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Regional Geology and Petroleum Potential of the Bakken Formation, Southwestern Manitoba

By C.D. Martiniuk

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Energy and Mines

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TABLE OF CONTENTS

FIGURES

TABLE

INTRODUCTION

The Bakken Formation is a thin, relatively uniform clastic unit that lies between the red dolomitic siltstones and shales of the Upper Devonian Lyleton (Three Forks) Formation and the carbonates of the Mississippian Lodgepole Formation (Souris Valley Beds). The unit as formally defined is restricted to the subsurface of the Williston Basin in southern Saskatchewan/southwestern Manitoba in Canada and northeastern Montana/western North Dakota in the United States. In type section (Nordquist, 1953) the Bakken consists of two, thin, radioactive, fissile black shale members separated by a very fine-grained calcareous, light grey to grey-brown sandstone, siltstone or dolomite member.

Recent exploration in southwestern Manitoba has led to the discovery and subsequent development of several oil occurrences within the middle (siltstone/sandstone) member of the Bakken Formation. The discovery and development of oil production within the Bakken has prompted the need for a comprehensive examination of the formation.

The study presented is a preliminary review of the regional geology and petroleum potential of the Bakken Formation in southwestern Manitoba. Stratigraphic relationships, lithologic character and lateral variations of the formation are discussed. A brief discussion of well log characteristics and identification of correlation problems of the formation are also presented. Aspects of the formation from an economic standpoint are considered.

STUDY AREA

The area of study covers approximately 18 250 km^2 (7,100 sq. mi.) along the northeastern flank of the Williston Basin from Townships 1 to 18 and Ranges 19 to 29 WPM of southwestern Manitoba (Fig. 1).

Data available up to December 31, 1987, from 434 wells drilled into or through the Bakken Formation, were incorporated into the study. Cores from a total of six wells were examined.

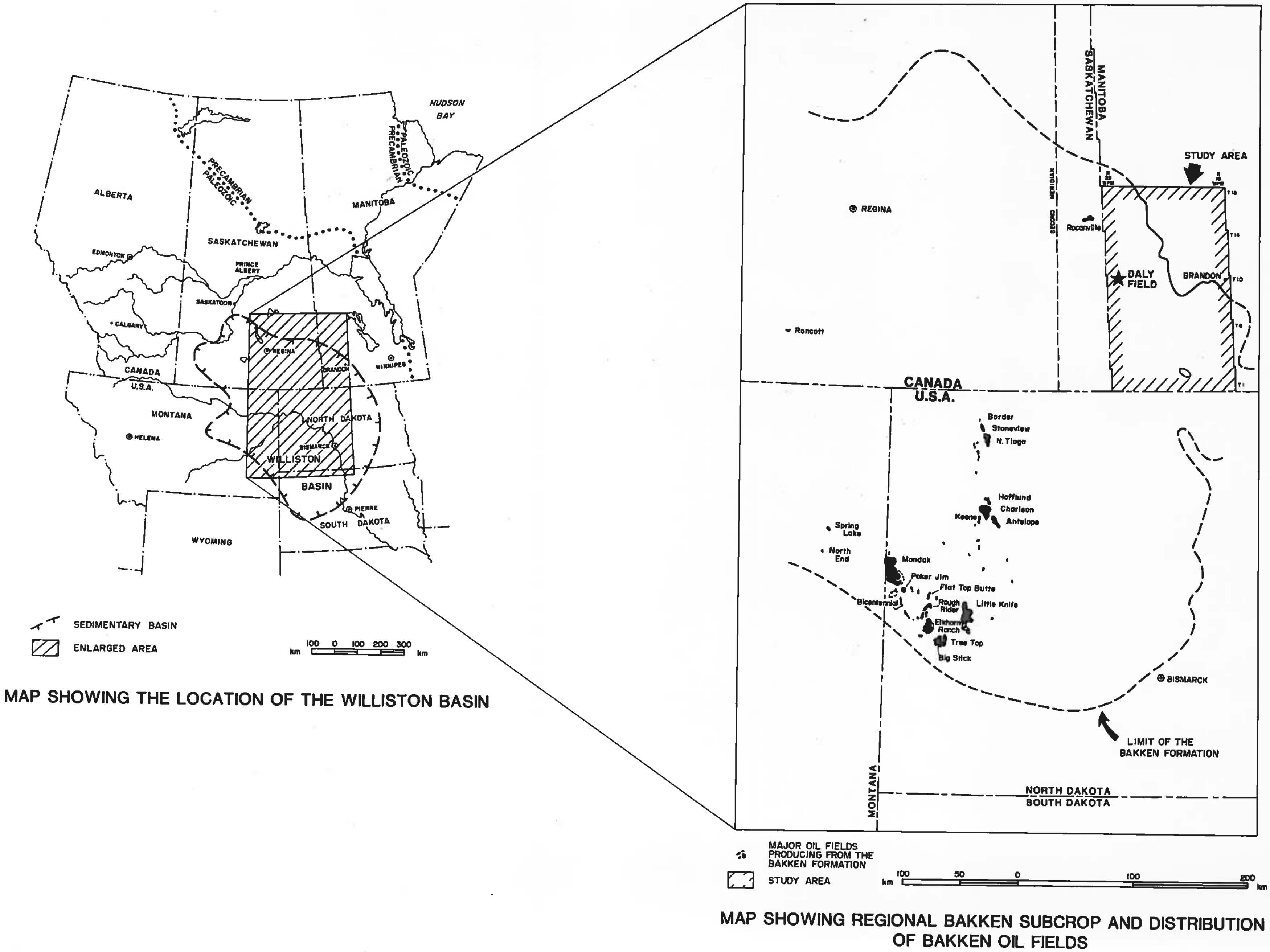


Figure 1: Index map of study area.

GEOLOGICAL SETTING

Southwestern Manitoba is located on the northeastern flank of the Williston Basin. Rocks of Paleozoic and Mesozoic age occur in this region forming a basinward-thickening sedimentary wedge dipping to the southwest. Strata within the Paleozoic and Mesozoic section of Manitoba are truncated by several unconformities.

A major angular unconformity separates the Paleozoic from the Mesozoic strata and probably represents one or more periods of erosion that occurred from late Mississippian to early Jurassic time. During this interval, Paleozoic strata in the northeastern part of the basin were uplifted and differentially eroded, while strata in the southern portion of the basin underwent relatively slight uplift (McCabe, 1959). Successively older Paleozoic strata were progressively truncated toward the basin margin. Deposition resumed during Mesozoic time when a thick sequence of Jurassic and Cretaceous strata was deposited on the eroded Paleozoic surface.

Within the Paleozoic itself, an unconformity separates Devonian and Mississippian strata and represents a period of uplift and erosion which occurred from late Devonian to early Mississippian time. During that interval Devonian strata were uplifted and exposed along the basin margins, while deposition continued in the deeper, central portions of the basin. Mississippian sediments were deposited on the eroded Devonian surface following this period of erosion (Sandberg, 1964).

STRATIGRAPHY

The Bakken Formation is a thin, widespread clastic unit stratigraphically positioned between the carbonates of the Mississippian Madison Group and the red, dolomitic shales and silts of the Upper Devonian Three Forks (Fig. 2). The unit is formally defined (Nordquist, 1953) as: the stratigraphic interval between 9,615 and 9,720 feet in the Amerada Petroleum Corporation - H.O. Bakken No. 1 deep test C SW NW sec. 12, T. 157 N., R. 95 W., Williams County, North Dakota. At its type locality the total thickness of the Bakken is 105 feet and is divided into three members: "...a lower black, fissile, calcareous shale (25 feet); a middle light grey to grey brown, very fine-grained calcareous sandstone, interbedded with minor amounts of grey-brown cryptocrystalline limestone (60 feet); and an upper black, fissile, calcareous shale (20 feet)."

The stratigraphic units of the Bakken Formation exhibit an onlapping depositional relationship, each successively younger member extensively overlapping the older member. The three members of the Bakken Formation converge and thin toward the margins or marginal shelf areas of the Williston Basin. In marginal areas of the basin, such as eastern Saskatchewan and southwestern Manitoba, the lower Bakken shale is absent.

In southwestern Manitoba the Bakken Formation is stratigraphically positioned above the Lyleton Formation of the Three Forks (Upper Devonian) and below the Lodgepole Formation of the lower Madison (Mississippian). The Bakken has been informally subdivided in Manitoba into the three members described in type section: the lower member, the middle member and the upper member.

The upper and middle members of the Bakken are present throughout most of the study area. The lower member is present only locally in the Waskada area. It is absent throughout most of the map area due to the overstep of the overlying middle member.

The Bakken Formation subcrops along the northeastern portions of the map area, where it is unconformably overlain by the Lower Amaranth "Red Beds" of Jurassic age.

AGE AND CORRELATIONS

a) Lyleton Formation

The Lyleton Formation is a mappable unit within Manitoba correlative with the Three Forks Formation of North Dakota and with the lower part of the Three Forks Group of Saskatchewan.

The unit was designated by Allan and Kerr (1950) to describe the red dolomitic shales and siltstones that overlie the carbonate strata of the Devonian and underlie the bituminous black shale of the Bakken in the Robert Moore No. 1 well, 5-20-1-27 WPM, of southwestern Manitoba. Usage of the term Lyleton Formation, as described, is limited to Manitoba.

b) Bakken Formation

The Bakken Formation of southwestern Manitoba is correlative with the Bakken Formation, as formally defined throughout the Williston Basin, and with the Exshaw Formation of Alberta.

The Bakken Formation has been placed by several workers in either the Mississippian (Kinderhookian) or the Upper Devonian. Christopher (1961) placed the Devonian-Mississippian boundary within the Bakken, at the contact between the middle and lower members. Recent work by Holland et al. (1987) suggests that the boundary be placed within the middle member of the Bakken.

In this report the Bakken has been included as the basal unit of the Mississippian sequence. The Devonian-Mississippian boundary is inferred as the contact between the base of the Bakken Formation and the top of the Lyleton Formation. Throughout most of the area studied the contact between the Bakken and Lyleton appears to be unconformable.

c) Lodgepole Formation

The Lodgepole Formation, as commonly used in Manitoba, is equivalent to the Bottineau Interval (Lodgepole) of North Dakota and the Souris Valley Beds of Saskatchewan.

