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Petrofacies and Depositional Systems of the Bakken Formation in the Williston Basin, North Dakota

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**Petrofacies and Depositional Systems of the Bakken Formation in the Williston Basin,
North Dakota**

Anne Steptoe

Thesis submitted to the
College of Arts and Sciences
at West Virginia University
in partial fulfillment of the requirements
for the degree of
Master of Science
in Geology

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Mississippian

ABSTRACT

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Anne Steptoe

Late Devonian and Early Mississippian Bakken Formation in the Williston basin of North Dakota is a large emerging unconventional oil play that taps into reserves previously thought to be uneconomical to produce. The hydrocarbon source rocks and unconventional oil reservoir are widespread across the intracratonic basin with an estimated 3.7 billion barrels of undiscovered, recoverable oil, and has significant economic potential in portions of North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba. Although the Bakken interval is the target of numerous horizontal wells throughout the basin, several uncertainties remain including the environment and distribution of depositional facies, especially in the shale members. An improved understanding of the dynamics of Bakken depositional facies is important to further explore and develop this unconventional reservoir.

The Bakken Formation consists of a mixed clastics and carbonate middle member bounded by two black, organic-rich shale units. Generally, the upper and lower shale members are considered to have been deposited under relatively deep marine anoxic conditions (>200 meters depth). However, the underlying Sanish sand unit and the middle member of the Bakken have been interpreted as deposited in an epicontinental sea under shallow-water high-energy conditions (< 10 meters depth). The middle member of the Bakken is a complex stacked interval of dolomitic and calcareous siltstone, as well as oolitic or calcareous sandstone. To evaluate the inferred rapid changes in sea level, and the influence on depositional environments and production, subunits in the shale members were correlated for approximately 100 wells. The upper and lower Bakken shale members are divided into transgressive-regressive subunits that can be recognized by changes in lithology, mineralogy and sedimentologic properties, and are attributed to fluctuating depositional conditions.

Log based solutions were also used to generate RHOMaa-Umaa cross plots and lithology composition graphs were generated for selected wells across the study area. In addition regional cross-sections and thickness maps were generated to further enhance the understanding of the vertical and lateral continuity of the depositional facies within the Bakken Formation. The result is an improved understanding of depositional patterns and basin evolution for the entire Bakken interval with emphasis on the shale units.

Implementation of a transgressive-regressive stratigraphic framework in the Bakken subunits harbors a better understanding of the changing depositional conditions such as fluctuating sea level and complicated sediment accumulation patterns. Thus the improved understanding of the dynamics of the depositional facies in the Bakken Formation, including the shale units, is important to further explore and develop this unconventional reservoir to its best potential.

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Chapter 1: Introduction

Oil was first discovered in the Late Devonian to Early Mississippian Bakken Formation in the Williston basin of North Dakota in 1951, but production rates were low and production was limited. New horizontal drilling and fracture stimulation technology, available starting in early 21st century, resulted in a boom in Bakken production that continues to the present day. By January 2012 oil production rates and producing wells had rapidly increased reaching 480,706 barrels per day (approximately 3% of United States consumption) from 3,377 wells (Figure 1.1). Technically recoverable oil in the Bakken Formation was estimated at 3.0 to 4.3 billion barrels (680,000,000 m³), with a mean of 3.65 billion (USGS, 2008). Various other estimates place the total reserves, recoverable and non-recoverable with today's technology from the Bakken and related units (e.g., Three Forks Formation and “Sanish”), at up to 24 billion barrels (LeFever and Helms, 2006; Helms and Canton, 2010). However, all estimates of total reserves, recoverable and non-recoverable are currently under review and could increase.

Oil was first discovered in North Dakota on April 4, 1951 when Amerada Petroleum Corporation drilled the Clarence Iverson #1, which produced from the Silurian Interlake Formation. This discovery lead to a 75 mile long trend before the first dry hole was drilled. The wells produced oil and gas from the Cambrian through Mississippian age rocks (Gerhard, et al., 1988).

Figure 1.1: Daily oil production and number of producing wells in the Bakken Formation of North Dakota from 1953 until January 2012. Data is from North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, Historical monthly Bakken Oil Production, at <https://www.dmr.nd.gov/oilgas/stats/historicalbakkenoilstats.pdf>.

The Bakken Formation has been considered a major source for oil produced in the Williston Basin. Early research suggested that the Bakken was capable of generating 10 billion barrels ($1.6 \times 10^9 \text{ m}^3$) of oil (BBbls) (Dow, 1974). Further refinement to this number has been completed over the years (Figure 1.2). Schmoker and Hester (1983) estimated the Bakken to contain 132 BBbls of oil in North Dakota and Montana alone. From Leigh Price's unpublished work in 1999 the estimated total amount of oil contained in the Bakken shale ranged from 271 billion to 503 billion barrels ($8.00 \times 10^{10} \text{ m}^3$), with a mean of 413 billion barrels ($6.57 \times 10^{10} \text{ m}^3$).

