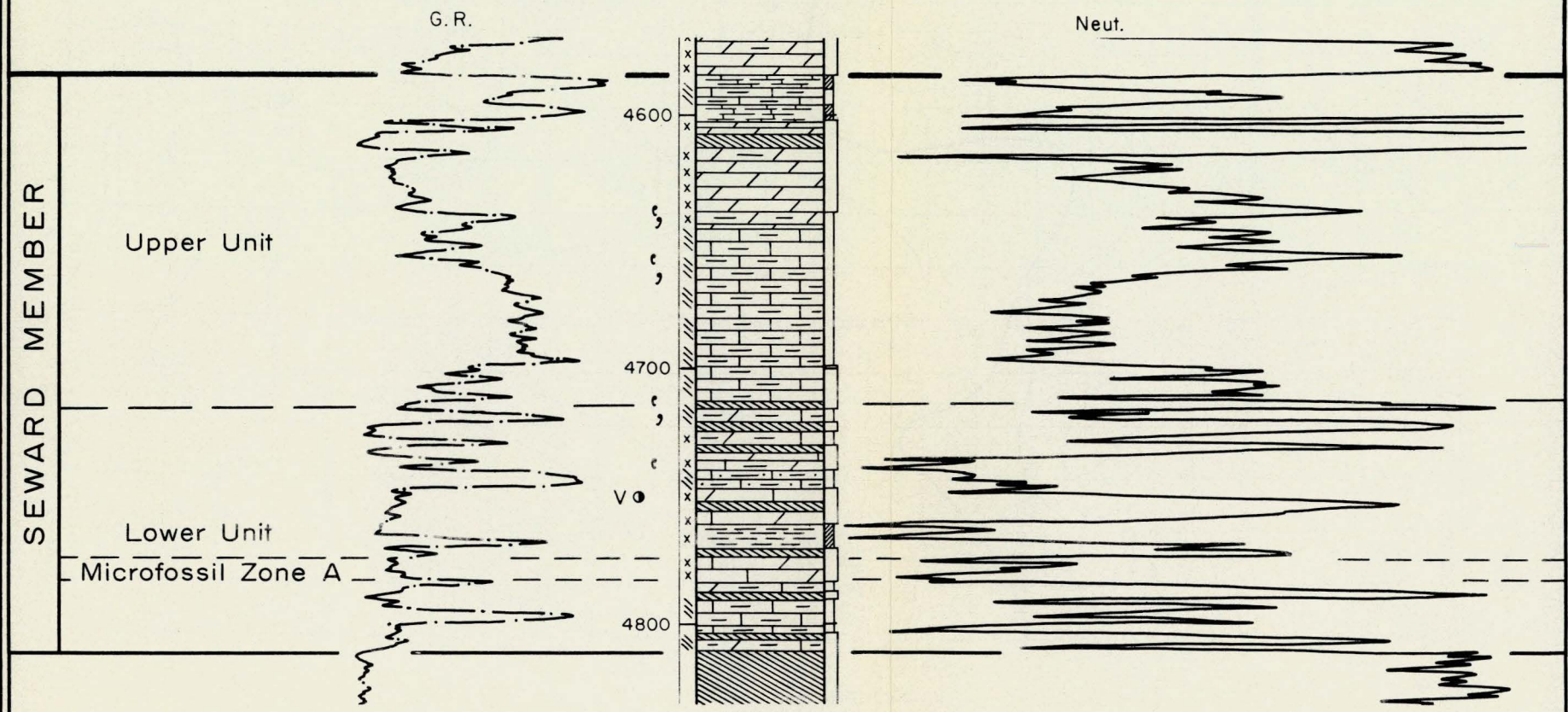
The Seward Member retains its gross lithologic character well beyond the limits of the area of study, and it is only in southern Alberta, as the southern Alberta reef complex of Upper Devonian age is approached, that this unit eventually loses its argillaceous content and passes laterally into "clean" carbonates. The isopachous map of the Seward Member (Figure 11) illustrates that there is a regional east-west variation in the thickness of this unit. Over most of the eastern half of the area the variation in thickness is slight (in the order of one foot in two miles). This gives the impression that the sediments were laid down on a slightly



# TYPE SECTION OF THE SEWARD MEMBER

MOBIL OIL WOODLEY SINCLAIR  
CANTUAR X-2-21  
L.S.D. 2-21-16-17W3

K. B. 2411



T. D. 7312

NOTE: For explanation of symbols, refer to legend on cross-sections.

Figure 10—Type Section of the Seward Member.

westward dipping platform or shelf. In contrast the unit thickens much more rapidly in the western and north-western portions of the map area, probably as a result of a more rapid deepening of this part of the area during deposition. The thickness of the Seward Member varies from a maximum of 325 feet to a minimum of 140 feet; however both of these appear to be abnormal and the regional variation is from 150 feet along the eastern margin to 270 feet in the western part of the study area.

For descriptive purposes the Seward Member may be divided into an upper unit and a lower unit. The lower part is composed of a number of thin (about 5 to 7 feet thick) greenish-gray to grayish green and light gray calcareous shales and very argillaceous limestones, interbedded with fossiliferous fragmental limestones (often highly dolomitic) and evaporites. The fossiliferous fragmental limestones have thicknesses between 3 feet and about 9 feet and are microcrystalline to cryptocrystalline in texture, and pale yellowish brown to medium yellowish brown, and occasionally yellowish gray, in color. Abundant fossil remains in the limestones and dolomitic limestones impart a bioclastic texture to these rocks. The remains include brachiopods, bryozoa, corals and exceptionally large numbers of crinoid ossicles. Distributed among the fossil remains are a small proportion of oolites and pseudo-oolites. As mentioned previously the lower part of the Seward Member also includes thin anhydrite beds, which in the northern part of the map area, in the region enclosed by the red line in Figure 11, aided the writer in delineating a number of evaporitic rhythms. A typical rhythm includes the following succession in ascending order:

- (4) marlstone<sup>1</sup> or calcareous shale
- (3) anhydrite
- (2) argillaceous limestone or dolomite
- (1) fossiliferous fragmental limestone.

The rhythms have thicknesses ranging from 8 feet to 23 feet and usually number about 5 or 6 within the area enclosed by the red line of Figure 11. The anhydrites which assist in the recognition of these rhythms are usually quite thin varying from 0.5 feet to about 3 feet. Beyond the enclosed area of Figure 11 the rhythms are only recognized with difficulty owing to the almost complete absence of anhydrite beds. In this region the succession is composed of fossiliferous fragmental limestones and calcareous shales or marlstones.

The top of the lower unit of the Seward Member was placed by the author at the top of a ten foot thick dolomitic limestone or anhydrite which overlies the last thin marlstone or calcareous shale of the rhythmic sequence.

The upper portion of the Seward Member has varying lithologies which include: dolomitic fossiliferous fragmental limestones (sometimes interbedded with argillaceous limestone, calcareous shales and evaporites), marlstones or very argillaceous limestones, and vari-colored calcareous shales. The lowest beds consist of about 10 feet of pale yellowish brown to medium yellowish brown, cryptocrystalline to microcrystalline, dolomitic (often highly dolomitic) limestone. The fossil remains are usually in a very poor state of preservation, because of the dolomitization, and as a result they are usually difficult to identify, but some brachiopods,

<sup>1</sup> In the sense of Dunbar and Rodgers (1957), pp. 226-227.

crinoid ossicles and ostracods were recognized. These strata are overlain by a light gray to medium light gray, and sometimes yellowish gray, very argillaceous limestone or marlstone about 25 feet to 70 feet thick. Much fossil debris has been observed in this unit usually as "pockets". The fossils are mostly crinoid ossicles and brachiopods. Superjacent to the marlstone is about 50 to 60 feet of pale yellowish brown to dark yellowish brown and yellowish gray, cryptocrystalline to microcrystalline, highly dolomitic limestones, fossiliferous in part, with occasional interbedded anhydrites. The anhydrites are particularly prominent in the northern and western parts of the region of study. Towards the eastern half they are absent, and in their place thin greenish-gray shales and light gray to yellowish gray marlstones enter into the sequence. A considerable amount of secondary anhydritization has taken place in this horizon with the result that large blebs of granular to cryptocrystalline, translucent, white to pale gray anhydrite and dark dusky brown porphyroblasts of anhydrite are disseminated through the rock. Any fossil remains present have been highly altered by dolomitization and are difficult to identify. A vari-colored grayish-green and grayish red calcareous shale or mudstone marks the top of the upper portion of the Seward Member and the top of the Duperow Formation. This shale is widespread, ranges from 6 feet to 15 feet in thickness, and makes an extremely good correlation datum. Thin reddish-brown siltstones and silty dolomites have also been observed interbedded in the shales. Along the western edge of the map area the shales pass laterally into medium light gray, calcareous shales and yellowish gray limestones.