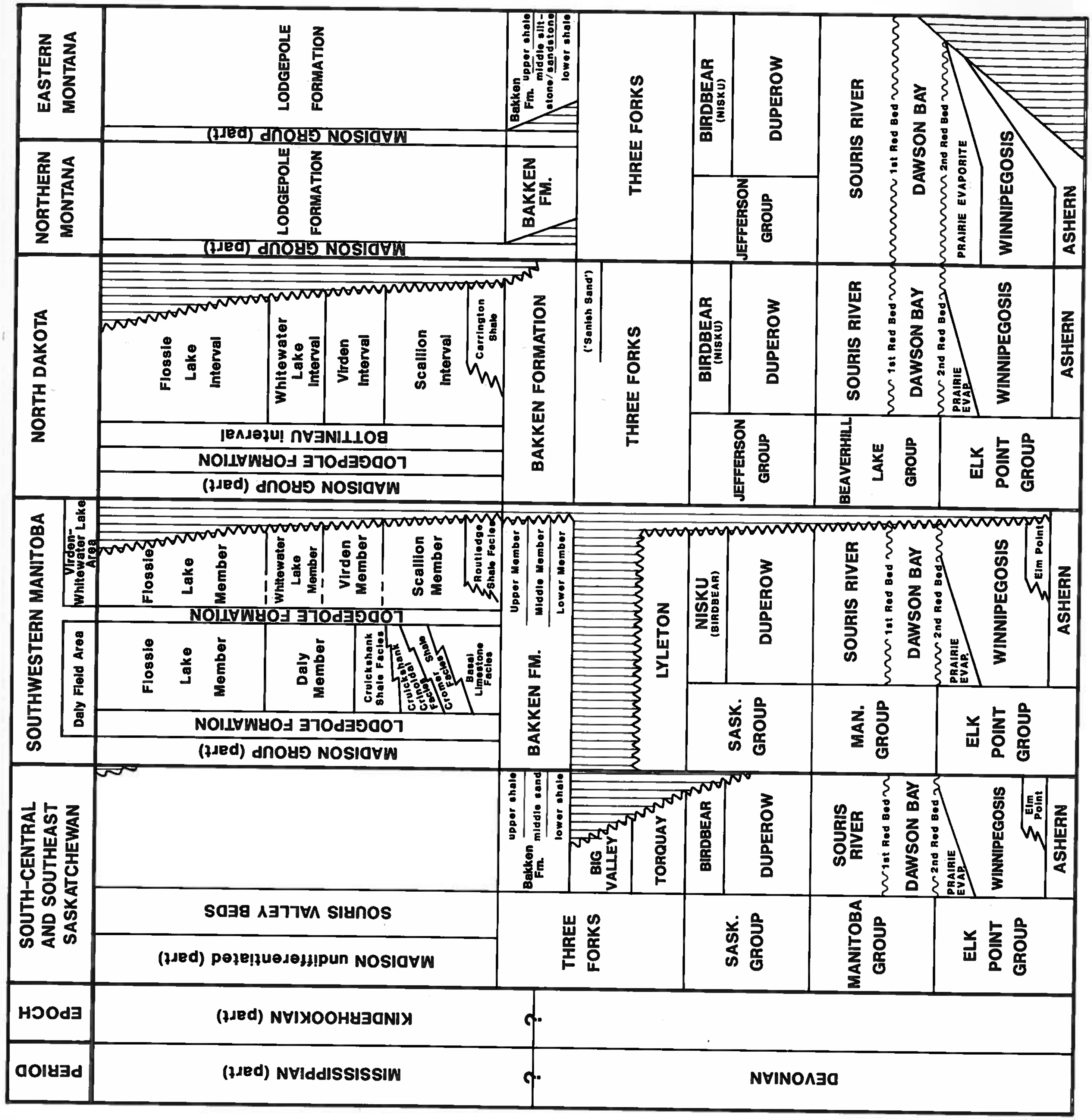


Figure 2: Stratigraphic Correlation Chart.
(modified after C.G. Carlson and J.A. LeFever, 1987; and Saskatchewan Department of Mineral Resources Petroleum and Natural Gas Branch, Drawing Number G-193, 1963)

In southwestern Manitoba, a distinct, discontinuous shale unit is developed within the basal portion of the Lodgepole Formation. The unit, known as the Routledge Shale Facies, is stratigraphically positioned above the Bakken Formation in Manitoba, and is believed to be the lateral facies equivalent of the lower portion of the Scallion Member, a basal member of the Lodgepole Formation (Stanton, 1958). The occurrence of the Routledge Shale Facies in Manitoba is limited to the Virden and Lulu Lake areas (McCabe, 1959). The Routledge Shale Facies is correlative with an equivalent shale unit in north-central North Dakota, known as the Carrington Shale Facies (Bjorlie and Anderson, 1978).

LITHOLOGY

Relatively few wells drilled into or through the Bakken Formation in Manitoba have cored the Bakken. Drill cuttings from the Bakken are of poor quality and are poorly recovered. Consequently, little lithologic information is available. For this report drill cuttings were not examined; however, a select number of cores were described and are included in Appendix I. An index of core and drill stem tests of the Bakken and Lyleton Formations is included in Appendix II.

UNDERLYING FORMATION (LYLETON)

Throughout the map area, the Bakken Formation is underlain by the Lyleton Formation of Upper Devonian age. The Lyleton is composed of red dolomitic shales and siltstones.

The upper contact of the Lyleton is easily recognized in the Waskada area of the study, where the lower Bakken shale occurs. The contact between the Bakken and Lyleton is identified in this area by the abrupt change in lithology from the red, argillaceous sediments of the Lyleton to the black shale of the lower member of the Bakken.

In most of the map area, however, the middle member directly overlies the Lyleton. The contact between the middle member and the Lyleton is difficult to determine due to the lithologic similarity of the units. The Bakken-Lyleton contact is defined by the colour change from the red silty argillaceous dolomite of the Lyleton to the greenish-grey argillaceous and dolomitic siltstone and sandstone of the Bakken (Petrie, 1956).

The contact between the Bakken and Lyleton appears to be unconformable where the lower shale is absent. Several indicators of a pre-Bakken unconformity exist. The absence of the lower black shale suggests that there was a break in sedimentation or erosional hiatus between the Bakken and Lyleton (McCabe, 1959). Where the lower shale is missing, truncation of marker beds within the Lyleton itself indicates a pre-Bakken unconformity. Intraformational breccia beds occurring at the base of the middle Bakken also indicate an erosional or non-depositional break between the Bakken and Lyleton (McCabe, 1959).

In the Waskada area, however, where the lower Bakken shale is present, it is uncertain whether the contact between the Bakken and Lyleton is unconformable. The limits of the lower shale may or may not have been modified by erosion prior to, or during deposition of the middle member.

BAKKEN FORMATION

a) Lower Member

The lower member of the Bakken occurs locally in the Waskada area and consists of black to brownish-black, fissile, non-calcareous, radioactive shale. Its lithology is essentially identical to that of the upper member. Contacts with the underlying Lyleton Formation and overlying middle member of the Bakken are sharply defined.

b) Middle Member

The lithology of the middle member varies from siltstone to very fine- to fine-grained and medium-grained sandstone. Much of the unit is dolomitic and argillaceous. The matrix consists of dolomite or dolomitic shale. Sorting varies from very well to poor. Colouration varies from light greenish-grey to reddish and purplish-grey.

Individual grains are composed predominantly of quartz. The silt-sized grains are generally angular to subangular, whereas the coarser grains are subrounded. Grain size of the sediments increases in the northern and eastern portions of the map area. Within the northern portion of the study area the sediments generally consist of dolomitic siltstone grading to fine- to medium-grained sandstone at the base (McCabe, 1959). Intergranular porosity is best developed within the coarser grained laminae of the middle member.

The middle member is often structureless or finely laminated and, in places, exhibits crossbedding or contorted bedding (McCabe, 1959). In several wells intraformational breccias and conglomeratic zones have been noted at, or near the base of the unit which may represent diastemic and/or erosional breaks within the middle Bakken (Petrie, 1956; McCabe, 1959).

c) Upper Member

The upper member generally consists of a black to brownish-black to dark grey, fissile, radioactive, non-calcareous shale essentially identical in lithology to the lower member. In the northern part of the map area the upper member is red or purplish-red (McCabe, 1959).

The contact with the underlying middle member is sharply defined. The contact with the overlying Lodgepole limestones is also generally sharp, except in areas where the upper member is overlain by the black shale of the "Routledge Shale Facies".

"ROUTLEDGE SHALE FACIES"

The Routledge Shale Facies occurs locally above the upper Bakken shale in the Virden and Lulu Lake areas of the study. The unit, as defined by Stanton (1958) is represented by the stratigraphic interval between 2,230 and 2,307 feet in the Chevron Routledge Prov. 13-29-9-25 WPM well and consists of black to dark grey, fissile, calcareous shale. The lithology of the Routledge shale is indistinguishable from that of the upper Bakken shale.

Differentiation between the units of the Routledge and upper Bakken shale is based on gamma ray log response. The upper Bakken shale displays a higher gamma ray log response than does the Routledge.

OVERLYING FORMATION (LODGEPOLE)

The Bakken Formation is conformably overlain by the fossiliferous, fragmental limestones of the basal Lodgepole Formation. Lithologies of the lower Lodgepole are extremely variable due to the rapid lateral facies changes of the formation. In most of the study area the lower Lodgepole consists of a dark grey argillaceous limestone separated from the Bakken shale by a thin bed of clean limestone. In the eastern portions of the mapped area the clean cherty limestone of the Scallion Member of the Lodgepole Formation overlies the Bakken. In the Virden and Lulu Lake areas the upper Bakken shale is overlain by the Routledge Shale Facies.

WELL LOG CHARACTERISTICS

The upper and lower shales of the Bakken are excellent lithologic markers. The distinct well log signature created by these shales is associated with the high uranium and organic content of these units. Both shales are characterized by extremely high gamma ray log intensity and high density-log porosity responses, which are recognized over much of the Williston Basin. The upper and lower limits of the Bakken Formation are determined on gamma ray logs by the characteristic response of the two shales.

The contact between the Bakken and Lyleton is easily recognized in the Waskada area where the lower shale is locally developed (Fig. 3).

However, in most of the area studied, where the lower shale is absent, it is difficult to determine the base of the Bakken. The contact between the middle member of the Bakken and Lyleton is defined by a deflection on both the gamma ray and neutron-density porosity logs. The gamma ray log alone cannot be used as a reliable indicator, as middle Bakken sediments within the study area display an abnormally high radioactivity response (Fig. 4).

In older wells, where only the SP and resistivity logs are available, it is difficult to determine the Bakken-Lyleton contact. The SP response is generally weak throughout the section. The resistivity shows minor changes, and is used to select the Lyleton top. The Bakken-Lyleton contact is a tenuous pick at best, and subject to interpretation.

The upper limit of the Bakken Formation is easily defined in the map area where the Scallion Member of the Lodgepole Formation directly overlies the upper Bakken shale. The Scallion Member is identified by a distinctive blocky SP response. In areas where the Routledge Shale Facies is locally developed within the Scallion Member, the gamma ray log is used to identify the Bakken-Lodgepole contact. The gamma ray log response of the upper Bakken shale is considerably higher than the response of the Routledge Shale Facies. The contact between the Bakken and Routledge is placed at the top of the zone of highest radioactivity (Fig. 3).