Current estimates of the amount of hydrocarbons generated by the Bakken petroleum system are based on computer models with existing Bakken data supplied by the North Dakota Geological Survey and Oil and Gas Division. A study by Flannery and Kraus (2006) estimated the amount of oil generated in the Bakken to be 300 BBbls. A report in 2008 issued by the state of North Dakota Department of Mineral Resources revealed that the North Dakota portion of the Bakken contained 167 billion barrels ($2.66 \times 10^{10} \text{ m}^3$) of oil.

Figure 1.2: History of reserve estimates according to Bakken authors cited in the text as depicted in a bubble chart display. Data is from the Bakken Decision Support System (BDSS) at <http://www.undeerc.org/bakken/oilproduction.aspx>

It is apparent the amount of oil generated in the Bakken Formation is impressive but uncertainties about recovery rates remain. Leigh Price (1999, unpublished) had an optimistic forecast of about 50% of the oil in the Bakken being technically recoverable. Headington Oil

Company revealed that in Richland County, Montana they have achieved a primary recovery factor of 18%. The numbers in North Dakota are smaller, ranging between 3 to 10%, as presented by the North Dakota Industrial Commission Oil and Gas hearings in 2008 (Helms and Canton, 2010).

The lower recovery rates in North Dakota portion of the basin may have led to the first horizontal Bakken well being drilled in the state. Meridian Oil, Inc. drilled and completed the first horizontal well in the Bakken Formation, the #33-11 MOI, on September 25, 1987. The decision to drill horizontally was made after the vertical hole was drilled and the formation was determined to be too tight and lacked sufficient permeability. Meridian opted to go back up hole and drill horizontally. The well was completed in the upper Bakken shale and produced 258 BOPD and 299 thousand cubic feet (MCF) of gas. The decline curve for the #33-11 MOI was stable for the first two years and ultimately produced 357,671 BO and 6,381 barrels of water (BW) through December 2003 (North Dakota Word Press, December, 2011). The success of producing oil from the Bakken formation is what has spurred operators to drill more wells into the interval, and can be attributed to the application of horizontal drilling methods and the advancement of hydraulic fracture stimulation technology.

Background

The Williston basin, an intracratonic sedimentary basin, occupies portions of North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba (Pitman, Price and LeFever, 2001) (Figure 1.3). It has been suggested that origin of the Williston Basin can be tied to Precambrian left-lateral shear systems that also affected the Central Rocky mountains (Gerhard,

et al., 1987). The stratigraphic record in the study area formed in a structurally uncomplicated basin under mostly eustatic controlled depositional conditions.

The Bakken Formation can be divided into three main units defined by lithology; the middle member, a mixed lithology of dolomitic siltstone, calcareous mudstone, oolitic sandstone bounded by two, seemingly homogeneous, organic-rich shale units (Figure 1.4). The upper and lower shale members in the Bakken Formation have high total organic carbon values (maximum TOC recorded in the upper shale is 35%) and are believed to have generated hydrocarbons found in reservoirs located stratigraphically above and below the Bakken Formation (Meissner, 1978); (Williams, 1974). The identification and closer analysis of facies within the shale intervals in the Bakken Formation have been largely neglected in the scientific community. It is the goal of this research to better understand specific properties that controlled depositional facies in the upper Bakken shale and the lower Bakken shale members.

Modified from Pitman et al., 2001

Figure 1.3: Location of the Williston basin and approximate study area within the North Dakota portion.

Study Area

Shown in Figure 1.5 is a map of the study area showing wells with digital log ascii standard (LAS) well logs indicated by yellow cross hatches and the top structure of the Three Forks Formation. The area encompasses approximately 3200 square kilometers (roughly 2,000 square miles). Approximately 100 wells were correlated using LAS logs for better resolution due to the anomalously high gamma-ray values through the shale intervals of the Bakken Formation.

Modified from: Webster, 1984

Figure 1.4: Detailed stratigraphic column of the Bakken Formation and associated units and north-south schematic cross-section (Webster, 1984). The sandstone at the top of the Three Forks Formation is often referred to as the “Sanish” (red arrow).

Depositional environments in the Bakken Formation have been disputed in the past for the upper and lower shale members, however there is a strong consensus in favor of a deep marine environment (>200 meters) with little to no circulation creating a stratified water column (Webster, 1984). This bottom water anoxia in an epicontinental sea occurred as a result of two episodes of transgression during Late Devonian and Early Mississippian (Meissner, 1978; Webster, 1984; Nordeng, 2009;). The Lower Bakken shale was deposited during the Late Devonian rise in sea level, while the Upper Bakken shale was deposited during the Early Mississippian rise in sea level (Smith & Bustin, 2000; LeFever, 1991). However, it is also suggested that small-scale, regional variations in sea level existed in the Williston basin during the Late Devonian and Early Mississippian affecting depositional conditions (Smith and Bustin, 2000).

Figure 1.5: The map shows the top structure of the Three Forks Formation underlying the Bakken Formation along with the Nesson (A) and Antelope (B) structural features. Also displayed is the study area outlined with the gray dashed line and the wells containing LAS well log data indicated by yellow cross hatches.