#### *Correlation*

Present interpretations indicate that the Seward Member correlates with the upper two-thirds of the Southesk Formation of southern Alberta as proposed by Belyea (1957, 1960) (Figure 4).

#### **BIRDBEAR FORMATION**

The Birdbear Formation was named by Sandberg and Hammond (1958) and the name has since been incorporated into the nomenclature of Saskatchewan by Kents (1959). The term is applied to the sequence of carbonate and evaporite rocks overlying the Duperow Formation and underlying the Three Forks Group (Figure 2). It occupies the interval between the depths of 4518 feet and 4583 feet in the characteristic section of the M.O.W.S. Cantuar X-2-21 well (Lsd 2-21-16-17w3) (Figure 2). It is this stratigraphic unit which has been called the 'Nisku' Formation in the Williston Basin, but the new term is applied because there is considerable doubt as to the correctness of the correlation of the 'Nisku' Formation of the Williston Basin with the Nisku Formation of the type area.

The Birdbear Formation is conformable with the overlying and underlying strata. The lower contact with the Duperow Formation is distinct as a result of the sharp change from the carbonate rocks of the Birdbear Formation to the argillaceous sediments of the Seward Member of the Duperow Formation. The upper contact with the Three Forks Group is equally distinct over the region of study, in that there is a change from the yellowish brown carbonates of the Birdbear Formation to the greenish-gray, reddish brown, argillaceous to arenaceous, anhydritic carbonate rocks of the Three Forks Group.

The Birdbear Formation underlies the entire region of study and extends beyond the borders of the area in all directions. It has a variable

thickness within the area, reaching a maximum of 136 feet in the B.A. Baciú 15-36 well, (Lsd 15-36-6-4w3) with a minimum of 70 feet in the M.O.W.S. Cantuar X-2-21 well, (Lsd 2-21-16-17w3).

The processes of dolomitization have been very effective in masking the original textures of the rocks of the Birdbear Formation. As a result it was not possible for the author to outline carbonate facies in this formation similar to those designated for the Wymark Member of the Duperow Formation. The Birdbear Formation is composed mostly of pale yellowish brown to dark yellowish brown, cryptocrystalline to microcrystalline, dolomitic limestones or dolomites. Some oolitic beds and algal or stromatoporoid structures are present, along with scattered remains of poorly preserved crinoid ossicles, brachiopods and pelecypods.

The basic rock types of the Birdbear Formation are those described in the previous paragraph. They have been modified to some degree by the presence of greater or lesser amounts of argillaceous material. For descriptive purposes the variation in the argillaceous content may be used to subdivide the Birdbear into two basic lithological units. The lower unit may be again divided into a basal "clean" carbonate and an overlying argillaceous carbonate. The basal carbonate maintains relatively uniform thickness ranging between 5 feet and 10 feet over the entire area of study. The overlying argillaceous carbonate thickens in a northerly direction being thinnest in the vicinity of the Mobil Oil Cypress Lake No. X-10-2 well, (Lsd 10-2-5-30w3) (Figure 4) where it is about 6 feet thick, and reaching 26 feet in thickness in the Tidewater Parkbeg No. 1 well, (Lsd 10-32-18-3w3) (Figure 5). Although this argillaceous unit appears to be insignificant in the region of study, it becomes a very important part of the succession north of the area, and as a consequence has been called the lower argillaceous unit (Figure 2) with a view to its probable future significance.

The upper portion of the Birdbear Formation is mainly a "clean" carbonate unit varying in thickness from about 70 feet along the southern boundary to about 50 feet along the northern edge of the map.

In the vicinity of the British American Baciú No. 15-36 well, (Lsd 15-36-6-4w3), the argillaceous unit of the lower part of the formation is anomalously thick. Southward it divides into two units, the second, uppermost, argillaceous unit, here called the middle argillaceous unit (Figure 5) dividing the upper carbonates of the Birdbear Formation into two units. The middle argillaceous unit appears to be a localized development occurring mainly in the area extending southward from the British American Baciú No. 15-36 well to the Sohio Standard Wood Mountain No. 1 well, (Lsd 16-10-4-4w3). The middle argillaceous unit ranges in thickness from 20 feet to 31 feet.

Anhydrite beds constitute a large portion of the Birdbear Formation in certain regions of the map area. The anhydrites are yellowish brown to dark yellowish brown and microcrystalline with thin carbonaceous shale streaks and pale yellowish brown stringers of dolomite dispersed throughout. Their contacts with the underlying and overlying beds vary from sharp to gradational. There is evidence of structures formed contemporaneous with deposition, that is, microfolds and microfaults along the sharp contacts and within the body of the anhydrites. The anhydrites of the Birdbear Formation have a distribution similar to those of the Wymark Member of the Duperow Formation. In the eastern part of the map area they are few in number and those which are present have a limited lateral extent. However, in the western portion of the area, especially toward the northwest, there is a marked increase in the num-

bers and lateral extent of the anhydrite beds, so that in the vicinity of the Alberta boundary, the upper part of the Birdbear Formation is almost entirely anhydrite. Considerable amounts of secondary anhydrite are distributed throughout the carbonate rocks of the Birdbear Formation in the form of dusky brown porphyroblasts, and white to light grey dense blebs and void infilling material.

### **Correlation**

Correlation of the Birdbear Formation with other units in adjacent areas is one of the major problems in the Upper Devonian rocks of the Williston Basin. Baillie (1953, 1955) first proposed a correlation of this unit with the Nisku Formation of the Edmonton area; a correlation which was supported by Meneley (1958). This correlation with the Nisku Formation of the Edmonton area is extremely uncertain and it has been suggested by Belyea (1955) that the rocks usually delineated as Nisku Formation in southern Alberta are actually stratigraphically lower than the type Nisku Formation, and that the latter formation thins and pinches out in southern Alberta. Belyea renamed the Nisku Formation of southern Alberta calling it the Delia Member and later (1957) the Delia Formation. It is thought that the Birdbear Formation of the Williston Basin area is correlative with the Delia Formation of southern Alberta.

### **Overlying Beds**

#### **THREE FORKS GROUP**

The beds superjacent to the Birdbear Formation were laid down during the closing stages of Devonian times in the Williston Basin area. These strata have been variously called the Qu'Appelle Group by Baillie (1953, 1955), the Three Forks Formation by Kents (1959) and most recently the Three Forks Group by Christopher (1961). Kents (*op. cit.*), who proposed a twofold subdivision of the Three Forks Formation suggested that it correlated with the Wabamun Group of Alberta. As a result of this proposal he named his two lithologic units Stettler Member and Big Valley Member (oldest to youngest). Christopher (*ibid.*) on the other hand included the Bakken in the Three Forks and raised the latter to group status. The three formations belonging to this group are:

- Bakken Formation
- Big Valley Formation
- Torquay Formation

The Torquay Formation of Christopher directly overlies the Birdbear Formation. The contact between these two formations appears to be conformable but a more detailed examination of it will be necessary before its true nature can be known, particularly since it has been suggested by Sandberg and Hammond (1958) that the contact appears to be disconformable in some areas of the Williston Basin south of the International Boundary. The Torquay Formation underlies the entire region of study and generally thickens in a northerly direction across the map area from 60 feet near the International Boundary to 130 feet in the vicinity of the northern limit. It is dominated by three lithologic types which are greenish gray to grayish red shales, yellowish gray to reddish brown dolomites and white anhydrites. The dolomites and anhydrites are strongly brecciated which Christopher interprets as a result of weathering mechanisms acting upon these rocks.