COMPOSITE LOGS

ROYALITE TURTLE MTN. PROV.
4-36-1-21 WPM

IMPERIAL CHEVRON HERNEFIELD PROV.
1-30-1-25 WPM

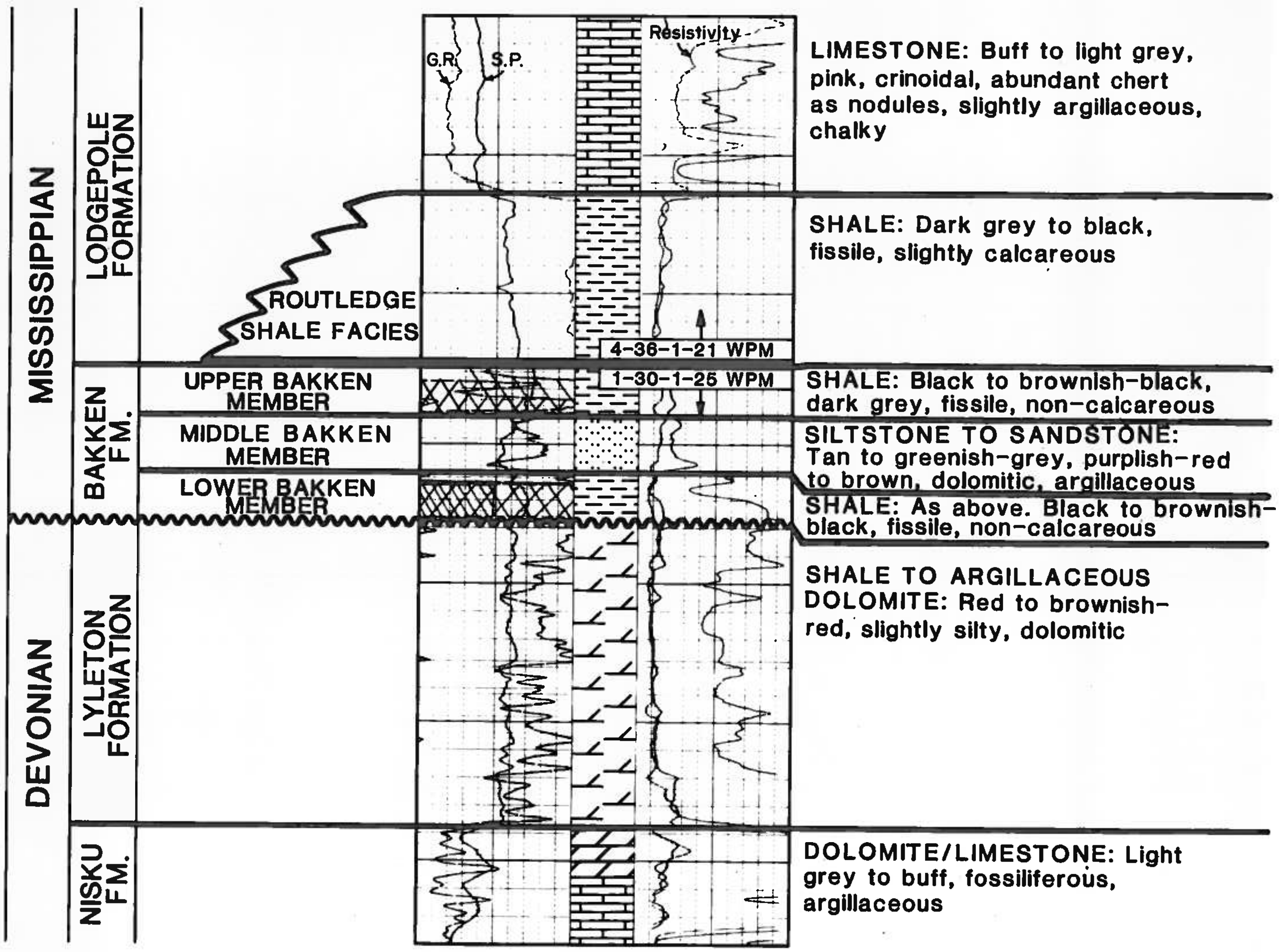


Figure 3: Composite reference section for areas where the lower member of the Bakken and the "Routledge Shale Facies" are present, showing generalized stratigraphic column.

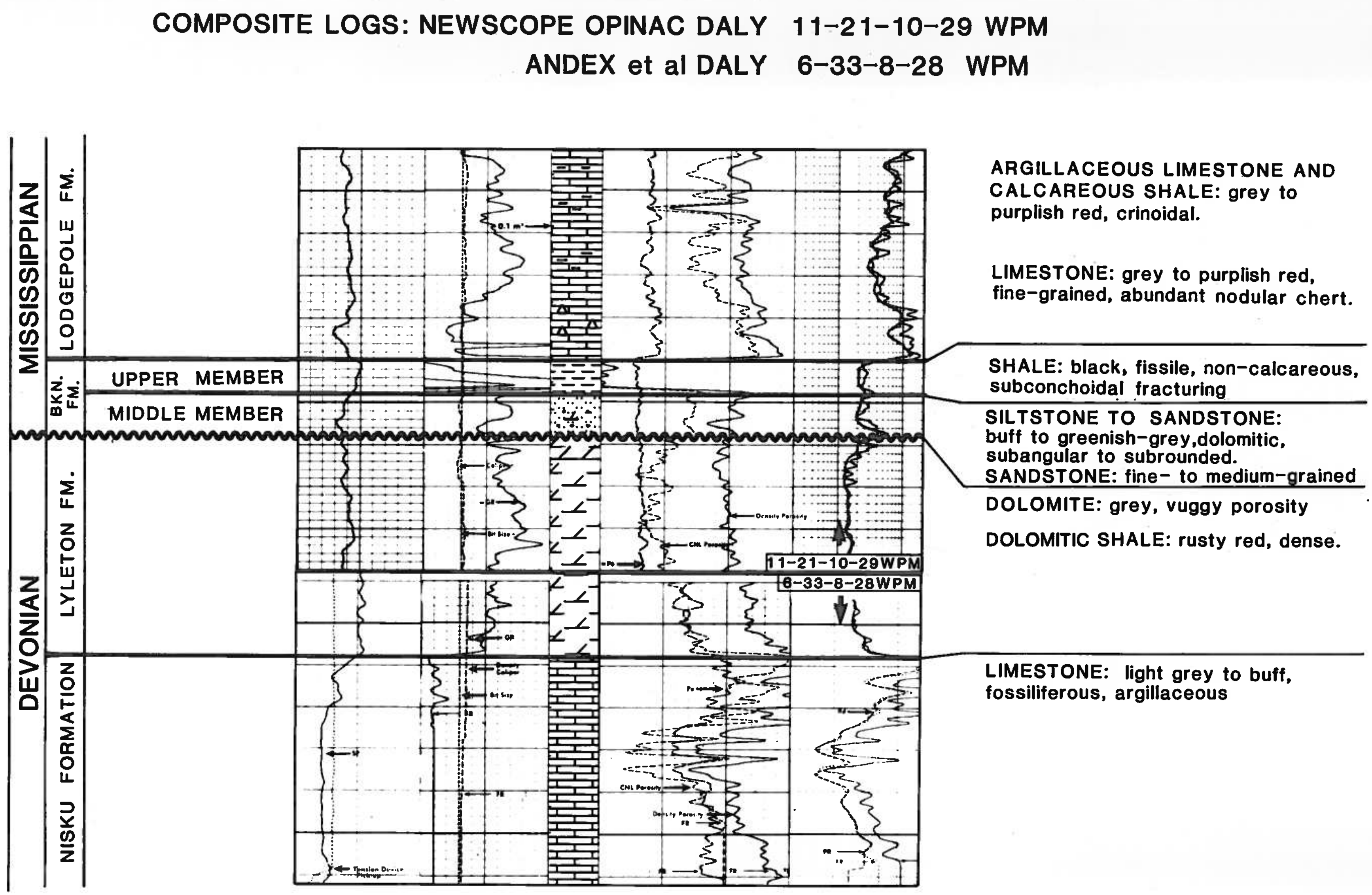


Figure 4: Composite reference section for areas where the lower member of the Bakken is absent, showing generalized stratigraphic column.

DEPOSITIONAL ENVIRONMENT

MISSISSIPPIAN SEQUENCE (Williston Basin)

The lower Mississippian, or Madison sequence, of the Williston Basin represents one complete sedimentary mega-cycle of marine transgression and regression. The vertical sequence of the Mississippian can be described as shallow water sediments that pass upward into deeper water deposits and end in shallow water and continental sediments. The cycle began with the advance of Mississippian seas from the west or northwest over the slightly eroded sediments of the Devonian. Basal black shales and siltstones of the Bakken Formation were first deposited. Rapid subsidence within the basin resulted in the deposition of the predominantly argillaceous limestones of the Lodgepole Formation.

As the rate of subsidence decreased during Mission Canyon time, fragmental and oolitic limestones were deposited. Cyclical fluctuations in sea level at that time had a major effect on sedimentation. During periods of shallow water a regressive sequence of fringing biostromal and calcarenite shoals were formed, while evaporites and clastics were deposited in marginal lagoons. Widespread deposition of limestone occurred during periods of deeper water. The marginal lagoonal evaporite facies continued regression into the basin during Mission Canyon and early Charles time, as the rate of subsidence in the Williston gradually decreased.

During late Charles time, the entire basin became restricted and evaporites were deposited throughout. Halite beds were deposited during latest Charles time in the central portions of the basin. Subsequent to the deposition of halite, Mississippian seas completely withdrew from the basin and the non-marine sandstone beds of the Kibbey Formation of the Upper Mississippian were deposited, terminating the sedimentary cycle (Kent 1984; McCabe, 1959).

BAKKEN FORMATION (Southwestern Manitoba)

Subsequent to the withdrawal of Devonian seas from the Williston Basin during late Devonian time, minor erosion of the Lyleton sediments occurred in marginal areas, such as southeastern Saskatchewan and southwestern Manitoba.

The cycle of Mississippian sedimentation commenced with the advance of Mississippian seas from the west (probably the Cordilleran region) over the slightly eroded, red, dolomitic shales of the Lyleton Formation (Baillie, 1953; Kume, 1963). Black bituminous shales of the lower Bakken member were deposited over much of the Williston Basin.

In southwestern Manitoba the lower Bakken shale is generally absent, but occurs locally in the Waskada area. The nature of the lower Bakken shale suggests that deposition was in very quiet, poorly oxygenated waters. Fossil assemblages noted within the organic content of the lower shale indicate shallow-water conditions of deposition (Holland et al., 1987). The lithologic constancy of the Bakken shales implies a uniform environment of deposition. The most probable environment of deposition of the Bakken shales, as proposed by McCabe (1959), is a restricted marine swamp.

The deposition of the lower Bakken shales was followed by an influx of clastics of the middle Bakken member. The sediments of the middle member were introduced into the Williston Basin in response to minor tectonic uplift and erosion of the stable, peripheral areas. Fine- to medium-grained sands and silts of the middle member were deposited throughout southwestern Manitoba during this minor transgressional period as a thin, blanket deposit (McCabe, 1959).

The sedimentary features noted within the unit, including cut-and-fill and crossbedding, suggest that the middle member was deposited under shallow marine to possibly terrestrial conditions (McCabe, 1959). The abundance of brachiopod fossils within the middle member suggests a marine to nearshore marine environment of deposition (Kume, 1963; Holland et al., 1987).

During middle Bakken time, restricted, reducing conditions prevailed in all but the northern portions of the map area. To the north, shallow-water, nearshore oxidizing conditions prevailed, as is indicated by the red colouration of sediments; increased grain size; and cut-and-fill and crossbedding sedimentary features (McCabe, 1959).

The source of Bakken clastics is difficult to determine. It is unlikely that the sediments were derived from the underlying Lyleton sediments. The middle Bakken consists primarily of well rounded, quartzose sands and silts. The underlying Lyleton sediments generally have a lower content of coarse clastics than the Bakken. The medial sands and silts of the Bakken may have been derived from either early Paleozoic sediments or Precambrian rocks (McCabe, 1959).

The deposition of the middle Bakken member was followed by a re-establishment of the stagnant, swamp conditions under which the upper Bakken black shale was deposited. Mississippian seas extended throughout the map area during this time, as is indicated by the widespread extent of the upper Bakken shale.

Argillaceous limestones of the Lodgepole Formation were deposited during the major marine transgressional period that followed Bakken sedimentation. In isolated areas of Manitoba a thickened black shale section ("Routledge Shale Facies") developed within the basal portion of the Lodgepole Formation. The unit is believed to represent the back-reef facies of several reefs or shoals developed during this period (Bjorlie and Anderson, 1978).

THICKNESS

The total "tectonic" subsidence that occurred during Bakken-Lyleton time, eliminating any effects of erosional topography, is represented by the isopach of the total Bakken-Lyleton interval (Fig. 5; in pocket). The total Bakken-Lyleton isopach is particularly useful in understanding the complex sequence of salt collapse events that occurred during that time-stratigraphic interval. It is defined by two marker beds - the top of the Nisku and the top of the Bakken.

The isopachs of the total Bakken-Lyleton generally trend north-northwest (Fig. 5; in pocket). The total Bakken-Lyleton thickness increases relatively uniformly toward the western edge of the map area. The average total combined thickness of the two formations is 35 metres. Maximum combined total Bakken-Lyleton thickness reaches 96+ metres in the Waskada area. Local anomalies, notably those in the Waskada area, and north of the Virden Field, are superimposed on the regional pattern.

BAKKEN FORMATION

The total Bakken Formation averages 6 metres in thickness (Fig. 6; in pocket). It reaches a maximum thickness of 35 metres in the Waskada Field area where the lower shale member is locally present. Local isopach thicks and thins of the total Bakken Formation within the map area trend generally northwest-southeast. The Bakken is absent locally in wells at 14-17-2-22 WPM and 8-31-2-23 WPM. It subcrops in the northeastern portion of the map area.