In contrast to the shale members, the Middle member was deposited rapidly, when the epicontinental sea was retreating at the close of the Devonian period resulting in relatively shallow-water levels (depth less than 10 meters) and episodic high-energy conditions in the Williston basin (Smith and Bustin, 2000). The contacts between the lower Bakken shale and the Middle member as well as the upper Bakken shale and the overlying limestone of the Lodgepole

Formation reflect widespread regressions of the epicontinental sea, which affected the entire North American interior (Smith and Bustin, 2000).

Research Claim

The Bakken Formation has been an important focus of research for many scientists for several decades. Determining the best place to drill can only be done successfully when many parameters are taken into account. Unconventional shale drilling techniques require more attention and examination of the reservoir. An important goal in this research is to contribute an interpretation of depositional facies and processes within the shale members of the Bakken Formation, which may aid exploration efforts.

The vast majority of the sedimentary record across the globe is composed of shale, yet the understanding of these bodies of rock and the reconstruction of their depositional environments are just recently falling under critical scrutiny. There are many problems to consider with respect to shale deposition. What roles do water depth and water chemistry play on deposition? How do sediment interparticle cohesion and the degree of consolidation affect shale deposition? Does the deposition of shale automatically correlate to greater water depths, lower current velocity, and lower wave activity? How is the preservation of organic matter in the sedimentary column affected by rapid changes in sea level?

The identification and closer analysis of facies within the shale intervals in the Bakken Formation have been largely neglected in the scientific community. It is the goal of this research to better understand specific properties that controlled depositional facies in the upper Bakken shale member and the lower Bakken shale member and relate these properties to known geologic

events. Hydrocarbon exploration may benefit from more consideration of the effects of relative sea level and the role it played in the origin of depositional sequences.

Dataset & Methodology

The majority of data for this project was acquired through the North Dakota Oil and Gas Commission (NDOGC) database and TGS well log services. Scout ticket general well data was imported from a spreadsheet provided by the NDOGC. Raster logs were available through TGS well log services as smart-rasters, which are raster formats with ascii files containing depth registration, ready to import into existing projects. Well logs (raster and digital), core photos, well reports, production data, deviated well-bore surveys, formation tops, etc. are available for wells drilled in North Dakota through the NDOGC. Tops were picked for wells in and around the study area for approximately 100 wells (see Appendix F).

Cores were examined previously for six wells to identify fractures in the Bakken Formation. This was done with only marginal success because most fractures existing in the Bakken Formation are in the middle member and are horizontal micro-fractures (Warner, 2010). Seven cores were described for the interval through the top of the Three Forks Formation to the top of the Bakken Formation (see Appendix B). Core photos for the study wells are provided in Appendix C as well.

Research Methods

Wire-line digital and raster logs were used to correlate identifiable parasequences of the Bakken shale members as well as define intervals above and below the unit including the Sanish sandstone, the top of the Three Forks Formation and the top of the Lodgepole Formation. Regional well log correlation for the Bakken interval was completed using approximately 100

digital well logs distributed throughout the study area and used to construct a series of cross-sections (Appendix E). Petrophysical calculations such as RHOMaa-Umaa plots and lithology solutions were used to constrain facies within the separate Bakken units (Appendix D).

The outstanding production of oil from the Bakken Formation can be attributed to reservoir characteristics such as over-pressurization, significant thermal maturity of the source rocks and complex migration paths (Meissner, 1978; Warner, 2010). However, the primary focus of this research is to interpret the depositional systems based on stratigraphic sequence, sedimentologic, lithologic, and paleontologic properties primarily with the use of digital well logs and cored sections. It is a goal of this research that recognition of depositional sequences will help to improve the focus of exploration and development techniques.

To evaluate the inferred rapid changes in base level, and the influence of depositional environments on reservoir parameters and overall production, log characteristics were tied to core for seven wells within the study area (Appendices A-C). Digital well log curves were especially helpful in the delineation of facies within the shale intervals of the Bakken Formation. Description of cored intervals revealed less useful information due to the homogeneous visual appearance of the Bakken shale intervals.

Research Contributions

The primary contributions of this study are:

- 1) Identification of depositional facies of the Bakken Formation with special attention to the upper and lower shale members.
- 2) Demonstration that the Bakken shale intervals may be broken down into separate units with the use of digital well log data.

- 3) The identified units are mapped throughout the study area and provide insight to the deposition of the Bakken shale units.

Chapter 2: Basin History & Lithostratigraphy

The history of the Williston basin dates back to the Precambrian (1.8-1.9 billion years ago) during which the Trans-Hudson orogeny was the culminating event of the Paleoproterozoic Laurentian assembly. The Trans-Hudson orogeny resulted in the collision of Superior craton of eastern Canada with the Hearne craton in northern Saskatchewan and the Wyoming craton of the western United States (Figure 2.1). This activity created a weak zone below the present-day Williston Basin, which lead to regional sagging and formation of accommodation space. Deposition of sediments began in the Cambrian; however increased subsidence and sedimentation took place during the Ordovician and continued through the Devonian. During the Taconic orogeny the Williston basin began to sag and became a structural depression. A broad, basinal shelf toward the west and northwest area of Montana existed which varied from the bowl shaped depression of western North Dakota (Gerhard et al., 1991).