The Torquay Formation is overlain by a sequence of marine, chloritic shales characterized by their green coloration, called the Big Valley Formation. This member is composed of a uniform succession of greenish gray to grayish green, non-calcareous, finely fissile shales, with a waxy

lustre. Kents (1959) reported a thin biostromal limestone in this unit which appears to rise from the middle to the top of the unit in a westerly direction. Christopher (op. cit.) attributes this apparent rise of the limestone to the removal of the upper part of the Big Valley Formation by erosion towards the west.

The Big Valley Formation passes upward into the overlying Bakken Formation which probably represents the close of Devonian sedimentation in the Williston Basin area, and the initiation of Mississippian deposition. Kents (1959) has suggested that the contact between these two units is unconformable. Later the disconformable nature of the Big Valley and Bakken Formations in the vicinity of the present study area was illustrated by Christopher (op. cit., p. 40). The Bakken Formation is made up of a middle sandstone unit overlain and underlain by black shales.

The Three Forks Group of the region of study is thought to be correlative to the Three Forks Formation of the type area as originally defined by Peale (Christopher, 1961). The lower two formations may be the eastward equivalents of the Wabamun Group and part of the Winterburn Group of Alberta.

## MICROFOSSIL ZONES

### Introduction

#### HISTORY OF THE GENERIC NOMENCLATURE OF *Tasmanites* AND *Leiosphaeridia*

*Tasmanites* and *Leiosphaeridia* are disc-shaped or globular spore-like microfossils of uncertain origin. The name *Tasmanites* was first proposed for them by Newton (1875, p. 341) when he described specimens from the "Tasmanite" and Australian "White Coal" in Tasmania. He encountered only one species which he called *Tasmanites punctatus*. About the same time that Newton described *Tasmanites*, Dawson (1871) described some sporomorph specimens from the Devonian black shale at Kettle Point, Lake Huron and called them *Sporangites huronensis*. Dawson had first proposed the term *Sporangites* in a paper published in 1863. In 1884 Dawson published descriptions of some other sporomorph specimens sent to him by O. A. Derby from the Rio Trombetus and Rio Curuá areas of Brazil. He called these specimens *Protosalvina braziliensis* and eventually included some previously described *Sporangites* from the Rio Tapajos area of Brazil with *Protosalvina*. In 1944 Schopf *et al.* in a summary of the literature on fossil spores rejected Dawson's (1863) term *Sporangites* on the grounds that it was ambiguous and included more than one genus. They also proposed that those specimens without haptotypic features be removed from Dawson's (1884) genus *Protosalvina* and be termed *Tasmanites*. With these recommendations they suggested the use of *Tasmanites punctatus* Newton as the type species. Shortly before this and unknown to Schopf *et al.* (1944), Eisenack (1938) described sporomorph forms similar to Dawson's *Sporangites* and called them *Leiosphaera*.

Sommer (1956a), who had access to the topotype material from Derby's localities and from the Rio Tapajos area, agreed with Schopf *et al.* (1944) by noting that Dawson had found sporomorphs of the unicentric group belonging to *Tasmanites* Newton (1875) emend. Schopf *et al.* (1944) in the material from the Rio Tapajos and *Protosalvina braziliensis* Dawson emend. Krausel, in the Rio Trombetus and Rio Curuá material. Sommer pointed out that the latter have haptotypic structures, and cannot be mistaken for *Tasmanites*. In the same paper he classified *Tasmanites* as "Algae incertae sedis" belonging to the Family *Tasmanacea* Sommer, new family.

In 1958, Eisenack divided his sporomorph genus *Leiosphaera* into two. Forms having radial pores he considered as belonging to the genus *Tasmanites* and those without pores the genus *Leiosphaeridia*, new genus. He established the type genus of the new genus as *Leiosphaeridia baltica* Eisenack 1958 and included both *Tasmanites* and *Leiosphaeridia* in the Family *Leiosphaeridae* Eisenack 1954 and in the Class *Hystricosphaeridea*.

#### GENERIC CHARACTERISTICS

The generic characteristics of *Tasmanites* were set out by Schopf *et al.* (1944), but the writer feels that a repetition of them here will assist in identifying this genus in the subsurface rocks of the Williston Basin area.

The characteristics as quoted in part from Schopf *et al.* are:

"Symmetry—Unicentric; there is evidently a center and not an axis of symmetry as in spores of bonafide plants.

Shape—Originally spherical; except where protected compression has altered them into disks with a few sporadic rounded folds.

Size—Ranging from less than 100 microns to 600 microns<sup>1</sup> or slightly greater diameters. Forms greatly in excess or much smaller than these diameters are suspect because they vary so greatly from the genotype species.

Ornamentation—Surface smooth and glistening in reflected light at low magnification; more detailed examination shows more or less rugosity which may be in part attributable to preservation. More or less regularly spaced punctae varying in number on different forms are visible, but not conspicuous. The forms may be described as essentially lacking in external ornamentation.

Haplotypic features—Entirely absent. False conclusions have been drawn either from different forms in association with *Tasmanites* or from specimens poorly preserved and misinterpreted. Absence of trilete sutures is diagnostic.

Wall—Generally moderately thick, mostly 1/10 to 1/25 of the diameter; wall evenly developed on all surfaces and never membranous, often punctate<sup>2</sup> with pores tapering from very small orifice on the outside; sometimes the punctae are very sparse, in other species they may be so densely packed as to give a radially striate appearance. Poorly defined concentric bands may be present in the wall, but these are ordinarily not easily visible unless material is sectioned. In optical section (transmitted light) aside from the punctae, walls generally appear homogeneous.”

Eisenack (1958) defined *Leiosphaeridia* as “the thin-walled remains of hollow, spherical organisms”. They consist of a very resistant light yellowish to dark red brown transparent, organic substance. Like *Tasmanites* they are often found in the form of compressed or irregularly folded discs. In contrast to *Tasmanites*, pores are absent even in the adult stage and a pylome is common.

## ORIGIN

The origin of *Tasmanites* and *Leiosphaeridia* is a matter of controversy. Newton (1875, p. 350) suggested that they might be spores or sporangia of some lycopodiaceous plant and was strongly convinced of their vegetative origin. Dawson (1884) also considered them to be spores and Jones (1956, p. 63) concurred with this idea. However, Schopf *et al.* (1944, pp. 16-17) suggested that because of the lack of markings on the case and also because of the absence of evidence of a tetradic nature, *Tasmanites* may be algal in origin. They also pointed out that the absence of nitrogen in the chemical composition of *Tasmanites* eliminated the animal kingdom as a possible origin and points to plant affinity. Sommer (1956a) and Johnson (1958) were strongly of the opinion that *Tasmanites* shows algal affinities; the former felt that they were independent organisms, and unlike spores in this respect which are, in fact, specialized

<sup>1</sup> (Author's footnote) Sommer (1956a, 1956b) has described 10 species with size ranges from a minimum of 100-175 microns in diameter for *Tasmanites moseai* Sommer, to a maximum of 370-710 microns in diameter for *Tasmanites avelinoi* Sommer.

<sup>2</sup> (Author's footnote) According to Eisenack (1958) in its youthfull stage *Tasmanites* is always thin walled and without pores and consequently not easily distinguished from *Leiosphaeridia* (See plate III Figure 5).

reproductive bodies. In a recent paper, Wall (1962), *Tasmanites* and *Leiosphaeridia* are compared to two recent phytoplanktonic organisms *Pachysphaera pelagica* Ostenfeld and *Halosphaera minor* Ostenfeld. On the basis of his comparisons, Wall considers both *Tasmanites* and *Leiosphaeridia* to be fossil green algae closely related biologically to *Pachysphaera pelagica* and *Halosphaera minor*, respectively.