The lower member of the Bakken Formation represents the smallest portion of total Bakken thickness. The lower member reaches a maximum thickness of 13 metres in the Waskada area where it locally occurs (Fig. 6; in pocket).

The isopach pattern of the middle member resembles that of the total Bakken isopach (Fig. 7; in pocket). Isopach trends are northwest-southeast. The most significant changes in thickness of the Bakken Formation occur within the middle member, which represents a large portion of the total Bakken isopach. Average thickness of the middle member is 4 metres. Maximum thickness of the middle member reaches 16 metres in the Waskada area.

The thickness of the upper member is relatively uniform throughout the map area, averaging 2 metres (Fig. 8; in pocket). Maximum thickness of the upper member reaches 18 metres in the Waskada area. Isopach trends of the upper member, as for those of the middle member and total Bakken isopachs, are generally northwest-southeast.

The nature of the thickness variations of the Bakken can be determined through examination of a series of stratigraphic cross-sections constructed for the study (stratigraphic cross-sections: C-C′, D-D′, E-E′ and F-F′; in pocket).

The cross-sections show that, in general, variation in thickness of the Bakken, specifically the middle member, is due primarily to differential erosion of the underlying Lyleton Formation. The thickest Bakken deposits occur in erosional lows on the Lyleton Formation. A good example of the effects of differential erosion is shown by the west-east stratigraphic cross-section C-C′ (in pocket). In the well at 3-5-9-19 WPM on the eastern end of C-C′, the middle member has been thickened at the expense of the underlying Lyleton Formation by differential erosion. Markers within the Lyleton illustrate the extent to which the Lyleton has been eroded. Similar examples of differential erosion are also evident in stratigraphic cross-sections D-D′, E-E′ and F-F′ (in pocket).

Variations in thickness of the Bakken may also possibly be due, in some places, to subsidence. This is best shown by the west-east stratigraphic cross-section E-E′ (in pocket). The well at 13-2-16-29 WPM on the western end of E-E′ shows considerable thickening of the middle member, and comparable thickening of the total Bakken-Lyleton interval, in comparison to adjacent wells. Subsidence appears to have occurred at this location during deposition of the middle member, resulting in a thickened middle Bakken section.

Evidence suggestive of subsidence during deposition of the middle member is also seen in the oil producing area of the Daly Field, as shown by the stratigraphic cross-section D-D′ (in pocket). Wells at both 13-21-10-29 WPM and 3-27-10-29 WPM on the western end of D-D′, show thickening of the middle member along with comparable thickening of the total Bakken-Lyleton interval, as compared to that of the well at 5-29-10-28 WPM to the east. Similar examples suggestive of subsidence are also evident in stratigraphic cross-sections C-C′ and F-F′ (in pocket).

ANOMALIES - EFFECTS OF SALT COLLAPSE

Several local anomalies are superimposed on the regional isopach patterns throughout the map area. Significant local variations in thickness have been noted within the Bakken section in each of the three individual members, and within the Lyleton section. The greatest variations occur in the Waskada area, where as much as 26 metres has been added to the total Bakken and over 79 metres added to the Lyleton. Local thickening also occurs north of the Virden Field where 43 metres has been added to the Lyleton Formation.

The anomalous thicks noted within the map area reflect deposition during highly localized events of subsidence. These localized events are believed to be the result of the dissolution of Devonian salts and resultant collapse of overlying strata during Bakken and Lyleton sedimentation.

The most direct evidence of salt collapse occurs within the Waskada area of the study. The thickening of the Bakken section, and complementary thinning of the underlying Devonian Prairie Evaporite section in the Waskada area, is believed to be the result of salt collapse during early Bakken time. The local occurrence of the lower Bakken shale in this area may also be accounted for by early Bakken salt collapse.

Stratigraphic cross-sections A-A′ and B-B′ (in pocket) illustrate the variations in thickness of the Bakken-Lyleton on a detailed individual well basis. The individual units affected by salt collapse are identified on the total Bakken-Lyleton isopach map (Fig. 5; in pocket). The most dramatic variation in thickness is seen in the well at 16-35-2-24 WPM where 26 metres of sand, believed to be equivalent to the "Sanish Sand", a local unit found deeper in the Williston Basin, is developed in the upper portion of the Lyleton. The local thickening of the Lyleton and individual members of the Bakken suggests that salt solution was not a single event, but rather a multiple stage event during Bakken-Lyleton time that resulted in a complex isopach pattern.

The local isopach thicks within the Waskada area are structurally high, indicating that a later salt collapse event occurred in surrounding areas, possibly during post-Mississippian pre-erosion time. The erosion that followed this late salt collapse event resulted in the partial truncation of these structural highs at the Mississippian unconformity.

Evidence of thickening due to salt solution is also indicated in other areas of the study. In wells at both 5-3-4-25 WPM and 6-24-12-26 WPM the Lyleton section has been thickened, possibly due to solution of underlying Devonian salts and resultant collapse during Lyleton sedimentation. It appears, as at Waskada, that a later collapse event occurred in the areas surrounding the well at 5-3-4-25 WPM, possibly during post-Mississippian pre-erosion time. In this well, strata from the top of the middle Bakken up through the Mississippian are all structurally high in comparison to surrounding wells. The erosion that followed the late event of salt collapse at this location resulted in the partial truncation of this structural high at the Mississippian erosion surface.

Salt solution at 6-24-12-26 WPM appears to have been a single event. There is no evidence of a structural high at this location indicating later collapse in surrounding areas.

The absence of the Bakken section within the wells at 14-17-2-22 WPM and 8-31-2-23 WPM may also relate to salt collapse. The underlying Devonian and overlying Mississippian sections are disrupted in both of these wells, possibly the result of later salt collapse and consequent faulting of the Devonian-Mississippian section. It is uncertain whether the absence of the Bakken section in these wells is related to the structural disturbance in this area, or to non-deposition.

In a well at 8-13-5-29 WPM, southeast of the Tilston Field, correlations throughout the Devonian-Mississippian section are obscured by what also appears to be a late salt collapse and consequent faulting event.

Salt solution and collapse has been invoked by other authors to explain the local structural and isopach anomalies affecting shallower Mississippian strata in southwestern Manitoba. In the Daly and Virden Field areas McCabe (1959) attributed the origin of local structural lows in Lodgepole strata to slump folding and minor faulting due to solution of underlying Devonian salt and collapse of overlying Mississippian strata. Rodgers (1986) related the structural complexity within the Waskada Field to multiple stage solution and collapse of Devonian salts during post-Mississippian pre-erosion time.

a) Probable factors contributing to the localization of salt collapse

The localized areas of salt collapse that have been described are aligned along the Birdtail-Waskada axis, a north-trending zone, approximately 32 km east of the Saskatchewan border, along which numerous local structure and isopach anomalies in the Devonian and later strata are concentrated. The Birdtail-Waskada axis coincides with: the Churchill-Superior crustal boundary; the western edge of the Winnipegosis fringing reef; and the present edge of the Prairie Evaporite salt basin (McCabe, 1966).

Several probable factors may have contributed to the localization of the areas of salt collapse in Manitoba. Salt collapse within southwestern Manitoba may be a direct or indirect result of minor tectonic movement related to Precambrian basement features (McCabe, 1966). "...the basement feature that appears to have the greatest effect on the Paleozoic tectonic framework is the discontinuity or boundary zone between the Churchill and Superior Precambrian provinces" (McCabe, 1966). Minor movements along the Churchill-Superior crustal boundary had a direct effect on sedimentation at various times during the Paleozoic. Fracturing created by minor tectonic movement along this boundary may have served to localize areas of salt solution. McCabe (1966) noted that the thick underlying porous section of the Winnipegosis reef or bank deposits could have provided an aquifer for the circulation of formation waters which dissolved the Devonian salt.

The numerous structural highs and lows and isopach thicks resulting from salt solution which are concentrated along the Birdtail-Waskada axis have been important in controlling Upper Mississippian (Lodgepole and Mission Canyon) oil accumulation within the Daly, Virden and Waskada producing areas of southwestern Manitoba (McCabe, 1963; Rodgers, 1986). The Paleozoic tectonic framework and related salt collapse features may also be important in the evaluation of oil accumulation within the Bakken Formation.

STRUCTURE

Structure on the top of the middle member of the Bakken (Fig. 9; in pocket) is fairly regular in the map area, and follows the regional Paleozoic tilt. The regional dip is to the southwest and averages 6 metres/km (structural cross-section DD-DD′; in pocket).

Several features depart from the relatively uniform regional pattern of the middle member. The Virden and Daly Fields are separated by a prominent north-south trending syncline which lies along the Birdtail-Waskada axis. Within the Daly Field itself, several minor closed structural highs are present which are coincident with areas of Bakken production. Within the Waskada Field a minor structural nose plunging south-southwest is coincident with areas of anomalous Bakken and Lyleton thickening. Several closed lows are also seen within the map area, notably at 8-13-5-29 WPM and at 4-32-3-25 WPM.

HARTNEY ANOMALY

In Township 5, Range 24 WPM of the study area a circular structural anomaly, approximately 10 km in diameter, is present near the town of Hartney. The anomaly is an upraised dish-shaped structure consisting of a highly disturbed, central uplift surrounded by a raised rim and is believed to be a meteorite impact crater or astrobleme of late Jurassic to early Cretaceous age (Anderson, 1980; Sawatzky, 1977).

Strata from the Precambrian to the top of the Blairmore marker of Cretaceous age have all been structurally disturbed in the area. "... Mississippian strata around the flanks of the anomaly are thrust over each other several times and in places are overturned. Mississippian-aged rocks are missing from the centre of the anomaly. Devonian-aged rocks are intensely brecciated and faulted, but are present within the core" (Anderson, 1980).

The map outline of the feature (Fig. 9; in pocket), as defined by Anderson (1980) is derived through seismic interpretation. Contouring has not been shown within the outline due to the complex structural nature of the feature.

ECONOMIC CONSIDERATIONS

The Bakken Formation has been documented as an excellent petroleum source rock within the Williston Basin and has, in some localities, been established as a producing zone. In the U.S. portion of the basin the most notable production has been obtained from the Antelope Field in North Dakota. The most significant production in the Canadian portion of the basin has been obtained in Saskatchewan at Roncott and Rocanville.

Recent exploration in the Daly Field of southwestern Manitoba has led to the discovery and subsequent development of several oil pools within the middle member of the Bakken Formation (Fig. 17).

The first pool, Daly Bakken 'A' (01 60A) established production on October 25, 1985 following the Newscope Resources Limited discovery at 13-21-10-29 WPM. The discovery well was completed in the middle member with 2 m of net pay. Initial production for the first year averaged 8.38 m^3/day of 824 kg/m^3 (40.2° API) oil. Thirteen successful development wells have been drilled within the Bakken 'A' Pool since that time, twelve by Newscope Resources Limited and one by Voyager Energy Limited.