During the Late Devonian reactivation of basement block-faulting in the interior of the Williston basin, and uplift of the Sweetgrass arch resulted in a restricted east-west seaway where the Bakken Formation was deposited. The Sweetgrass arch was active during several stages of geologic time, thus becoming an important control on basin development. At the same time, the northern and eastern margins of the Williston basin were redefined by the formation of the Transcontinental, Severn, and Wisconsin arches. The tectonic activity of the Acadian orogeny to the east, the Antler orogeny to the west, and the Ellesmere orogeny to the north produced compressive stresses which resulted in changes in base level, fluctuation of clastic input, and periodic adjustment of interior platforms (Smith & Bustin, 2000).

Figure 2.1 Trans-Hudson orogeny and the Superior craton of eastern Canada, the Hearne craton of northern Saskatchewan, and the Wyoming craton of the western United States. Red star indicates approximate study area. Modified from US Government, Wikipedia images (public domain).

The North Dakota portion of the Williston basin is characterized by a semi-circular structure and is one of two depocenters, which formed during Silurian and Devonian. The Elbow sub-basin is located in west-central Saskatchewan and is not as structurally deep as the North Dakota sub-basin. The structural relief of the Williston basin is a result of the episodic reactivation of basement faults during the Ordovician, Silurian, and Devonian; in addition to salt

dissolution of the Prairie evaporite and a significant erosional event during the Late Devonian drop in relative sea level (Smith & Bustin, 1997). Evidence of multi-stage salt dissolution is commonly observed where there is negative bathymetry and the Middle and Upper Devonian salt beds are either very thin or absent (Kent & Christopher, 2008).

The uplift of the ancestral Rocky Mountains during the Mississippian caused a temporary shift of the depocenter toward the west. At this time a sequence of thick, post-Bakken strata was deposited along the western margin (present day eastern Montana) and into the original depocenter of western North Dakota (Gerhard et al, 1987; Pitman, et al., 2001; LeFever et al. 1991). Sedimentation during the Triassic returned the original depocenter to present day northwestern North Dakota. During the Cretaceous, reactivation of basement faults coinciding with the Laramide orogeny shed an interval of clastics into the basin. The north-south trending epicontinental seaway formed during the Late Devonian was modified to the present day orientation of the northwest-southeast Williston basin (Meissner, 1978, Pitman et al., 2001) (Figure 2.2).

Figure 2.2: Map of regional Paleogeography during the Late Devonian from Ron Blakey with the approximate study area indicated by a red star.

The complex patterns of sediment thickening, thinning, onlapping, offlapping, and truncation throughout the Williston Basin is the product of subsidence and erosional events, in addition to the distal uplift of flanking arches and mountain building (Kent & Christopher, 2008). Multiple subsidence events which led to erosion are depicted in the burial history graph in Figure 2.3. This graph was constructed using *Genesis*© basin modeling software.

Figure 2.3: Burial history graph shows two increases in the rate of subsidence; one during the Late Devonian into the Mississippian during basement block faulting. Also another increase in subsidence occurred during the Early Cretaceous when basement faults were reactivated.

The onlapping of the Bakken interval is evident along the basin edges as well as on the eastern flank of the Nesson anticline, a positive structural feature, which was in place during Late Devonian and Early Mississippian. The Nesson anticline, in addition to the lesser positive feature of the Antelope anticline, plays a very important role in the success of conventional oil fields in the Williston basin. These features create fractures and allow greater permeability in the rock (Meissner, 1978). The Williston basin edge stratigraphic traps are correlated to success in fields such as the Parshall field, where the stratal packages are truncated and pinched out.

Figure 2.4 Cross-section illustrating the onlapping relationship of the Bakken members.

Lithostratigraphy

In the North Dakota portion of the Williston basin, a complete Paleozoic stratigraphic column exists. The regional depositional history of this portion of the basin is characterized by fluctuating sea levels and overall, a sediment starved basin (Lineback, 1982). Intervals of shale, carbonate, and evaporite dominate the stratigraphic record with the depositional history beginning in the Cambrian. These continental-scale packages represent fluctuations in sea-level and subsequent sedimentation and disconformities (Gerhard et al., 1991). The sediments in the Williston basin are characterized by cyclic transgressions and regressions repetitively depositing clastics and carbonates (LeFever et al., 1991).

The Bakken Formation was deposited during the late Devonian and early Mississippian and reaches a maximum thickness of 145 feet (44 meters) in the center of the Williston basin. The Bakken thins towards the eastern margins of the basin. Within the Bakken Formation, an onlapping relationship is observed with each successively younger member extending further

towards the basin edges than its stratigraphically older member (Webster, 1982). This pattern is observed from the lower Bakken member to the upper Bakken member (Figure 2.4)

Figure 2.5: Stratigraphic column displaying the Bakken Formation, the overlying Madison Group, the underlying Three Forks, and Nisku formations.