#### STRATIGRAPHIC DISTRIBUTION

According to Radforth and Rouse (1956) *Tasmanites* are confined to Upper Devonian, Lower Mississippian, Lower Cretaceous, and Tertiary strata. The type genus identified by Newton (1875) was taken from the "Tasmanite" and Australian "White Coal", which according to Reed (1921) are Permo-Carboniferous in age. Further evidence suggests that *Tasmanites* may have a greater vertical range than is suggested by Radforth and Rouse. For example, Sommer (1956a) has observed them extending from Silurian rocks through Devonian rocks in the drill cores from an oil exploration bore hole at Bon Jardin in the town of Itaituba, State of Para, Brazil. According to Schopf *et al.* (1944), P. F. Reinsch described the group *Disciae* (in which he included *Tasmanites*) from the Carboniferous of Central Russia and Saxony, and from older Mesozoic rocks. Jodry and Campau (1961) reported *Tasmanites* from a number of horizons in the Palaeozoic strata of the Williston Basin including rocks of Middle Devonian, Upper Devonian and Mississippian age. Eisenack (1958) suggested that *Leiosphaeridia* may be obtained from rocks in Europe ranging in age from Upper Cambrian to Lower Jurassic.

#### *Tasmanites* and *Leiosphaeridia* in the Duperow Formation of Southwestern Saskatchewan

Jodry and Campau (1961) were the first to report the presence of *Tasmanites* and Chitinozoa in certain zones in the subsurface of Western Canada and the northwestern United States. In their paper, they discussed the vertical stratigraphic distribution of these microfossils and the use of them as stratigraphic correlation markers. They found that *Tasmanites* and Chitinozoa were confined to relatively thin zones in the geologic column in the Williston Basin and adjacent areas and, further that in this area Chitinozoa were found only in the lower part of the column overlapping slightly with *Tasmanites* in the Middle Devonian (a zone of Chitinozoa was found in the Middle Devonian Dawson Bay Formation, while the first *Tasmanites* zone was found in the underlying Winnipegosis Formation). Other than the zone of occurrence of *Tasmanites* in the Middle Devonian Winnipegosis Formation the remaining sporomorph zones are confined to strata younger than Middle Devonian and include zones in the Upper Devonian Duperow and Birdbear<sup>1</sup> Formations and in the Bakken and Charles Formations of Mississippian age.

A detailed examination of forms from the Duperow Formation, which are similar to the microfossils obtained by Jodry and Campau (1961), indicates that at least two genera exist. One genus which contains radial pores is probably *Tasmanites*, and the other genus without radial pores is probably *Leiosphaeridia*.

Four prominent microfossil zones are present in the Duperow Formation and are here designated the microfossil zones A, B, C and D in

<sup>1</sup> Since the completion of this manuscript, the author has located the zone in the Birdbear Formation but has not been able to outline its vertical and lateral distribution.

descending order. The B, C and D zones are particularly well developed and were observed in nearly every well examined in the region of study. The A zone although not quite so consistent was recognized in enough wells to satisfy the author that it, too, represents a good stratigraphic marker. The fact that these microfossil zones were not observed in some wells does not, in the opinion of the writer, detract from their usefulness as a correlation tool, nor does it suggest that they are not present in these wells. On the contrary, a number of factors may enter into the apparent absence of these zones, including:

(1) Sample catching techniques at the well site.

(2) Examination techniques employed by the geologists. The author found that, in order to ascertain whether or not sporomorphs were present in a particular sample, a number of cuttings from each interval had to be dissolved in hydrochloric acid, rather than just one or two. This ensures fairly representative sampling of the interval.

(3) The final and probably the most important factor is the manner in which these sporomorphs are distributed from their source area. Regardless of their origin these microfossils were probably transported from their source either by wind or currents. As a consequence, the farther away a well is from the source of the sporomorphs the smaller the numbers of *Tasmanites* and *Leiosphaeridia* present. This is exemplified by the microfossil zone D which was not recognized by Jodry and Campau (1961) in any of the wells they examined in southeastern Saskatchewan and western Manitoba. The most easterly indication of the presence of this zone occurs in the Socony Sohio Strathallen 23-5 well, (Lsd 5-23-2-3w3) (Figure 5) and as it is traced farther west *Tasmanites* and *Leiosphaeridia* become increasingly more numerous in this zone, pointing to a probable westerly source. Any change in the direction of or strength of the transporting mechanism could also account for the absence of these microfossils from certain areas.

A distribution count of the 170 specimens of *Tasmanites* and *Leiosphaeridia* collected by the author indicates that *Tasmanites* is prominent in the D zone making up about 73 per cent of the total number of specimens collected from this zone. The proportion of *Tasmanites* becomes less in the higher zones as they make up about 35 per cent of the specimens in the C zone and 28 per cent in the B zone. At this time only *Leiosphaeridia* has been collected from the A zone.

The microfossil zones are thought to represent time planes (Jodry and Campau, 1961). It is hoped that they will be useful in making correlations from one area to another, for example, from southwestern Saskatchewan into southern Alberta, where at present such correlations have been hindered by the scarcity of good marker horizons and by the restricted lateral extent of the existing ones. The author has found the zones are easily correlated within the region of study (Figures 3, 4 and 5) but not enough data have been obtained at this time to evaluate fully the possibility of further correlations beyond the limits of this area.

#### GENERAL DESCRIPTION OF THE *Tasmanites* AND *Leiosphaeridia* OF THE DUPEROW FORMATION

The *Tasmanites* found in the Duperow Formation resemble others described in the literature (Sommer 1956a, 1956b and Eisenack, 1958), but are much smaller in diameter. They range from 40.7 microns to 92.5 microns and have wall thicknesses between 3.7 microns and 9.25 microns.

They are usually globular (Plate I—Figures 1 and 2, 4, 6-8 and Plate II—Figures 1, 3 and 5) or disc-shaped (Plate I—Figure 9, Plate II Figure 4) but may be in some cases compressed into elliptical shapes (Plate I—Figure 3, Plate II Figure 2). They have no visible haplotypic features and are straw yellow to dusky brown in color. Some forms have a dense distribution of radial pores in the wall (Plate I—Figure 2, Plate II—Figure 1) while others have only a few pores.

For the most part the *Leiosphaeridia* have a similar appearance to *Tasmanites* (Plates III and IV) and cannot be distinguished from them by means of a 10x binocular microscope. The specimens collected by the author have diameters between 22.2 microns and 99.9 microns, with wall thicknesses from 1.85 microns to 9.25 microns. Under high magnification (270x) it can be seen that they have no pores and are usually thinner walled than *Tasmanites* (Plates III and IV). Some forms which have thick walls without visible pores (Plate III Figures 7-9, Plate IV Figures 2, 4 and 5) have been included with *Leiosphaeridia* but may be, in fact, another genus. However, it will be necessary to collect considerably more specimens before further generic subdivisions can be made, or indeed before any species can be established.

## ECONOMIC PROSPECTS

It was suggested at the beginning of this report that the best hydrocarbon traps in the Saskatchewan Group would probably be of the stratigraphic or structural-stratigraphic type. The presence of numerous anhydrite beds to form the cap rocks over potential reservoirs particularly in the Wymark Member of the Duperow Formation increases the possibilities of such traps occurring.

### DISTRIBUTION OF POROSITY IN THE SASKATCHEWAN GROUP

On the basis of this study of the Saskatchewan Group, the Wymark Member of the Duperow Formation appears to have the most promising horizons for the occurrence of hydrocarbons. In this member porosity is best developed in the dolomitized portions of the rocks of the organic facies where good intergranular to vuggy porosity is present. The porosity is less well developed where rocks of this facies are composed of algal or stromatoporoid colonies. Here, fair to good intergranular porosity exists in the dolomitized portions and only poor to fair porosity in the less dolomitic areas.

The porosity decreases in the carbonate ooze and oolitic facies and where present is mostly of an intergranular type. However, parts of these facies have good intergranular porosity, particularly where there is a relatively high degree of dolomitization. The development of this porosity is sporadic and unpredictable, rendering exploration for petroleum accumulations difficult.