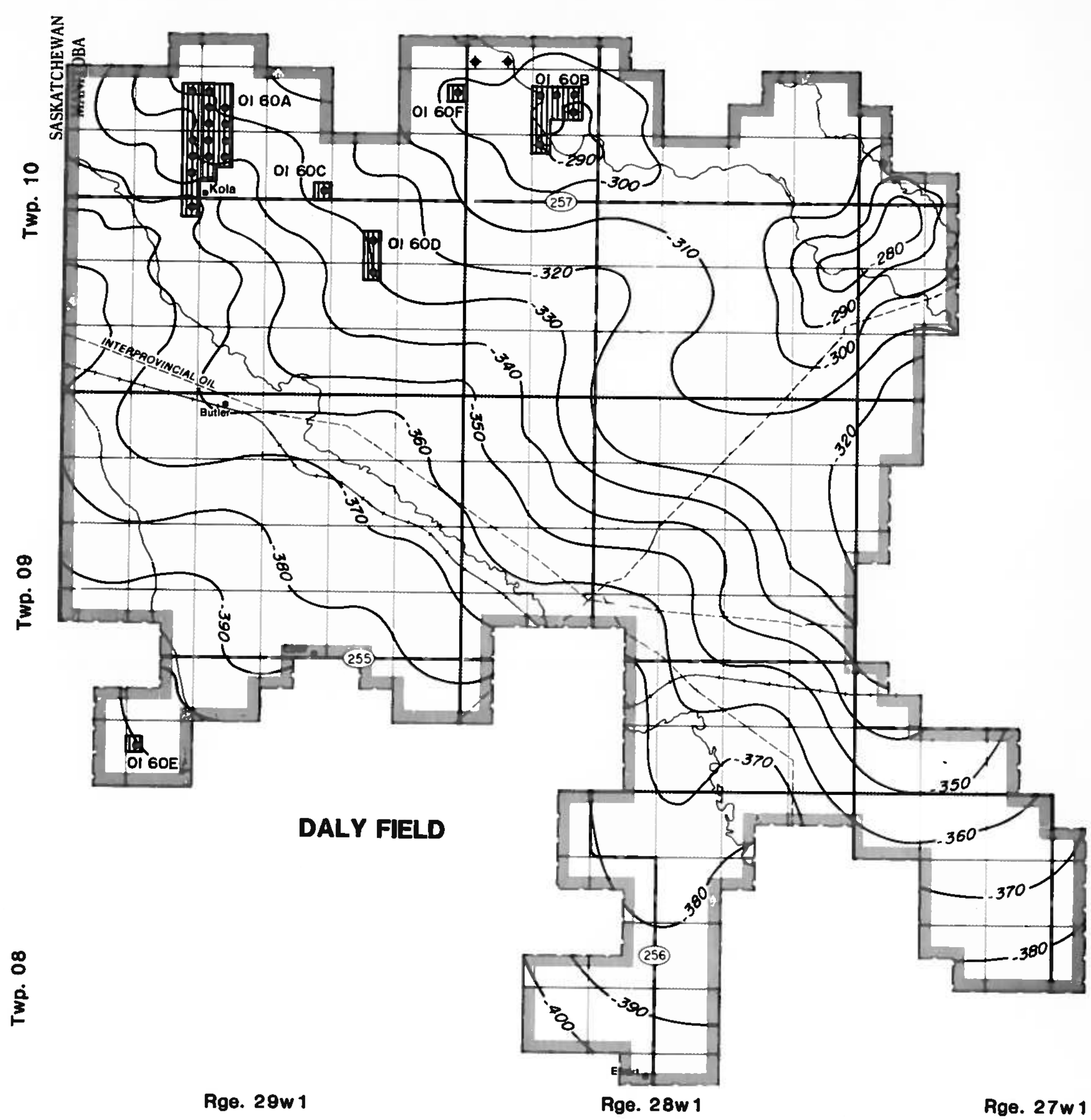
Five additional Bakken pools have been established in the Daly Field since the initial discovery. In total, 24 wells were active Bakken producers as of December 31, 1987 and had produced 20 727.1 m^3 (130,433.6 bbls) of oil and 9 692.7 m^3 (60,965.1 bbls) of water. Table 1 summarizes the production for wells drilled within the six Bakken pools of the Daly Field: Bakken A, B, C, D, E and F.

OIL ACCUMULATION

The accumulation of oil within the Bakken pools of the Daly Field appears to be controlled primarily by stratigraphic factors. Accumulation is localized within minor paleotopographic lows on the Devonian erosional surface, where the thickest deposits of the middle member occur. Porosity is best developed within medium-grained sandstones deposited within the basal portions of the these paleotopographic lows. The stratigraphic trap created by the lateral pinch-out of the basal sandstones against the unconformity, in combination with an upward fining to fine-grained tight sandstone is the primary factor in Bakken oil accumulation in the Daly Field (stratigraphic cross-section D-D'; in pocket).

Bakken oil is also stratigraphically trapped, but to a lesser extent, within the upper portions of the thickened middle member, where porous sandstone interbeds have been pinched-out laterally against tight siltstone.

Structural factors are of secondary importance in the accumulation of Bakken oil in the Daly Field. Minor structural closure is evident on some highs on the middle member, as previously noted (Fig. 9; in pocket).



FIELD/POOL DESIGNATIONS

(December 31, 1987)

FIELD	POOL	FIELD/POOL CODES
Daly (01)	Bakken A	01 60A
	Bakken B	01 60B
	Bakken C	01 60C
	Bakken D	01 60D
	Bakken E	01 60E
	Bakken F	01 60F

Figure 17: Plat of the Daly Field showing the location of Bakken oil wells and pools.
Structure contours (subsea elevations in metres) are on the top of the middle member of the Bakken.

TABLE 1

PRODUCTION HISTORY: Daily Field - Bakken A Pool
(to December 31, 1987)

OPERATOR & WELL LOCATION (WPM)	INITIAL ON-PRODUCTION DATE (M/Y)	INITIAL PRODUCTION RATE (1st month of production) (m^3/day) OIL	WATER	AVERAGE DAILY PRODUCTION (1st 12 months of production) (m^3/day) OIL	WATER	AVERAGE WATER-CUT (1st 12 months of production) (%)	CUMULATIVE PRODUCTION (to December 31, 1987) (m^3) OIL	WATER	AVERAGE WATER-CUT (%)
POOL: Bakken A FIELD/POOL CODE: 01 60A									
Newscope Resources Limited									
16-17-10-29	12/86	2.24	2.95	1.40	0.87	38	524.0	324.2	38
09-20-10-29 Prov.	01/86	3.85	0.90	2.80	0.74	21	2 037.8	393.9	16
16-20-10-29 Prov.	07/87	8.24	0.41	6.65	0.18	3	1 177.8	31.9	3
11-21-10-29	02/86	4.15	3.37	2.02	2.44	55	744.7	1 359.7	65
12-21-10-29	07/87	4.37	7.05	3.08	9.13	75	533.3	1 582.0	75
13-21-10-29	10/85	11.55	2.50	8.38	0.17	2	5 758.2	96.3	2
14-21-10-29	06/87	2.52	0.82	2.21	0.09	4	415.4	16.1	4
03-28-10-29	11/87	7.67	0.77	6.53	0.35	5	241.6	12.9	5
04-28-10-29	06/86	3.50	0.00	6.55	0.05	1	3 172.4	46.8	2
05-28-10-29	12/86	3.28	8.18	2.58	8.60	77	864.2	2 935.1	77
06-28-10-29	09/87	4.66	0.15	3.65	0.12	3	412.0	13.2	3
12-28-10-29 Prov.	10/87	4.84	7.00	5.14	7.79	60	370.3	560.6	60
09-29-10-29 Prov.	12/87	5.23	6.05	5.23	6.05	54	109.8	127.0	54
Voyager Energy Limited									
08-20-10-29	08/87	2.76	7.40	2.28	1.74		295.9	225.9	43
						TOTAL PRODUCTION:	16 657.4	7 725.6	

TABLE 1 (Continued)

PRODUCTION HISTORY:
Daly Field - Bakken B and C Pools
(to December 31, 1987)

OPERATOR & WELL LOCATION (WPM)	INITIAL ON-PRODUCTION DATE (M/Y)	INITIAL PRODUCTION RATE (1st month of production) (m^3/day)		AVERAGE DAILY PRODUCTION (1st 12 months of production) (m^3/day)		AVERAGE WATER-CUT (1st 12 months of production) (%)	CUMULATIVE PRODUCTION (to December 31, 1987) (m^3)		AVERAGE WATER-CUT (%)
		OIL	WATER	OIL	WATER		OIL	WATER	
POOL: Bakken B FIELD/POOL CODE: 01 60B									
Tundra Oil & Gas									
13-20-10-28 Prov.	06/87	3.70	2.97	1.03	0.86	45	106.6	88.3	45
Remarks: Recompleted to the Mississippian Lodgepole Formation (Lodgepole 'J' Pool) - Oct./87									
07-29-10-28 Prov.	02/86	2.94	1.96	1.84	0.70	27	538.4	198.2	27
Remarks: Recompleted to the Mississippian Lodgepole Formation (Lodgepole 'E' Pool) - Mar./87									
10-29-10-28 Prov.	02/86	2.80	0.90	2.35	0.81	26	909.5	424.6	32
11-29-10-28 Prov.	07/87	2.00	6.10	0.96	0.82	46	138.8	119.6	46
12-29-10-28 Prov.	06/86	4.96	1.30	2.56	0.58	19	1 206.4	256.6	18
					TOTAL PRODUCTION:		2 899.7	1 087.3	
POOL: Bakken C FIELD/POOL CODE: 01 60C									
Manitoba Oil and Gas Corporation									
01-22-10-29 Prov.	05/87	3.16	2.34	1.06	0.68	39	237.1	151.0	39
Remarks: Recompleted from the Mississippian Lodgepole Formation (Lodgepole 'L' Pool) - May/87									

TABLE 1 (Continued)

PRODUCTION HISTORY:
Daly Field - Bakken D, E and F Pools
(to December 31, 1987)

OPERATOR & WELL LOCATION (WPM)	INITIAL ON-PRODUCTION DATE (M/Y)	INITIAL PRODUCTION RATE (1st month of production) (m^3/day)		AVERAGE DAILY PRODUCTION (1st 12 months of production) (m^3/day)		AVERAGE WATER-CUT (1st 12 months of production) (%)	CUMULATIVE PRODUCTION (to December 31, 1987) (m^3)		AVERAGE WATER-CUT (%)
		OIL	WATER	OIL	WATER		OIL	WATER	
Pool: Bakken D Code: 01 60D									
Manitoba Oil and Gas Corporation									
15-11-10-29 Prov.	12/86	3.00	7.50	1.59	1.31	45	550.1	447.8	45
07-14-10-29	02/87	1.85	1.85	1.28	0.57	31	203.0	90.7	31
Remarks: Recompleted to the Mississippian Lodgepole Formation (Lodgepole 'D' Pool) - June/87. Commingled production (Lodgepole 'D' Pool & Bakken 'D' Pool) - Oct./87									
						TOTAL PRODUCTION:	753.1	538.5	
Pool: Bakken E Code: 01 60E									
Tundra Oil & Gas									
12-05-09-29	10/87	1.47	4.48	0.91	1.77	66	51.7	100.9	66
Remarks: Recompleted from the Mississippian Lodgepole Formation (Lodgepole 'R' Pool) - Oct./87									
Pool: Bakken F Code: 01 60F									
Manitoba Oil and Gas Corporation									
09-25-10-29	11/87	3.27	2.81	2.78	1.94	41	128.1	89.4	41
Remarks: Recompleted from the Mississippian Lodgepole Formation (Lodgepole 'E' Pool) - Nov./87									

CONCLUSIONS

The Bakken Formation of southwestern Manitoba is a thin, widespread clastic unit that lies between the carbonates of the Mississippian Lodgepole Formation of the lower Madison, and the red dolomitic shales and siltstones of the Upper Devonian Lyleton Formation.

The Bakken represents the basal portion of the Mississippian sedimentary cycle of marine transgression and regression. In southwestern Manitoba, deposition of the Bakken is believed to have occurred under shallow-water, restricted, marine conditions. The lower and upper black shales were deposited in stagnant, poorly oxygenated waters. The middle siltstone was deposited during a minor period of transgression (McCabe, 1959).

The upper black shale member and middle (siltstone/sandstone) member of the Bakken are present throughout most of the map area. The lower shale member occurs only within the Waskada area. It is absent in most areas of the study due to the overstep of the overlying middle member. The lithology of the middle member varies from a siltstone to a very fine- to fine-grained and medium-grained sandstone. Grains are predominantly quartzose. The matrix consists of dolomite or dolomitic shale. Intergranular porosity is best developed within the coarser grained beds of the middle member.

The upper and lower members of the Bakken consist generally of black to brownish-black to dark grey, fissile, radioactive, non-calcareous shales. Both members of the Bakken are excellent lithologic markers and can be easily recognized on gamma ray logs by their high radioactive response.