Three Forks Formation

The Three Forks was deposited during the Late Devonian as a result of sea-level fall when the deposition of carbonate intervals was dominant across the Williston basin. The Three Forks Formation is characterized by a silty dolomite lithology and reaches a maximum thickness of about 250 feet (76 meters) in the center of the basin (Thrasher, 1985). The Three Forks Formation varies across the basin from silty dolomite to gray anhydrite however, the apple green (sometimes red) mud laminae are distinctive (Sesack, 2011).

The basal Bakken silstone unconformably overlies the Three Forks Formation with an onlapping facies in between (Sanish” sandstone). During the Late Devonian, a drop in relative

sea level resulted in the erosion and reworking of sediment that affected the most of the cratonic platform and the Williston basin. However, the deepest portions of the basin experienced little to no reworking during this time. The unconformity that occurs at the top of the Three Forks is recorded across the Williston basin and is related to the Acadian unconformity (Smith & Bustin, 2000).

“Sanish” Sandstone

The “Sanish” sandstone occurs erratically at the top of the Three Forks Formation, and where present is highly productive. The “Sanish” consists of an argillaceous siltstone to sandstone, with a dolomitic component, and is characterized by *Skolithos* burrows, storm wave deposits, and in some cases displays ripples or laminations (LeFever, 2008). This sandstone facies is interpreted to have been deposited in a near-shore or beach marine environment at a time when much of the Williston basin floor was briefly exposed (Smith & Bustin, 2000).

Located stratigraphically above the “Sanish” interval is the basal Bakken silty shale. Both the basal Bakken unit and the “Sanish” sandstone unit are interpreted to have been deposited in an epicontinental sea under shallow-water, high-energy conditions (< 10 meters depth), prior to a major sea-level transgression at the close of the Devonian (Sesack, 2011).

Basal Bakken siltstone

The basal Bakken is a dull brown to dark gray siltstone with laminated shale partings and is distinguished from the lower Bakken “organic” interval through powdering with a mortar and pestle, and aid of the gamma ray tool. The basal Bakken siltstone averages an 8.2% TOC level, with the lowest value recorded at 7.7% and the highest recorded values being 8.7% (Sesack, 2011). This interval directly overlies the “Sanish” sandstone facies, where present.

Lower Bakken Member

The lower Bakken shale member is a black, organic-rich, hemipelagic, well-indurated, and finely laminated shale. In the upper and lower shale units total organic carbon (TOC) averages 12% (Smith & Bustin, 1997). The organic material within the shale consists of almost entirely marine algal remains (Smith & Bustin, 2000). Abundant pyrite occurs as finely disseminated particles but some form thin laminae, nodules, and concretions. Phosphatic fragments are present occasionally, as well as a coarse lag deposit towards the base of the lower member (LeFever et al., 1991). Lag deposits occur more frequently in the lower Bakken member than they do in the upper Bakken shale member (Huber, 1986).

The uppermost lower Bakken, “organic, black” shale onlaps with the underlying lower Bakken “silty” shale in some areas of the basin; and in others an erosional surface exists, marking a possible sequence boundary (Webster, 1982). The contact of the lower Bakken shale member and the Middle Bakken is interpreted as a sequence boundary which varies from gradational to sharp in nature (Pitman et al., 2001). In portions of the basin, an unconformity between the lower Bakken shale member and the Middle Bakken was reported (Karma, 1991).

Middle Bakken Member

The middle member of the Bakken Formation is a mixed lithology composed of light-gray to medium-dark-gray dolomitic siltstone, inter-bedded with thin calcareous, sometimes oolitic sandstone. Oolites are present in the sandstone interval of the middle member in some portions of the study area (Warner, 2011).

Lesser amounts of shale, dolostone, and limestone are present as well (Webster, 1984; Thrasher, 1985). Lithofacies have been previously identified within the Middle Member based

on lithology, mineralogy, sedimentary structures, and interpreted depositional processes (LeFever et al., 1991; Pittman et al., 2001; Smith & Bustin, 2000) in an attempt to better constrain facies relationships within this interval.

The siltstone and sandstone intervals within the middle member are typically massive to coarsely-bedded with planar cross-bedding and trough cross-bedded sedimentary structures. The rock is well sorted with evidence of frequent bioturbation and disturbed bedding planes, such as micro-faults and flow structures (Pitman et al., 2001; Warner, 2010). Fossils in the middle member are primarily found in the lowermost portion of the interval and include remains of brachiopods, gastropods, pelmatozoan fragments and various trace fossils.

The middle member ranges from 45-150 feet (15-45 meters) thick throughout the Williston basin and is composed of successions of shallow marine siltstone, carbonate, and clastics indicating fluctuations of sedimentation, energy levels, water chemistry, and water depth. It has been interpreted to have been deposited as a result of dramatic sea-level drop at the close of the Devonian. During this time the major epicontinental sea was in a state of regression with water depths no greater than 33 feet (10 meters) and high-energy wave action was common (Webster, 1984).