Secondary anhydrite infilling the voids in all the facies of the Wymark Member has resulted in a lowering of the overall porosity and permeability. This infilling is most evident in parts of the organic facies where crystals of clear anhydrite are present in what appears to have been, at one time, highly porous rock.

Little well-developed porosity occurs in the Seward Member, due mostly to the high argillaceous content of the rocks and in part owing to secondary anhydrite infilling void spaces. However, the presence of thin impervious shale beds overlying carbonate rocks which in part may be highly dolomitized, introduces the possibility of hydrocarbon reservoirs occurring in this member, and therefore, it should not be completely disregarded as a possible oil-bearing stratum.

Although the highly dolomitic nature of the rocks of the Birdbear Formation suggests the presence of good secondary porosity, it appears that dolomitization has reached a stage where much of the secondary porosity has been obliterated. As a consequence porosity in this formation is confined to a few patches of dolomitized organic material having good to very good intergranular to vuggy porosity.

### OIL AND GAS SHOWS

Three wells in the area reviewed had oil shows in the Saskatchewan Group. Two wells the M.O.W.S. Fosterton X-15-3 well, (Lsd 15-3-17-18w3) and the Tidewater Eastend Crown No. 1 well, (Lsd 15-11-6-20w3) had shows in the Wymark Member of the Duperow Formation. It is significant that both of these wells had the oil staining distributed over a wide vertical interval in the organic facies. The Tidewater Eastend Crown No. 1 well had slight to fair oil staining over a 37 foot interval

from 6031 to 6068 feet. Within this interval the organic and carbonate ooze facies are interbedded and the staining occurs in both. These rocks have fair to good, intergranular and vuggy porosity. In the M.O.W.S. Fosterton X-15-3 well, oil staining was observed in the organic, oolitic and carbonate ooze facies of the Wymark Member, where poor to good, intergranular and vuggy porosity occurs.

Some oil staining was seen in the Birdbear Formation in the M.O.W.S. Cantuar X-2-21 well, (Lsd 2-21-16-17w3). Light staining was noted at 4549 feet while stronger staining was observed over the interval 4555 feet to 4565 feet where there is fair to good intergranular and vuggy porosity.

Non-combustible gases were obtained in drill stem tests of the Duperow Formation in at least two wells in the region of study (Sawatzky, Agarwal and Wilson, 1960), United Canso Consumer Co-op Calvin Battle Creek No. 4-31 (Lsd 4-31-3-26w3) and Tidewater Eastend Crown No. 1 (Lsd 15-11-6-20w3). Significant amounts of helium in both these wells have intensified interest in the helium prospects of southwestern Saskatchewan. Two zones were tested in the United Canso *et al.* Battle Creek No. 4-31 well, and an analysis of the recovered gases indicated helium contents of .14 per cent and (.47) per cent respectively, with an initial flow of gas of 6 to 7 MMcf per day. In the Tidewater Eastend Crown No. 1 well a 150 foot interval in the Duperow Formation was tested and produced non-inflammable gas at the rate of 4.7 MMcf per day, while a second zone in the same well produced non-inflammable gas at an initial flow rate of 3.5 MMcf per day. The helium analyses for these two zones were unavailable to the author.

#### CONCLUSIONS

Porous rocks in the organic facies of the Wymark Member of the Duperow Formation and in similar facies in the Birdbear Formation, and the good impervious anhydrites overlying these zones, provide ideal stratigraphic traps for the accumulation of oil or gas. The organic facies attains thicknesses in the order of 60 feet, in the Wymark Member, making substantial "pay zones" possible. Finally, the presence of oil-staining in the more porous facies of the Saskatchewan Group attests to the presence of hydrocarbons in these rocks.

Regarding non-combustible gases, Sawatzky *et al.* (1960) believe that the conditions required for the entrapment of helium are similar to those required for the trapping of hydrocarbons. If this is the case, then the highly porous zones of the Duperow Formation capped by anhydrites, also may form helium reservoirs.

## BIBLIOGRAPHY

- Andrichuk, J. M.**, 1951, "Regional Stratigraphic Analysis of Devonian System in Wyoming, Montana, Southern Saskatchewan and Alberta", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 35, No. 11, pp. 2368-2408, also, 1954, Western Canada Sedimentary Basin, *Amer. Assoc. Petrol. Geol. Symposium*, Rutherford Memorial Volume, pp. 68-108.
- , 1958, "Cooking Lake and Duvernay (Late Devonian) Sedimentation in Edmonton Area of Central Alberta, Canada", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 42, No. 9, pp. 2189-2222.
- Baillie, A. D.**, 1953, "Devonian System of the Williston Basin Area", *Manitoba Mines Branch*, Pub. 52-5, also, 1955, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 39, No. 5, pp. 575-629.
- Beales, F. W.**, 1958, "Ancient Sediments of Bahaman Type", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 42, No. 8, pp. 1845-1880.
- Belyea, H. R.**, 1955, "Cross-Sections Through the Devonian System of the Alberta Plains", *Geol. Surv. Canada*, Paper 55-3.
- , 1957, "Correlation of Devonian Subsurface Formations, Southern Alberta", *Geol. Surv. Canada*, Paper 55-38.
- , 1960, "Distribution of Some Reefs and Banks of Upper Devonian Woodbend and Fairholme Groups in Alberta and Eastern British Columbia", *Geol. Surv. Canada*, Paper 59-15.
- Christopher, J. E.**, 1961, "Transitional Devonian-Mississippian Formations of Southern Saskatchewan", *Sask. Dept. Min. Res.*, Report No. 66.
- Dawson, J. W.**, 1863, "Synopsis of the Flora of the Carboniferous Period in Nova Scotia", *Canadian Nat.*, N.W., Vol. 8, No. 6, pp. 431-457.
- , 1871, "On spore-cases in coals", *Amer. Jour. Sci.*, Ser. 3, Vol. 1, No. 4, pp. 256-263.
- , 1884a, "Rhizocarps in the Paleozoic Period", *Amer. Assoc. Adv. Sci. Proc.*, 32nd meeting (Minneapolis, 1883), pp. 260-264.
- , 1884b, "On Rhizocarps in the Paleozoic Period", *Canadian Rec. Sci.*, Vol. 1, pp. 19-27.
- Eisenack, A.**, 1938, "Hystrichosphaerideen und verwandte Formen im baltischen Silur", *Z. Geschiebeforsch.*, 14, pp. 1-30.
- , 1958, "Tasmanites Newton 1875 und Leiosphaeridia n.g. als Gattungen der Hystrichosphaeridia", *Palaeontograph.*, Abt. A, Band 110, Lief. 1-3, pp. 1-92.
- Dunbar, C. O.**, and **Rodgers, J.**, 1957, "Principles of Stratigraphy", *John Wiley and Sons*, New York City, New York, 356p.
- Geological Staff, Imperial Oil Ltd.**, 1950, "Devonian Nomenclature in Edmonton Area, Alberta, Canada", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 34, No. 9, pp. 1807-1825.
- Graf, D. L.**, 1960, "Geochemistry of Carbonate Sediments and Sedimentary Carbonate Rocks": Part II—"Sedimentary Carbonate Rocks", *Ill. State Geol. Surv.*, Circ. 298.
- Jodry, R. L.**, and **Campau, D. E.**, 1961, "Small Pseudochitinous and Resinous Microfossils—New Tools for the Subsurface Geologist", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 45, No. 8, pp. 1378-1391.
- Johnson, J. H.**, and **Konishi, K.**, 1958, "Studies of Devonian Algae"—Part I, "A Review of Devonian Algae"; Part II, "Devonian Calcareous Algae From Alberta, Canada", *Quart. Colo. School of Mines*, Vol. 53, No. 2.
- Jones, D. J.**, 1956, "Introduction to Microfossils", *Harper's Geoscience Series, Harper and Bros.*, New York, pp. 271 and 275.
- Kent, D. M.**, 1960, "The Evaporites of the Upper Ordovician Strata in the Northern Part of the Williston Basin", *Sask. Dept. of Min. Res.*, Report No. 46.
- Kents, P.**, 1959, "Three Forks and Bakken Stratigraphy in West Central Saskatchewan", *Sask. Dept. of Min. Res.*, Report No. 37.
- Lane, D. M.**, 1959, "Dawson Bay Formation in the Quill Lakes-Qu'Appelle Area Saskatchewan", *Sask. Dept. of Min. Res.*, Report No. 38.