The contact between the middle member and the underlying Lyleton Formation is commonly difficult to recognize both lithologically and on well logs due to the lithologic similarities of the two formations. In localities where the lower member is absent, the contact between the Bakken and Lyleton is considered to be unconformable.

Structure on the middle member follows the regional Paleozoic tilt dipping southwest at an average of 6 metres/km.

The isopach trends of the Bakken Formation are generally northwest-southeast. The most significant changes in thickness of the Bakken occur within the middle member, which represents a major portion of the total Bakken thickness. The middle member averages 4 metres in thickness. The upper member averages 2 metres in thickness. Sedimentation of the Bakken is controlled, in part, by the paleotopography of the erosion surface of the underlying Lyleton Formation.

Local variations in thickness in both the Bakken and Lyleton section are evident throughout the map area. The greatest thickness variations occur in the Waskada area where as much as 26 metres has been added to the total Bakken, and over 79 metres added to the Lyleton. These anomalies are believed to be the result of the multiple stage solution of Devonian salts and collapse of overlying strata during Bakken-Lyleton time.

Recent exploration in the Daly Field of southwestern Manitoba has led to the discovery and subsequent development of several oil pools within the middle member of the Bakken. As of December 31, 1987, the 24 producing wells within the six pools of the Daly Field had produced 20 727.1 m^3 (130,433.6 bbls) of oil and 9 692.7 m^3 (60,965.1 bbls) of water.

The accumulation of oil within the Bakken pools of the Daly Field appears to be controlled primarily by stratigraphic factors. Accumulation is localized within minor paleotopographic lows on the Devonian erosional surface, where the thickest deposits of the middle member occur. Porosity is best developed within medium-grained sandstones deposited within the basal portions of these paleotopographic lows. The stratigraphic trap created by the lateral pinch-out of the basal, porous sandstone against the Devonian unconformity, in combination with an upward fining to fine-grained tight sandstone is the primary factor in Bakken oil accumulation in the Daly Field.

Structural factors are of secondary importance to the accumulation of Bakken oil in the Daly Field as is evident by minor structural closure on highs on the middle member.

RECOMMENDATIONS

The report presented is a preliminary study of the regional geology and petroleum potential of the Bakken Formation as it occurs in southwestern Manitoba. Regional geologic aspects examined include: the general stratigraphic relationships, lithologic character, correlations and lateral variations of the Bakken Formation. The effect of salt collapse on the depositional processes of the Bakken and Lyleton Formations are considered. A brief discussion of the economic aspects of the Bakken, its exploration, development and production history and nature of oil entrapment, are also discussed.

The information and interpretation presented in this report provide the basic framework for future studies of the Bakken Formation as it occurs in southwestern Manitoba and may be applied to other areas of the Williston Basin where the Bakken occurs.

The following recommendations are proposed for future studies of the Bakken Formation:

1. detailed petrologic examination of the formation through: core examination; thin-section petrography; scanning electron microscopy and x-ray diffraction analysis;
2. detailed lithofacies mapping of the formation;
3. analysis of the reservoir characteristics of the middle member with respect to porosity/permeability and diagenesis;
4. determination of average water saturations, resistivities, porosities and permeabilities of the reservoir;*
5. detailed mapping of net pay and oil-in-place within producing areas*; and
6. paleontological evaluation of the Bakken Formation and the Bakken-Lyleton contact.

*Note: With respect to recommendations 4 and 5, refer to:

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APPENDIX I: Core Descriptions

APPENDIX II: Index of Drill Stem Tests and Core for the Bakken and Lyleton Formations

APPENDIX I: Core Descriptions

NEWSCOPE OPINAC DALY PROV. 9-20-10-29 WPM
879.0 - 897.0 m

Interval (m)	Thickness (m)	Description
Bakken (Upper Member)		
879.0 - 880.5	1.5	Shale: black, fissile, non-calcareous, bituminous.
880.5 - 882.0	1.5	Shale: as above; grey-green, dolomitic.
Bakken (Middle Member)		
882.0 - 882.9	0.9	Sandstone: buff, dolomitic, very fine-grained.
882.9 - 884.4	1.5	Sandstone: tan to grey, dolomitic, very fine- to fine-grained.
884.4 - 884.9	0.5	Sandstone: light grey, dolomitic, fine-grained, subrounded.
884.9 - 887.2	2.3	Sandstone: tan to grey, dolomitic, very fine- to fine-grained, subangular to subrounded, trace pyrite.
887.2 - 887.4	0.2	Shale: cream to buff, dolomitic, trace pyrite.
Lyleton		
887.4 - 888.3	0.9	Dolomite: buff to light grey, dense, trace pyrite.
888.3 - 892.4	4.1	Shale (interbedded with dolomite): green, silty. Dolomite: buff to brown, silty.
892.4 - 897.0	4.6	Shale: rusty red, dolomitic.

NEWSCOPE OPINAC DALY 11-21-10-29 WPM
872.0 - 890.0 m

Interval (m)	Thickness (m)	Description
Bakken (Upper Member)		
872.0 - 874.0	2.0	Shale: black, fissile, non-calcareous, bituminous, subconchoidal fracturing.
Bakken (Middle Member)		
874.0 - 875.4	1.4	Siltstone: grey to cream, dolomitic, subangular to subrounded, some burrowing infilled with trace pyrite.
875.4 - 876.3	0.9	Sandstone: greenish-grey, dolomitic, very fine-grained, some burrowing infilled with trace pyrite.
876.3 - 877.1	0.8	Sandstone: cream to light grey, dolomitic, very fine- to fine-grained, subrounded.
877.1 - 877.6	0.5	Sandstone: buff to cream, slightly dolomitic, fine- to medium-grained, subrounded.
877.6 - 877.9	0.3	Sandstone: as above; fine- to medium-grained.
877.9 - 878.6	0.7	Sandstone: as above; light grey, shale partings, convoluted bedding, trace pyrite, fair to good intergranular porosity, **patchy oil-staining**.
878.6 - 879.0	0.4	Shale: grey-green, dolomitic, trace pyrite.
Lyleton		
879.0 - 881.3	2.3	Dolomite: grey, pyrite infilling some vugs, vuggy porosity.
881.3 - 885.7	4.4	Dolomitic Shale: grey-green, silty.
885.7 - 890.0	4.3	Shale: rusty red, dolomitic, massive.

SUN et al BIRDTAIL CREEK **3-21-15-27 WPM**
1705 - 1765′ (519.7 - 537.9 m)

Interval (m)	Thickness (m)	Description
Lodgepole		
1705 - 1739′ (519.7 - 530.0)	34′ (10.3)	Limestone: buff to grey, pink, dense, mottled vuggy near base, chert nodules 1-3" (2.5 - 7.6 cm), dolomite near base.
Bakken (Upper Member)		
1739 - 1739.3′ (530.0 - 530.1)	0.3′ (0.1)	Shale: light green, fissile, waxy.
1739.3 - 1746.0′ (530.1 - 532.2)	6.7′ (2.1)	Shale: purple to grey, black, massive, waxy, some hematite staining.
Bakken (Middle Member)		
1746.0 - 1747.75′ (532.2 - 532.7)	1.75′ (0.5)	Sandstone: pink to light grey, dolomitic, very fine-grained to silty, subangular to subrounded, fine wavy bedding, brachiopods near top, some hematite staining.
1747.75 - 1750.0′ (532.7 - 533.4)	2.25′ (0.7)	Sandstone: light grey to buff, salt and pepper, dolomitic, very fine- to fine-grained, subangular, well sorted, wavy laminations near middle, poor to fair pinpoint porosity, **good oil-staining** where porosity developed.
1750 - 1757′ (533.4 - 535.5)	7′ (2.1)	Sandstone: grey to pinkish-purple, dolomitic, fining upwards from fine- to very fine-grained to silty, subangular, laminated throughout, hematite stained.
1757 - 1758′ (535.5 - 535.8)	1′ (0.3)	Sandstone: as above; salt and pepper near base, very fine- to fine-grained, dolomitic, friable, subangular to subrounded.
Lyleton		
1758 - 1765′ (535.8 - 537.9)	7′ (2.1)	Dolomite: grey to purple, mottled, grey shale partings, silty, laminated.

CDCOG et al BIRDTAIL CREEK **12-22-15-27 WPM**
1685 - 1750′ (513.6 - 533.4 m)

Interval (m)	Thickness (m)	Description
Lodgepole		
1685 - 1718′ (513.6 - 523.6)	33′ (10)	Limestone/Dolomite: grey to buff, mottled,some minor vuggy porosity.
Bakken (Upper Member)		
1718 - 1719′ (523.6 - 523.9)	1′ (0.3)	Shale: dark grey, fissile, waxy, slightly dolomitic.
1719 - 1724.1′ (523.9 - 525.5)	5.1′ (1.6)	Shale: purplish-pink, fissile, waxy, slightly dolomitic.
Bakken (Middle Member)		
1724.1 -1725.1′ (525.5 - 525.8)	1.0′ (0.3)	Siltstone: red to purple, dolomitic, argillaceous, no visible porosity.
1725.1 - 1728.1′ (525.8 - 526.7)	3′ (0.9)	Sandstone: tan to light brown, very dolomitic silty to very fine-grained, subangular to subrounded, medium sorting, trace pinpoint porosity.
1728.1 - 1728.7′ (526.7 - 526.9)	0.6′ (0.2)	Sandstone: tan, very fine-grained, subangular to subrounded, poor intergranular porosity, **uniformly oil-stained** near top.
1728.7 - 1730′ (526.9 - 527.3)	1.3′ (0.4)	Sandstone: salt and pepper , dolomitic, fine-grained, subrounded, well sorted.
1730 - 1732.6′ (527.3 - 528.1)	2.6′ (0.8)	Sandstone: tan, dolomitic, fine-grained, well sorted, good intergranular porosity, **good oil-staining**.
1732.6 - 1734′ (528.1 - 528.5)	1.4′ (0.4)	Siltstone: red to purple, dolomitic, with shale blebs 0.5" (1.3 cm).
1734 - 1738′ (528.5 - 529.7)	4′ (1.2)	Sandstone: salt and pepper, very fine-grained, slightly silty, dolomitic, numerous green shale partings, very dense.
Lyleton		
1738 - 1741′ (529.7 - 530.6)	3′ (0.9)	Shale: pale green, banded with thin siltstone beds, dolomitic.
1741 - 1744′ (530.6 - 531.5)	3′ (0.9)	Siltstone: yellow, grey, brown, purple banded, argillaceous, dense, grades to silty shale near base.
1744 - 1750′ (531.5 - 533.4)	6′ (1.9)	Shale: grey-green.