Figure 2.6: Lithofacies of the Middle member of the Bakken Formation as defined by Pitman, Price and LeFever (2001).

Upper Bakken Member

The upper Bakken shale member is, lithologically, very similar to the lower Bakken shale member. It consists of black, organic-rich, well indurated, hemipelagic shale with a common constituent of pyrite visually obvious throughout the interval (Schmoker & Hester, 1983). Organic matter in the upper Bakken shale member is primarily derived from marine algal remains (Smith & Bustin, 2000).

Differences between the upper Bakken member and the lower Bakken member are that the upper Bakken member is more organic-rich and lacks any gray, silty shale beds and thin limestone laminations (Pitman et al., 2001). Also the upper Bakken member is more fossiliferous than the lower Bakken member, containing abundant Chondrites burrows, conodonts, and Tasmanites (Webster, 1984).

Lodgepole Formation

The Lodgepole Formation, stratigraphically above the Bakken Formation, is a thick carbonate unit that serves as a competent seal in most portions of the basin. Lithologically, the Lodgepole is characterized by dense lime wackestone with some dark-gray shale partings close to the contact of the upper Bakken shale (Smith & Bustin, 2000). It is the basal unit of the Mississippian Madison Group and was deposited as a result of a dramatic drop in sea-level at the beginning of the Mississippian.

Chapter 3: Petroleum Geology, Related Work &

Interpretation Models

Organics & Hydrocarbon Migration

Several important factors affect the deposition and accumulation of an exceptionally good source rock or shale. Conditions such as high primary productivity, sea-level rise events, sediment starvation, and microbial activity all play key roles in the organic carbon and preservation of organic-rich shale (Sageman et al., 2003).

Organic matter in both Bakken shale members was primarily derived from marine, algal or phytoplanktonic material (Webster, 1984). Kerogen typing in the Bakken shale members is dominated by Type I and Type II kerogen material and has a high hydrogen content, making it an excellent petroleum source rock (Webster, 1984).

In thin sections, the organic matter is well distributed in the shale and not concentrated into laminations, as is characteristic of other source rocks (Meissner, 1978). The lower Bakken shale member has a recorded maximum TOC (total organic carbon) of 20% and an average TOC of 8%. The upper Bakken shale member has a maximum TOC of 35% with an average TOC of 8% (Smith & Bustin, 1997). Over certain portions of the basin the TOC may average between 25-28% of which, according to ROCK-EVAL analyses, up to 58% is capable of hydrocarbon generation (Price, 2000).

The Bakken Formation in the Williston basin, as well as other formations, has produced large amounts of oil from wells drilled on structural highs where there are clear migration paths via tensional fractures. However, there are limits in spatial distribution of these natural fractures

associated with fluid migration potential in the hydrocarbon system of the Bakken Formation. The Nesson and Antelope structural features play an important role in the dynamics of fluid expulsion from the Bakken Formation into overlying reservoirs. Price and LeFever (1994) proposed that in the absence of such faulting and fracturing the Bakken is a closed fluid system in which hydrocarbons remain in the Bakken petroleum system. However, if permeable carrier beds exist adjacent to the source rocks then lateral migration can occur.

The expulsion and migration of oil from the Bakken Formation to overlying reservoirs has been debated at length (Price & LeFever, 1994; Price, 2000; Smith & Bustin, 2000; Warner, 2010). Recent geochemical evaluation of Bakken reservoir oil and oil produced from overlying Mississippian carbonate intervals reveal two separate families sourcing these reservoirs. The study revealed the Bakken sourced oils to be more naphthenic, less paraffinic (less waxy), and having different n-paraffin and isoprenoid-hydrocarbon profiles (Price & LeFever, 1994). It is possible that the Mississippian carbonate units produce oil that is sourced from both the Bakken Formation shale units in addition to the shale source rocks throughout the Mississippian interval (Meissner, 1978, Webster, 1984, Schmoker & Hester, 1985).

Previous/Related Work

Several workers (Schmoker, 1996; Smith & Bustin, 1997; Pitman et al., 2001) have identified lithofacies in the middle member using well logs, core descriptions, petrographic, and geochemical analyses, etc. An example illustrating the lithofacies is shown in Figure 2.6. The lithologic variability in the middle member provoked workers of previous studies to better constrain the differences seen in the interval of the Bakken Formation. These variations in

lithology are directly related to reservoir properties such as porosity, permeability, fracture capability, and rock mechanics.