- Meneley, R. A.**, 1958, "The Nisku Format", *Unpublished Master of Science Thesis, University of Saskatchewan*, Murray Memorial Library, Saskatoon.
- Newton, E. T.**, 1875, "On 'Tasmanite' and Australian 'White Coal'," *Geol. Mag., N.S.*, Decade 11, Vol. 11, No. 8, pp. 337-342.
- North Dakota Geological Society**, 1954, "Stratigraphy of the Williston Basin".
- Pettijohn, F. J.**, 1957, "Sedimentary Rocks", *Second Edition, Harper and Bros., New York*.
- Porter, J. W.**, and **Fuller, J. G. C. M.**, 1959, "Lower Palaeozoic Rocks of the Northern Williston Basin and Adjacent Areas", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 43, No. 1, pp. 124-189.
- Powley, D.**, 1951, "Devonian Stratigraphy of Central Saskatchewan", *Unpublished Master of Science Thesis, University of Saskatchewan*, Murray Memorial Library, Saskatoon.
- Radforth, N. W.** and **Rouse, G. E.**, 1956, "Floral Transgressions of Major Geological Time Zones", *Trans. Roy. Soc. Canada, 3rd Series, Section V, Vol. L, Pp. 17-26*.
- Reed, F. R. C.**, 1921, "Geology of the British Empire", *Edward Arnold, London*.
- Sandberg, C. A.**, and **Hammond, C. R.**, 1958, "Devonian System in Williston Basin and Central Montana", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 42, No. 10, pp. 2293-2334.
- Sawatzky, H. B.**, **Agarwal, R. G.**, and **Wilson, W.**, 1960a, "Helium Prospects in Southwest Saskatchewan", *Oil in Canada*, Vol. 12, No. 23, pp. 54-76.
- , 1960b, "Helium Prospects in Southwest Saskatchewan", *Sask. Dept. of Min. Res.*, Report No. 49.
- Schopf, J. M.**, **Wilson, L. R.**, and **Bentall, R.**, 1944, "An Annotated Synopsis of Paleozoic Fossil Spores and the Definition of Generic Groups", *Illinois State Geol. Surv.*, Rept. Invest. No. 91.
- Sloss, L. L.**, **Krumbein, W. C.**, and **Dapples, E. C.**, 1949, "Integrated Facies Analysis" in "Sedimentary Facies in Geologic History", *Geol. Soc. America*, Mem. 39, pp. 91-124.
- Sommer, F. R.**, 1956a, "South American Paleozoic, Sporomorphae without Haptotypic Structures", *Micropaleontology*, Vol. 2, No. 2, pp. 175-181.
- , 1956b, "New Species of Tasmanites from Devonian of Para", *Am. Acad. Bras. Ci.*, Summary, Vol. 28, No. 4, pp. 459-461.
- Stanton, M. S.**, 1953, "Ordovician, Silurian and Devonian Stratigraphy of Western Saskatchewan", *Guidebook Billings Geol. Soc.*, Fourth Annual Field Conf., pp. 59-63.
- Walker, C. T.**, 1957, "Correlation of Middle Devonian Rocks in Western Saskatchewan", *Sask. Dept. of Min. Res.*, Report No. 25.
- Wall, D.**, 1962, "Evidence from Recent Plankton Regarding the Biological Affinities of *Tasmanites* Newton 1875 and *Leiosphaeridia* Eisenack 1958", *Geol. Mag.*, Vol. XCIX, No. 4, pp. 353-362.

## **APPENDIX**

### *Well Data*

Formation and member tops determined from cores, samples and mechanical logs.

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Top of Birdbear Formation (feet below K.B.)	DUPEROW FORMATION		
				Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Basal Member (feet below K.B.)
Socony Sohio Congress No. 13-13.....	Lsd 13-13-9-1w3.....	2391	5642	—	—	—
Socony Sohio Canopus No. 25-12.....	Lsd 12-25-3-2w3.....	3221	6911	—	—	—
Socony Sohio Elm Springs No. 14-12.....	Lsd 12-14-5-2w3.....	2780	6364	6465	6621	—
Tidewater Johnstone Lake No. 1.....	Lsd 9-20-12-2w3.....	2421	5183	5302	5469	5843
Socony Sohio Strathallen No. 23-5.....	Lsd 5-23-2-3w3.....	3026	6640	6735	6896	7221
Sohio Standard Regent Wood Mountain No. 1.....	Lsd 9-18-3-3w3.....	3259	6768	6877	7032	7392
Socony Sohio Limerick No. 1.....	Lsd 6-35-8-3w3.....	2502	5720	5849	6007	—
White Rose Wood Mountain No. 12-19.....	Lsd 12-19-4-3w3.....	2997	6442	6549	6707	7066
Tidewater Signal Johnstone Lake No. 2-2.....	Lsd 2-2-13-3w3.....	2331	5155	—	—	—
Tidewater Parkbeg No. 1.....	Lsd 10-32-18-3w3.....	2217	4565	4653	4815	5220
Sohio Standard Wood Mountain No. 1.....	Lsd 16-10-4-4w3.....	3115	6571	6683	6848	7197
British American Baciú No. 15-36.....	Lsd 15-36-6-4w3.....	2531	5803	5940	6098	6477
Christie Quintana Melaval No. 1.....	Lsd 2-14-8-4w3.....	2562	5676	5793	5957	6319
Sun Christie Gravelbourg No. 7-16.....	Lsd 7-16-9-4w3.....	2561	5686	5802	5976	6326
Stanolind-Tidewater Wood River No. 1-A.....	Lsd 4-18-10-4w3.....	2308	5333	5454	5617	5996
Paramount <i>et al.</i> Chaplin Lake No. 13-21.....	Lsd 13-21-16-4w3.....	2240	4746	4828	—	—
Amerada-Shell "S-O" No. 13-17.....	Lsd 13-17-3-6w3.....	3255	6508	6649	6822	7160
Tidewater Kelstern No. 1.....	Lsd 5-27-15-6w3.....	2415	4956	5036	5218	5610
British American Moore No. 6-27.....	Lsd 6-27-15-6w3.....	2411	4871	4983	5161	5553
Tidewater Signal Morse No. 12-17.....	Lsd 12-17-16-7w3.....	2512	4988	—	—	—
Imperial Morse No. 1.....	Lsd 1-6-18-7w3.....	2332	4690	4773	4964	5350
Texaco Wood Mountain No. 12-10.....	Lsd 12-10-5-8w3.....	2839	5928	6042	6215	6562
Tidewater Glen Bain No. 1.....	Lsd 8-22-10-8w3.....	2499	5382	—	—	—