APPENDIX I (Continued)

BISON BURMAH BIRDTAIL — **8-8-16-27 WPM**
1692 - 1742′ (515.7 - 531.0 m)

Interval (m)	Thickness (m)	Description
Bakken (Upper Member)		
1692 - 1695.75′ (515.7 - 516.9)	3.75′ (1.2)	Shale: purple and grey mottled, slightly dolomitic, fissile, waxy.
1695.75 - 1697.0′ (516.9 - 517.3)	1.25′ (0.4)	Shale: yellow and grey mottled, partly silty at base, shell fragments?
Bakken (Middle Member)		
1697 - 1697.75′ (517.3 - 517.5)	0.75′ (0.2)	Siltstone: grey, dense, argillaceous.
1697.75 - 1698.25′ (517.5 - 517.6)	0.5′ (0.1)	Sandstone: reddish brown, dolomitic, silty to very fine-grained, shell fragments, poor to fair intergranular porosity, some vuggy porosity.
1698.25 - 1700.0′ (517.6 - 518.1)	1.75′ (0.5)	Sandstone: buff to grey to medium brown, dolomitic, very fine- to fine-grained, subangular to subrounded, well sorted, trace fossils, poor to fair intergranular porosity, **patchy oil-staining.**
1700 - 1700.75′ (518.1 - 518.3)	0.75′ (0.2)	Sandstone: grey, dolomitic, very fine- to fine-grained, subangular to subrounded, well sorted, good intergranular porosity.
1700.75 - 1701.0′ (518.3 - 518.4)	0.25′ (0.1)	Sandstone: reddish-brown, silty to very fine-grained.
1701 - 1701.8′ (518.4 - 518.7)	0.8′ (0.3)	Sandstone: grey, dolomitic, very fine - to fine-grained, subangular to subrounded, well sorted, good intergranular porosity.
1701.8 - 1704.2′ (518.7 - 519.4)	2.4′ (0.7)	Sandstone: red and grey mottled, dolomitic, very fine- to fine-grained, subangular to subrounded, fair intergranular porosity, poor pinpoint porosity.
1704.2 - 1706.5′ (519.4 - 520.1)	2.3′ (0.7)	Shale: greenish-grey mottled, dolomitic, massive.
1706.5 - 1709.8′ (520.1 - 521.1)	3.3′ (1.0)	Siltstone: red, purple, buff mottled, dolomitic, argillaceous.
1709.8 - 1712.2′ (521.1 - 521.8)	2.4′ (0.7)	Siltstone: red, very dolomitic, argillaceous.
Lyleton		
1712.2 - 1722.7′ (521.8 - 525.0)	10.5′ (3.2)	Shale: purple, mottled, silty.
1722.7 - 1739.5′ (525.0 - 530.2)	16.8′ (5.2)	Shale: brick red, dolomitic massive.
1739.5 - 1742′ (530.2 - 531.0)	2.5′ (0.8)	Shale: grey, dolomitic, massive.

CDCOG et al BRDTAIL CREEK — **11-9-16-27 WPM**
1680 - 1730′ (512.0 - 527.3 m)

Interval (m)	Thickness (m)	Description
Lodgepole		
1680 - 1688.7′ (512.0 - 514.7)	8.7′ (2.7)	Limestone: greenish grey to pink, green shale partings, dolomite near base, vuggy porosity near base, **patchy oil-staining.**
Bakken (Upper Member)		
1688.7 - 1691.6′ (514.7 - 515.6)	2.9′ (0.9)	Shale: light green, slightly dolomitic, fissile, waxy.
1691.6 - 1694.9′ (515.6 - 516.6)	3.3′ (1.0)	Shale: purple to red at base, finely laminated, hematite staining.
Bakken (Middle Member)		
1694.9 - 1697.8′ (516.6 - 517.5)	2.9′ (0.9)	Siltstone: pink to yellow, dolomitic, brachiopod fragments, hematite in small veinlets.
1697.8 - 1701.2′ (517.5 - 518.5)	3.4′ (1.0)	Sandstone: salt and pepper to pink, dolomitic, very fine-grained, subangular to subrounded, finely laminated, wavy bedding near base, some hematite staining.
1701.2 - 1702.5′ (518.5 - 518.9)	1.3′ (0.4)	Siltstone: buff to pink, slightly dolomitic,hematite staining, poor to fair pinpoint porosity, **moderate to good oil-staining** near base.
1702.5 - 1703.6′ (518.9 - 519.2)	1.1′ (0.3)	Siltstone: buff, salt and pepper, dolomitic, hematite staining, marl-like appearance, poor pinpoint porosity.
1703.6 - 1710.7′ (519.2 - 521.4)	7.1′ (2.2)	Siltstone: light brown to buff, pink, finely laminated near base, some shale, light green, as blebs 1-2" (2.5 - 5.0 cm).
Lyleton		
1710.7 - 1717.0′ (521.4 - 523.3)	6.3′ (1.9)	Dolomite: pink. light green, and rust mottled, silty.
1717 - 1720′ (523.3 - 524.2)	3.0′ (0.9)	Shale: rust red, massive.
1720.1 - 1726.3′ (524.2 - 526.1)	6.2′ (1.9)	Shale: purple, light grey-green mottled, dolomitic, silty, finely laminated.
1726.3 - 1730.0′ (526.1 - 527.3)	3.7′ (1.2)	Shale: rusty red, massive.

APPENDIX II: Index of Drill Stem Tests and Core for the Bakken and Lyleton Formations

Sources of Data:

Data included in this appendix have been obtained from reports submitted by the oil companies to the Petroleum Branch of Energy and Mines and from two government publications entitled: "Index of Core and Sample Storage" and; "Lower Paleozoic Drill Stem Tests and Oil and Gas Shows, Bakken to Precambrian". Information is complete up to and including December 31, 1987.

Data are provided in imperial and metric measurements.

List of Abbreviations:

Rec.	-	drill stem test recovery
O	-	oil, oily
G	-	gas, gassy, gassified
GTS	-	gas to surface
W	-	water, watery
M	-	mud, muddy, drilling mud
F	-	flecked
S	-	salt, salty, saline
GC	-	gas-cut
OC	-	oil-cut
V	-	very
sl.	-	slightly
H	-	heavily
VO	-	valve open, flowing time during drill stem test
FP	-	flowing pressure
SI	-	shut-in time
SIP	-	shut-in pressure
BS&W	-	basal sludge and water
Mcf	-	thousand cubic feet

APPENDIX II (Continued)

LOCATION (WPM)	FORMATION TESTED	DST INTERVAL	DST RECOVERY AND OIL OR GAS SHOWS	VO	FP	SI	SIP	FORMATION CORED	CORED INTERVAL
06-21-01-19	Bakken-Lyleton	3223′-3269′	Rec. 65′ M	45	0	30	1120	Lodgepole-Bakken-Lyleton	3196′-3269′
10-26-01-20	Bakken-Lyleton	3439′-3500′	Rec. 10′ M; 710′ W	-	-	-	-	-	-
14-29-01-20	Lyleton-Nisku	3515′-3560′	Rec. 945′ MSW	60	500	20	1175	-	-
04-36-01-21	-	-	-	-	-	-	-	Bakken Bakken-Lyleton	3590′-3610′ 3610′-3650′
09-13-01-26	Bakken	3777′-3802′	Rec. 65′ M	45	0	15	450	Bakken	3781′-3802′
16-13-01-26	Bakken	3750′-3777′	Rec. 10′ M	60	0	15	-	-	-
05-32-02-26	-	-	-	-	-	-	-	Bakken	3715′-3735′
02-29-02-29	Bakken-Lyleton	4201′-4225′	Rec. 70′ M	30	0	30	1510	-	-
02-02-03-21	-	-	-	-	-	-	-	Bakken	2995′-3010′
05-23-03-24	-	-	-	-	-	-	-	Bakken	3291′-3311′
06-07-04-21	-	-	-	-	-	-	-	Bakken-Lyleton	2799′-2824′
10-22-04-26	Bakken-Lyleton	3260′-3280′	Rec. 5′ GCOFM	50	45/45	90/120	604/264	-	-
04-08-05-22	Lyleton-Nisku	2830′-2880′	Rec. 210′ SM	60	195	45	1225	-	-
01-19-05-24	Lyleton-Nisku	2734′-2754′	Rec. 20′ SM	75	-	30	-	-	-
07-27-05-24	-	-	-	-	-	-	-	Bakken	2480′-2500′
10-18-05-25	Bakken	3005′-3020′	Rec. 25′ M	45	0	-	659	-	-
03-03-05-28	Lodgepole-Bakken-Lyleton	3601′-3655′	Rec. 25′ M	45	-	15	-	-	-
07-27-06-27	Bakken	3079′-3104′	Rec. 60′ M	60	0	-	-	Bakken	3073′-3088′
04-03-06-29	Bakken	3654′-3669′	Rec. 35′ M	60	0	30	1040	-	-
02-21-07-28	Bakken-Lyleton	3072′-3088′	Rec. 7′ M	45	0/675	15	-	Bakken-Lyleton	3068′-3088′
02-28-07-29	Bakken-Lyleton	3292′-3315′	Rec. 60′ M., slight oil show	60	-	25	-	-	-
04-14-08-28	Bakken	2889′-2909′	Rec. 25′ sl. OCM	45	-	-	-	Bakken	2899′-2909′
15-17-08-28	-	-	-	-	-	-	-	Bakken	903.0-913.0 m
11-22-08-28	-	-	-	-	-	-	-	Bakken-Lyleton	871.0-883.8 m
08-27-08-28	Bakken-Lyleton	2804′-2827′	Rec. 4′ M	45	0	15	0	Bakken-Lyleton	2802′-2827′
07-34-08-28	-	-	-	-	-	-	-	Bakken-Lyleton	844.0-856.0 m
07-36-08-28	-	-	-	-	-	-	-	Bakken-Lyleton	2780′-2810′
13-29-09-25	Bakken	2311′-2327′	Rec. 30′ M	60	0	15	875	-	-
01-22-09-26	-	-	-	-	-	-	-	Bakken-Lyleton-Nisku	2419′-2470′
07-26-09-26	-	-	-	-	-	-	-	Bakken-Lyleton	2401′-2431′
05-18-09-27	Lodgepole-Bakken-Lyleton	2637′-2672′	Rec. 40′ M	30	0	15	600	Bakken	2662′-2672′
13-14-09-28	Bakken	2735′-2755′	Rec. 3′ O, high gravity; 30′ OCM	90	0	60	1050	Bakken-Lyleton	2730′-2755′
01-20-09-28	-	-	-	-	-	-	-	Lodgepole-Bakken-Lyleton	857.0-975.0 m
13-26-09-28	Bakken-Lyleton	817.0-825.0 m	Rec. 6 m M	10/60	520/349	60/120	7250/7190	-	-
01-30-09-28	Bakken	2865′-2875′	Rec. 30′ M	65	0	30	1070	Lodgepole-Bakken-Lyleton	2780′-2920′
09-32-09-28	-	-	-	-	-	-	-	Bakken	2723′-2748′
15-12-09-29	Bakken	903.0-908.0 m	Rec. 1 m M	5/45	243/243	30/90	5094/7258	-	-
01-16-09-29	Bakken-Lyleton	921.0-936.0 m	Rec. 36 m M	15/60	673/673	60/120	8401/8233	-	-

APPENDIX II (Continued)