Smith & Bustin (2000) took a sequence stratigraphic approach to better understand depositional conditions during the Late Devonian and Early Mississippian deposition of the Bakken and the Exshaw formations. The Exshaw Formation was deposited in the Prophet trough and is correlative to the Bakken Formation. It consists of organic-rich, black shale underlying a carbonate mudstone, similar to the lower Bakken shale member and the middle member. The Williston basin and the Prophet trough were affected differently by fluctuations in relative sea level; however Smith & Bustin (2000) identified three systems tracts in the Bakken Formation and the Exshaw Formation. They were divided into: (1.) a transgressive systems tract (lower Bakken member), (2.) a lowstand systems tract (lowermost and middle portion of the Middle Member), (3.) and a second transgressive systems tract (uppermost Middle Member and the upper Bakken shale member) with the Lodgepole Formation overlying the Bakken being a part of the highstand systems tract.

Pitman, Price & LeFever (2001) identified lithofacies (Figure 2.6) in the middle member in an effort to tie them to reservoir quality. Drill core samples and geochemical analyses were used in combination with existing knowledge of the lithostratigraphy of the interval to define the lithofacies. An important finding of this work was that geologic controls on sandstone porosity and permeability in unconventional reservoir rocks are thermal maturity, framework grain composition and sorting (Thrasher, 1985; Karma & Parslow, 1989; LeFever et al., 1991; Pitman et al., 2001). Continued work to map the lithofacies and attempt to identify them in a vertical, as well as a lateral, framework was also performed (Pitman, Price & LeFever 2001).

Demaison & Moore (1980) mention three types of shale and their associated depositional environments. The common shale is homogeneous, shows evidence of bioturbation, contains abundant benthic fossil content, and siderite nodules. The common shale facies is deposited in well-oxygenated bottom waters. The restricted shale is poorly laminated with scattered calcareous concretions and burrows. This facies is deposited in oxygen depleted waters (0.5 ml/l). Lastly, the bituminous shale is finely laminated, contains pyritic concretions, little to no bioturbation, benthic fauna, or burrows (Demaison & Moore, 1980). The three facies of shale described above have been interpreted as the result of variations in the oxic-anoxic boundary within the water column. This boundary is controlled by the effects of relative sea-level which is governed by global climate patterns. This particular study relates to this research by raising important questions concerning the true depositional environments of black, organic-rich shale.

Webster (1986) performed a stratigraphic and geochemical study to investigate the properties of the shale intervals of the Bakken Formation to better understand depositional conditions, post-burial processes, and hydrocarbon potential. The shale intervals in the Bakken Formation were deposited in anoxic conditions, with a stratified water column, and restricted circulation. The presence of planktonic algal spores (tasmanites), fish remains, cephalopods, ostracods, conodonts, and inarticulate brachiopod in combination to the planar, laminated nature of the shale in the Bakken Formation suggested they were deposited in a marine environment below wave base. It also may be important to note that Webster (1986) recommended perforating the shale units in addition to the Middle Member where fractured.

Meissner (1978) offered an explanation of how petrophysical behavior, oil generation and expulsion mechanisms, and thermal maturity of the shale in the Bakken Formation contribute to an exploration play. It was interpreted that generated oil was expelled from the rock as a

continuous, porosity saturating phase through oil-wet rock matrix, where anomalous fluid pressures introduced by compaction processes were present. The research conducted by Meissner in 1978 led to speculative conclusions regarding the relationship between source rock maturity, hydrocarbon generation mechanisms, geo-pressures, and resulting fractures, however these relationships are crucial to better understand unconventional hydrocarbon plays today.

Figure 3.1: Formation pressure versus depth displaying the over-pressurization of the Bakken interval from Meissner (1978).

Based on the focus of previous work completed on the Bakken Formation the facies within the middle member are better understood than the underlying and overlying shale members. Despite the diversity of studies that exist, a few key items about the Bakken shale intervals remain commonly accepted. First, deposition of black, organic-rich shale such the

upper and lower shale members is deposited in conditions where water depth exceeds 100-200 meters (300-600 feet) and the deposition of a shale source rock requires a completely stratified water column (Smith & Bustin, 2000; Webster, 1984). This eliminates the possibility of bottom water mixing or “traction”. Second, the facies in the Bakken shale intervals are indistinguishable based on petrophysical characteristics. Third, many authors speculate that both the upper Bakken member and the lower Bakken member had identical depositional environments and neither possess distinct properties (Meissner, 1978; Webster, 1984; Smith & Bustin, 2000). This study attempts to investigate these preconceptions in an attempt to better understand effects of ancient depositional events on the components of the Bakken shale intervals seen in cored section and in well logs today.

Interpretation Models

Transgressive-regressive (T-R) Sequences

A common approach to depositional modeling is done using the sequence stratigraphic transgressive-regressive model (T-R) (Figure 3.2). This model defines sequences, which are bounded by composite surfaces that can include subaerial unconformities or their correlative conformities (Van Wagoner et al., 1990; Embry, 2002). These depositional sequences are relative to the T-R curve and record cycles of relative sea level drop or rise resulting in a predictable internal structure of surfaces and systems tracts (Van Wagoner et al., 1990; Embry, 2002). The transgressive-regressive model allows interpretation of subaerial unconformities to be recognized as sequence boundaries and their respective distal, basinward correlative conformities (Embry, 2002).