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Top of Birdbear Formation (feet below K.B.)	DUPEROW FORMATION		
				Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Basal Member (feet below K.B.)
Canadian Gulf Stelter No. 4.....	Lsd 4-28-14-8w3.....	2566	5203	5284	—	—
Tidewater Morse No. 1.....	Lsd 16-25-16-8w3.....	2354	4760	4846	5022	5420
Western Calvin Wideview No. 6-29.....	Lsd 6-29-2-9w3.....	3271	6198	6317	6490	6778
Amerada Shell "SF" No. 5-11.....	Lsd 5-11-6-9w3.....	2757	5811	5922	6107	6458
Canadian Gulf Wills No. 2.....	Lsd 2-5-12-9w3.....	2486	5230	—	—	—
Tidewater Vanguard No. 1.....	Lsd 14-30-12-9w3.....	2676	5275	5358	5548	5929
Gulf-Tidewater Burns No. 12.....	Lsd 12-14-10-10w3.....	2510	5416	5505	—	—
Tidewater Braddock No. 1.....	Lsd 5-7-14-10w3.....	2654	5120	5214	Tops Undeterminable Due to Brecciated Zone	
Gulf-Tidewater Sabine No. 9.....	Lsd 9-27-14-10w3.....	2591	5172	5250	5442	5820
Amerada Shell "SA" No. 5-31.....	Lsd 5-31-2-11w3.....	2735	5241	5351	5528	5875
Shell Wood Mountain No. 1.....	Lsd 7-37-9-11w3.....	2544	5320	5403	5579	5955
Shell Wood Mountain No. 2.....	Lsd 13-36-1-12w3.....	2687	5137	5262	5439	5731
Amerada Shell "SE" No. 10-26.....	Lsd 10-26-1-13w3.....	2691	4928	5042	5222	5522
Imperial McCarty Coleman Val Marie No. 16-23.....	Lsd 16-23-4-13w3.....	2802	5374	—	—	—
Imperial Swift Current No. 1.....	Lsd 11-20-13-13w3.....	2893	5336	5405	5600	5995
Williston Swift Current Harlow No. 4-19.....	Lsd 4-19-15-13w3.....	2441	4816	4882	5083	—
Tidewater Wymark No. 1.....	Lsd 3-10-14-14w3.....	2788	5153	5217	5422	5826
British American Wilhelm No. 1-9.....	Lsd 1-9-17-14w3.....	2387	4521	4586	4794	5196
Tidewater Battrum No. 1.....	Lsd 2-6-19-15w3.....	2426	4395	—	—	—

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Top of Birdbear Formation (feet below K.B.)	DUPEROW FORMATION		
				Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Basal Member (feet below K.B.)
Socony Woodley Southern Success No. 3-7.....	Lsd 7-3-17-16w3.....	2438	4560	4628	4953	5352
Norcanols Pennant No. 1.....	Lsd 4-14-18-16w3.....	2459	4492	4579	4770	5155
Pan American A-1 Climax No. 13-30.....	Lsd 13-30-6-17w3.....	3201	5948	6050	6243	6605
Mobil Oil Woodley Sinclair Cantuar No. X-2-21	Lsd 2-21-16-17w3.....	2411	4513	4584	4810	5200
Imperial Tidewater Climax No. 6-10.....	Lsd 6-10-3-18w3.....	3076	5695	5783	5936	6316
Socony Woodley Southern Premier No. 28-3.....	Lsd 3-28-14-18w3.....	2551	4826	4894	5116	—
Mobil Oil Woodley Sinclair Fosterton No. X-15-3.....	Lsd 15-3-17-18w3.....	2440	4459	4529	4748	5149
Delhi Husky Phillips Rock Creek No. 2-4.....	Lsd 2-4-10-19w3.....	3051	5566	5636	5836	6226
Mobil Oil Woodley Sinclair S.E. Midway No. 6-3	Lsd 3-6-14-19w3.....	2663	4774	4846	5089	5554
Mobil Oil Woodley Sinclair Stanford 23-15.....	Lsd 15-23-18-19w3.....	2222	4059	—	—	—
Tidewater Eastend No. 1.....	Lsd 15-11-6-20w3.....	3246	5720	5793	6007	6366
Tidewater Eastend No. 5-12.....	Lsd 5-12-6-20w3.....	3250	5729	5818	6030	6385
Socony Western Prairie Tompkins No. 1.....	Lsd 14-19-13-20w3.....	2664	4820	4869	5116	5585
Socony Woodley Southern N. Eastbrook No. 4-15.....	Lsd 15-4-5-21w3.....	3128	5640	5722	5941	6277
Socony Woodley Southern Roadene No. 14-7.....	Lsd 7-14-18-21w3.....	2390	4182	—	—	—
Mobil Oil Woodley Sinclair Dorrell No. 32-9.....	Lsd 9-32-6-22w3.....	3458	5851	5930	6160	6529
Delhi Husky Phillips Skull Lake No. 1.....	Lsd 12-22-9-22w3.....	3679	5970	6059	6276	6690
Socony Woodley Southern North Bestville No. 30-3.....	Lsd 3-30-18-22w3.....	2382	4051	4164	4420	—
Amurex Canada Southern Kieville No. 1-4.....	Lsd 4-27-15-23w3.....	2426	4274	4367	4600	5024
Richfield Jackpot Lake No. 7-21.....	Lsd 7-21-8-24w3.....	3886	6034	—	—	—

Well Name	Location	Kelly Bushing Elevation (feet above sea level)	Top of Birdbear Formation (feet below K.B.)	DUPEROW FORMATION		
				Top of Seward Member (feet below K.B.)	Top of Wymark Member (feet below K.B.)	Top of Basal Member (feet below K.B.)
Shell Albercan Arena No. A-6-30.....	Lsd 6-30-1-25w3.....	2940	5282	5390	5611	—
Imperial <i>et al.</i> Robsart No. 1-1.....	Lsd 1-1-5-25w3.....	3157	5448	5553	5769	6197
Trans Empire Maple Creek No. 1.....	Lsd 16-20-9-25w3.....	3556	5607	5732	5962	6367
Canada Southern Allenbee Keno and Assoc. Co. Golden Prairie No. 1.....	Lsd 13-7-14-25w3.....	2344	4253	4358	4609	5021
United Canso Consumer Co-op Calvan Battle Creek No. 4-31.....	Lsd 4-31-3-26w3.....	3072	5151	5259	5475	5847
Calvan Canadian Devonian Imperial Jackpot Lake No. 11-23.....	Lsd 11-23-8-26w3.....	3788	5842	5960	6188	—
Imperial Calvan Senate No. 14-7.....	Lsd 14-7-5-27w3.....	3194	5326	5400	5637	6020
British American Wilnichenko No. 2-12.....	Lsd 2-12-13-27w3.....	2450	4326	4443	4699	5110
British American Arndt No. 15-15.....	Lsd 15-15-14-27w3.....	2406	4200	4297	4569	4960
Shell Albercan Govenlock No. 1.....	Lsd 2-7-1-28w3.....	2845	4964	5074	5296	5618
Shell Barclay Supreme No. 1.....	Lsd 7-2-2-28w3.....	3044	5248	5352	5548	5905
Mobil Oil North Richmond No. 31-1.....	Lsd 1-31-18-28w3.....	2521	4029	4179	4409	4878
Shell Albercan Govenlock No. 2.....	Lsd 16-3-1-29w3.....	2845	4994	5083	5290	—
Mobil Oil Cypress Lake No. X-10-2.....	Lsd 10-2-5-30w3.....	3343	5312	5396	5599	5980
Socony Wildhorse No. 1.....	Lsd 15-36-1-2w4.....	2875	4783	4878	5073	5450



PLATES I-IV

(All figures x 500)

PLATE I

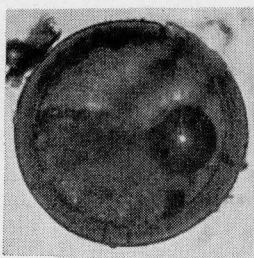
MICROFOSSIL ZONE B

Figure 1 *Tasmanites* sp., Mobil Oil North Richmond No. 1 well,  
4450 feet-4460 feet.

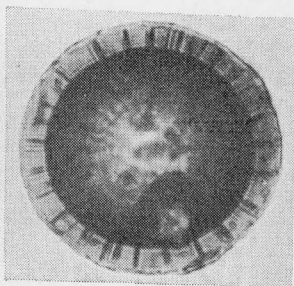
MICROFOSSIL ZONE C

Figures 2-7 *Tasmanites* sp., Gulf Tidewater Sabine No. 9 well, 5740  
feet-5750 feet.

Figures 8-9 *Tasmanites* sp., British American Baciú No. 15-36 well,  
6465 feet-6470 feet.