LOCATION (WPM)	FORMATION TESTED	DST INTERVAL	DST RECOVERY AND OIL OR GAS SHOWS	VO	FP	SI	SIP	FORMATION CORED	CORED INTERVAL
01-31-09-29	Bakken	3000′-3011′	Rec. 50′ M	60	0	30	0	Bakken-Lyleton	2996′-3031′
	Bakken-Lyleton	3011′-3031′	Rec. 12′ v. sl. OFM	60	0	30	1000	-	-
06-30-10-24	-	-	-	-	-	-	-	Bakken	632.0-639.0 m
								Lyleton	657.0-667.0 m
03-13-10-25	Bakken	1930′-1949′	Rec. 25′ SWM	60	-	30	860	-	-
15-18-10-27	-	-	-	-	-	-	-	Bakken	2512′-2517′
14-04-10-28	Bakken-Lyleton	2695′-2727′	Rec. 15′ sl. O and GCM; 30′ sl. GCM	60	0	15	900	Bakken-Lyleton	2695′-2727′
01-10-10-28	-	-	-	-	-	-	-	Lodgepole-Bakken	2631′-2672′
08-14-10-28	Lodgepole-Bakken-Lyleton	2587′-2625′	Rec. 30′ OFM	60	0	30	0	Bakken-Lyleton	2600′-2625′
12-20-10-28	-	-	-	-	-	-	-	Lodgepole-Bakken-Lyleton	805.0-820.0 m
03-29-10-28	-	-	-	-	-	-	-	Bakken-Lyleton	800.0-818.0 m
05-29-10-28	Bakken-Lyleton	806.0-817.0 m	Rec. 10 m OCM	10/60	365/365	60/90	9425/9365	-	-
07-29-10-28	Bakken	807.0-814.0 m	Rec. 35 m sl. OCM	10/60	357/447	60/120	7603/7513	Bakken-Lyleton	812.0-821.0 m
08-29-10-28	Bakken-Lyleton	2647′-2668′	Rec. 100′ sl. GOCM	60	0	15	900	Lyleton	2658′-2668′
10-29-10-28	-	-	-	-	-	-	-	Lodgepole-Bakken-Lyleton	801.0-819.0 m
11-29-10-28	-	-	-	-	-	-	-	Bakken-Lyleton	811.0-822.0 m
12-29-10-28	-	-	-	-	-	-	-	Bakken-Lyleton	805.0-823.0 m
10-30-10-28	-	-	-	-	-	-	-	Bakken-Lyleton	811.0-823.0 m
11-30-10-28	Bakken-Lyleton	813.0-822.0 m	Rec. 2 m OCM with trace oil	10/60	215/268	60/120	9201/8884	-	-
18-11-10-29	Bakken	2803′-2818′	Rec. 25′ M (misrun)	45	-	15	-	-	-
	Bakken-Lyleton	2807′-2860′	Rec. 900′ W cushion; 30′ M	60	470	15	1100	-	-
11-11-10-29	Bakken	861.0-863.0 m	Rec. 1 m OFM	10/60	440/440	60/120	4690/6040	Bakken-Lyleton	861.5-870.5 m
15-11-10-29	Bakken	855.0-865.0 m	Rec. 59 m GCOFM	15/45	730/1157	60/120	7981/8162	-	-
07-14-10-29	Bakken	855.0-862.0 m	Rec. 3 m OCM; 18 m oil stained mud	10/45	365/426	60/120	7981/7800	-	-
04-16-10-29	Bakken-Lyleton	2929′-2952′	Rec. 110′ sl. OFM	50	0	-	1150	-	-
14-16-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	881.0-899.0 m
16-17-10-29	Bakken-Lyleton	906.5-923.0 m	Rec. 37 m OFM; 1 m MCO	10/60	677/800	60/90	8801/8436	-	-
09-20-10-29	-	-	-	-	-	-	-	Bakken	879.0-897.0 m
11-21-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	872.0-890.0 m
13-21-10-29	Bakken	875.5-882.0 m	Rec. 5 m sl. MCO; 198 m GO	5/60	938/2252	60/120	8580/8280	-	-
02-25-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	824.0-837.0 m
13-27-10-29	-	-	-	-	-	-	-	Bakken	2730′-2800′
04-28-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	870.0-889.0 m
05-28-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	865.0-883.0 m
01-29-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	877.0-895.0 m
04-29-10-29	-	-	-	-	-	-	-	Bakken-Lyleton	878.0-896.0 m
08-30-10-29	Bakken-Lyleton	882.0-892.5 m	Rec. 10 m WCM	5/90	430/553	60/180	8519/8515	-	-
05-11-11-26	-	-	-	-	-	-	-	Bakken	2234′-2259′
								Lyleton	2279′-2284′
12-16-11-26	-	-	-	-	-	-	-	Bakken-Lyleton	2292′-2342′

APPENDIX II (Continued)

LOCATION (WPM)	FORMATION TESTED	DST INTERVAL	DST RECOVERY AND OIL OR GAS SHOWS	VO	FP	SI	SIP	FORMATION CORED	CORED INTERVAL
15-12-11-27	-	-	-	-	-	-	-	Bakken-Lyleton	2408′-2433′
09-05-11-28	Bakken	2758′-2766′	Rec. 15′ OCM	90	0	20	0	Bakken-Lyleton	2766′-2776′
16-03-11-29	Bakken-Lyleton	2835′-2865′	Rec. 70′ M	45	-	15	-	-	-
7A-08-11-29	Bakken	2780′-2800′	Rec. 93′ sl. OGCM	30	0	15	-	Bakken	2790′-2800′
11-11-11-29	-	-	-	-	-	-	-	Bakken-Lyleton	841.5 - 859.0 m
04-36-11-29	Bakken	2705′-2725′	Rec. 120′ diesel fuel cushion; 270′ MSW	60	80/165	30	890	-	-
03-17-12-24	Lyleton-Nisku	2005′-2035′	Rec. 5′ M	45	0	-	500	-	-
01-10-12-26	-	-	-	-	-	-	-	Bakken-Lyleton	2176′-2201′
01-03-12-27	Bakken-Lyleton	2275′-2300′	Rec. 97′ MSW	30	30/70	30	935	-	-
09-22-12-27	Bakken-Lyleton	2111′-2135′	Rec. 31′ M	40	0	15	750	Bakken-Lyleton	2124′-2135′
13-21-12-28	Bakken-Lyleton	2352′-2382′	Rec. 660′ MSW	75	370	30	1020	-	-
09-28-12-28	-	-	-	-	-	-	-	Bakken-Lyleton	2315′-2365′
16-03-12-29	Bakken	2638′-2668′	Rec. 50′ MSW	60	25	30	910	Lodgepole-Bakken	2623′-2668′
13-04-12-29	Bakken-Lyleton	2699′-2720′	Rec. 30′ M	60	0	45	975	Bakken-Lyleton	2700′-2720′
16-05-12-29	Bakken	2700′-2715′	Rec. 2′ M	90	0	30	0	Lodgepole-Bakken	2683′-2715′
14-07-12-29	-	-	-	-	-	-	-	Lodgepole-Bakken-Lyleton	823.0-832.0 m
12-19-12-29	-	-	-	-	-	-	-	Bakken	807.3-818.0 m
16-29-12-29	Bakken	2542′-2564′	Rec. 360′ MSW	5/90	40/80	30/60	1030/975	Bakken-Lyleton	2600′-2638′
12-28-13-26	Lyleton-Nisku	1910′-1980′	Rec. 10′ M	40	0	-	0	-	-
04-20-13-27	Lodgepole-Bakken	2006′-2019′	Rec. 25′ MCW	80	-	-	-	-	-
03-28-13-29	-	-	-	-	-	-	-	Bakken	2282′-2297′
06-31-14-27	Bakken-Lyleton	1780′-1810′	Rec. 174′ M; 544′ SW	90	99/363	120	704/707	Bakken-Lyleton	1795′-1835′
09-25-14-28	Lodgepole-Bakken-Lyleton	1835′-1875′	Rec. 1330′ SW	60	255/630	60	730	-	-
11-04-14-29	-	-	-	-	-	-	-	Lodgepole-Bakken	2231′-2255′
14-05-14-29	Lodgepole-Bakken	2242′-2264′	Rec. 920′ MSW	60	600	15	850	-	-
08-07-14-29	-	-	-	-	-	-	-	Bakken	2289′-2304′
09-09-14-29	Bakken-Lyleton	2185′-2220′	Rec. 15′ M	60	23/23	30/120	1042/853	Bakken-Lyleton	2191′-2227′
05-11-14-29	Bakken-Lyleton	2181′-2198′	Rec. 30′ M	120	35/35	30/120	860/760	Bakken-Lyleton	2177′-2198′
09-11-14-29	Bakken	2118′-2138′	Rec. 40′ OCM, strong initial blow	110	0	0	0	Lyleton	2138′-2157′
03-13-14-29	Bakken-Lyleton	2095′-2130′	Rec. 25′ M	60	39/39	30/120	830/830	Bakken-Lyleton	2105′-2140′
04-29-15-26	-	-	-	-	-	-	-	Bakken-Lyleton	1849′-1869′
10-08-15-27	-	-	-	-	-	-	-	Bakken-Lyleton	1786′-1806′
03-21-15-27	Lodgepole-Bakken-Lyleton	1730′-1770′	Rec. 1000′ W; 300′ M	60	235/583	30/90	677/677	Lodgepole-Bakken-Lyleton	1705′-1765′
09-21-15-27	Lodgepole-Bakken	1692′-1711′	Rec. 10′ O; 40′ M	60	0	15	550	Bakken	1711′-1716′
12-22-15-27	Lodgepole-Bakken-Lyleton	1710′-1750′	Rec. 70′ OCM	60	29/49	120	632/632	Lodgepole-Bakken Bakken-Lyleton	1685′-1735′ 1735′-1750′
10-28-15-27	Bakken-Lyleton	1687′-1705′	Rec. 5′ M; 20′ SW	120	14/26	30/30	641/557	Lodgepole-Bakken-Lyleton	1660′-1705′
04-19-15-28	-	-	-	-	-	-	-	Bakken-Lyleton	1859′-1899′
15-29-15-28	Bakken	1795′-1809′	Rec. 35′ M, trace oil flecks	60	0	-	520	Bakken	1809′-1817′

APPENDIX II (Continued)

LOCATION (WPM)	FORMATION TESTED	DST INTERVAL	DST RECOVERY AND OIL OR GAS SHOWS	VO	FP	SI	SIP	FORMATION CORED	CORED INTERVAL
04-32-15-28	-	-	-	-	-	-	-	Bakken-Lyleton	1807'-1860'
12-02-15-29	-	-	-	-	-	-	-	Bakken	2026'-2036'
02-11-15-29	Bakken	1961'-1991'	Rec. 1020' SW	60	10/530	60	770	Lodgepole-Bakken	1949'-1991'
13-12-15-29	Lodgepole-Lyleton	1925'-1960'	Rec. 260' MW	60	56/106	30/120	893/753	Lodgepole-Bakken-Lyleton	1910'-1960'
03-03-16-27	Bakken-Lyleton	1725'-1750'	Rec. 35' sl. OCSWM	90	0	60	590	Bakken-Lyleton	1720'-1750'
08-08-16-27	-	-	-	-	-	-	-	Bakken-Lyleton	1692'-1742'
09-08-16-27	Bakken	1701'-1719'	Rec. 55' M; 5' MCO; 2' O	60	49/58	20	528	Bakken-Lyleton	1690'-1719'
11-09-16-27	-	-	-	-	-	-	-	Bakken-Lyleton	1680'-1730'
14-35-16-27	Bakken-Lyleton	1790'-1828'	Rec. 204' MSW	75	160	20	1010/995	Bakken-Lyleton	1809'-1828'
02-14-16-28	-	-	-	-	-	-	-	Lodgepole-Bakken-Lyleton	1408'-1473'
14-25-16-28	Lodgepole-Bakken	1660'-1682'	Rec. 230' MSW	30	130	30	620	-	-
17-15-16-29	-	-	-	-	-	-	-	Lodgepole-Bakken Bakken-Lyleton	1710'-1760' 1760'-1780'
01-21-16-29	Lodgepole-Bakken-Lyleton	528.0-541.0 m	Rec. 35 m sl. GM	5/60	457/743	45/90	4565/4509	Lodgepole-Bakken-Lyleton	527.0-541.5 m
A4-22-16-29	Bakken	532.0-541.0 m	Rec. 23 m M	10/60	597/682	60/120	4334/4418	Lodgepole-Bakken-Lyleton	527.0-545.0 m
12-34-16-29	Bakken	1700'-1725'	Rec. 120' W; 20' M	125	0	30	869	-	-
16-17-17-27	Lodgepole-Bakken	1798'-1814'	Rec. 85' MC SW	60	5/75	20	590/600	Bakken-Lyleton	1811'-1836'
02-16-17-28	-	-	-	-	-	-	-	Bakken-Lyleton	1621'-1671'
11-30-17-28	Bakken-Lyleton	1576'-1624'	Rec. 120' MSW	90	19/65	45	576/493	Bakken-Lyleton	1576'-1624'
08-28-17-29	-	-	-	-	-	-	-	Bakken-Lyleton	1636'-1671'
06-29-17-29	Bakken-Lyleton	1652'-1672'	Rec. 327' SW	90	145	30	525	Lodgepole-Bakken-Lyleton	1617'-1672'
02-06-18-29	-	-	-	-	-	-	-	Bakken-Lyleton	1645'-1689'
16-18-18-29	Lodgepole-Bakken Bakken	1570'-1614' 1615'-1635'	Rec. 180' GSW; 60' GOFM Rec. 10' sl. OCGM	60 60	0 0	- -	- -	- -	- -