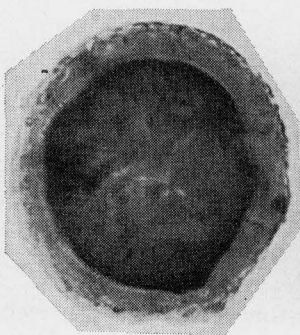
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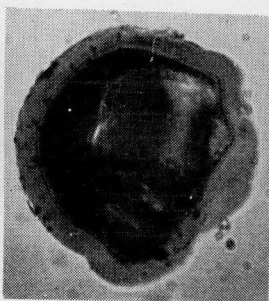
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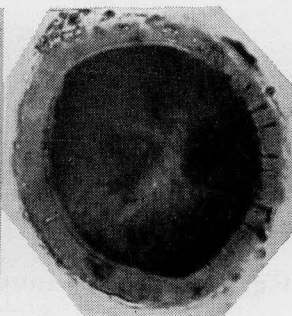
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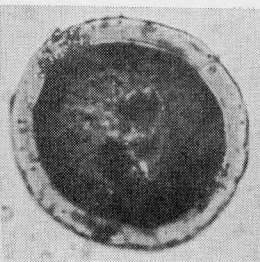
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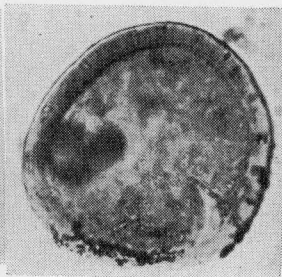
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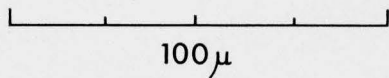


PLATE II

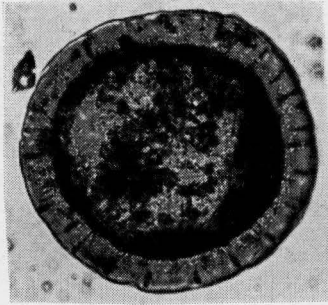
MICROFOSSIL ZONE C

Figures 1-2 *Tasmanites* sp., British American Baciú No. 15-36 well,  
6465 feet-6470 feet.

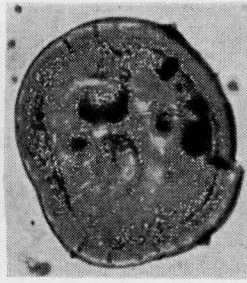
MICROFOSSIL ZONE D

Figures 3-4 *Tasmanites* sp., Tidewater Johnstone Lake No. 1 well,  
4860 feet-4870 feet.

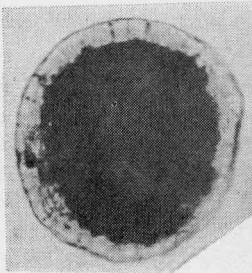
Figure 5 *Tasmanites* sp., British American Baciú No. 15-36 well,  
6516 feet-6526 feet.



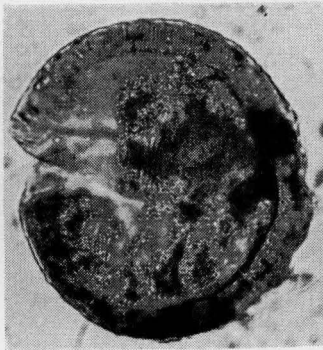
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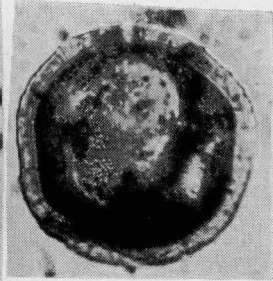
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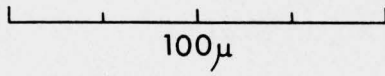
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4



5



## PLATE III

### MICROFOSSIL ZONE A

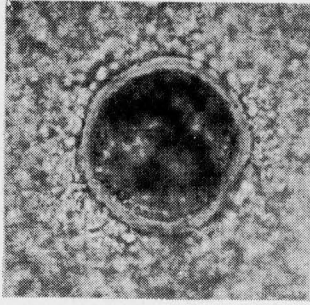
- Figure 1 *Leiosphaeridia* sp., Tidewater Parkbeg No. 1 well, 4788.5 feet. (As seen in thin section).
- Figure 2 *Leiosphaeridia* sp., Sohio Standard Wood Mountain No. 1 well, 6800 feet-6810 feet (Broken specimen).

### MICROFOSSIL ZONE B

- Figure 3 *Leiosphaeridia* sp., British American Baciú No. 15-36 well, 6250 feet-6255 feet.
- Figure 4 *Leiosphaeridia* sp., Socony Sohio Standard Regent Wood Mountain No. 1 well, 7180 feet-7190 feet.
- Figure 5 *Leiosphaeridia* ? sp., Gulf Tidewater Sabine No. 9 well, 5530 feet-5540 feet. (The surface of this specimen appears to be ornamented or punctate. Since no pores were visible in the wall, it has been called a *Leiosphaeridia*, but the punctate surface may indicate that it is a youthful form of *Tasmanites*.)
- Figure 6 *Leiosphaeridia* sp., Gulf Tidewater Sabine No. 9 well, 5530 feet-5540 feet.

### MICROFOSSIL ZONE C

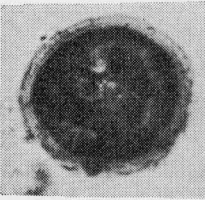
- Figure 7-9 *Leiosphaeridia* ? sp., Gulf Tidewater Sabine No. 9 well, 5740 feet-5750 feet.



1



2



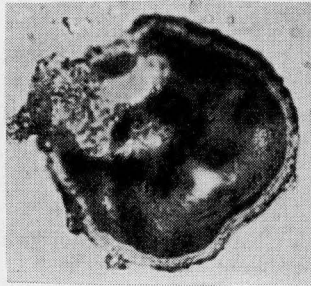
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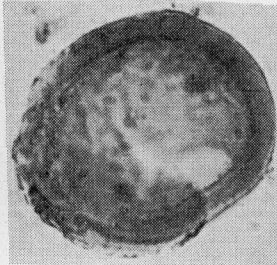
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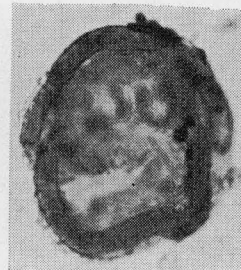
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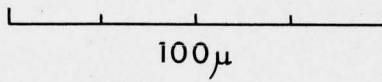


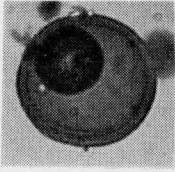
PLATE IV

MICROFOSSIL ZONE C

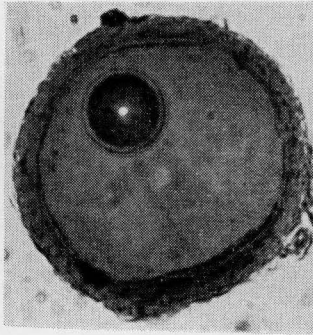
- Figure 1 *Leiosphaeridia* sp., Socony Sohio Standard Regent Wood Mountain No. 1 well, 7380 feet-7390 feet.
- Figure 2 *Leiosphaeridia* ? sp., Gulf Tidewater Sabine No. 9 well, 5740 feet-5750 feet.
- Figure 3 *Leiosphaeridia* sp., Tidewater Johnstone Lake No. 1 well, 5820 feet-5830 feet.
- Figure 4 *Leiosphaeridia* ? sp., Mobil Oil North Richmond No. 31-1 well, 4640 feet-4650 feet.

MICROFOSSIL ZONE D

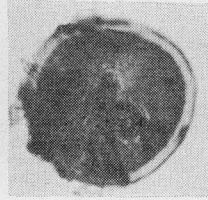
- Figure 5 *Leiosphaeridia* ? sp., British American Baciú No. 15-36 well, 6520 feet-6525 feet.



1



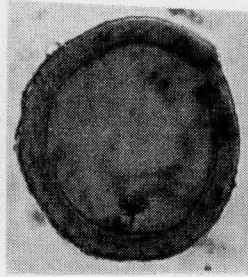
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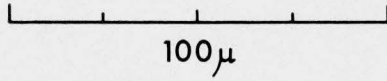
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4



5



Regina, Saskatchewan  
Printed by Lawrence Amon, Printer to the Queen's Most Excellent Majesty  
1963