T-R model vs. Type I and Type II Sequence Stratigraphy

Type I and Type II sequence stratigraphic models are also popular methods in identifying depositional sequences however this particular model uses the location of the sea floor at the start and end of base level fall. The T-R model applies the correlative conformity sequence boundary using the MRS (maximum regressive surface) when defining the depositional sequences (Embry, 2002). Using the MRS allows the interpreter to define the transition from transgression to regression within the cyclic framework without requiring the defined surface (MRS) to coincide with the fall of base level. MRS records the change from prograding strata (shallowing upward) below to retrograding strata (deepening upward) above (Catuneanu, 2002). The T-R model was used in this study to better reveal the transition from transgressive systems tracts to regressive systems tract.

Figure 3.2: The schematic above illustrates base level changes, transgressive-regressive events, and the associated systems tracts. (Modified from Embry, 2002)

Parasequences

Parasequences are defined by relatively conformable surfaces of genetically related beds or bed-sets bounded by marine flooding surfaces (VanWagoner, 1990; Catuneanu, 2002). In addition to these defining characteristics, most parasequences are asymmetrical shallowing-upward sedimentary cycles. However, parasequences may be interpreted several ways and do not necessarily reflect the entire vertical succession of a complete shallowing upward facies. Commonly the parasequences will only display a portion of the shallowing upward facies (VanWagoner, 1990).

Facies within a parasequence are commonly deposited in lateral continuity to one another. In other words, the order in which a particular suite of facies occurs is predictable. A parasequence represents an episode of progradation, that is, the seaward migration of a shoreline without a recognizable unconformity (Catuneanu, 2002). This seaward, shoreline movement produces the familiar shallowing-upward succession observed within many parasequence suites (Figure 3.3). The upper and lower Bakken shale members display shallowing-upward patterns, which can be recognized in digital well log signatures (i.e., increased density and decreased gamma ray) and supported by the lithologic and sedimentologic properties observed in core.

Figure 3.3: Facies within a typical parasequence succession and the associated depositional environments. (Van Wagoner, 1990)

Facies and Petrofacies

Recognition of facies and compartmentalizing them into units provides greater insight into the depositional environments in which the interval was deposited. The petrofacies concept is commonly used for the analysis of rock units based on their petrophysical as opposed to their form, boundaries or relationship to other rock units. Petrofacies, like sequence stratigraphic units, have both lateral (spatial) and vertical (time) components, which are both important in understanding depositional environments.

Walther's Law of Facies states that vertical successions of facies reflect lateral changes in the physical environment in which a sedimentary unit has been deposited. Conversely, it states that when a depositional environment "migrates" laterally, sediments of one depositional environment come to lie on top of another. This is observed in the vertical stratigraphic succession that is common in marine, T-R sequences (VanWagoner, 1990).

Previous work has concentrated on defining facies in the middle member of the Bakken Formation, using core descriptions and analysis as well as using well log characteristics to make interpretations on rock composition and depositional settings (Pitman, Price and LeFever, 2001; LeFever, 2008). Overall, the facies within the Bakken Formation are interpreted to exhibit large-scale cyclic transgressive and regressive patterns that were influenced by the change in relative sea-level. The entire Bakken interval is divided into a transgressive systems tract (lower Bakken), a lowstand or regressive systems tract (middle Bakken), and a transgressive systems tract (upper Bakken) (Smith & Bustin, 2000) (Figure 4.1). However, the goal of this study is to focus on the lower and upper Bakken shale members and to define and map internal shale facies.

The identification and definition of these facies have important implications for exploration and production from the Bakken Formation. For example the sandstone facies possesses good reservoir properties such as greater porosity and permeability than the surrounding tight rock. The more calcareous facies represent exceptional types of lithology to target during horizontal drilling and fracture stimulation practices because of the brittleness of the rock.

Chapter 4: Integrated Log and Core Analysis

Identification of facies within the Bakken Formation was undertaken by integrating well logs, core descriptions and lithology and mineralogy plots. The latter two methods were completed for a small number of wells, and provide only limited contributions to the overall results. Petrophysical evaluation using log ascii standard (LAS) digital well log suites provided the most useful information, thus making it the dominant approach in delineating the facies within the Bakken Formation.

Landmark Geographix® subsurface modeling software was used to correlate stratigraphic units and create subsurface structure and isopach maps. Correlation of stratigraphic units was conducted using the *CrossSection*® module. Isopach maps of the stratigraphic units as well as gross isopach maps of the individual shale members of the Bakken Formation were constructed using the *Landmark* module *GeoAtlas*®. *Landmark Prizm*® was used for enhanced well log analysis and to refine the well log display. *WellBase*® and *QueryBuilder*®, two additional modules within *Landmark Geographix*®, provided tools for data storage, imports, exports and other manipulations.

Well Log Characterization and Definition of Units

Petrophysical evaluation involved the use of digital well log curves including gamma ray, density, neutron, and resistivity logs as well as the photo-electric curve. Stratigraphic units including units in the Bakken Formation and overlying (Lodgepole Limestone) and underlying (Three Forks) formations were correlated across the study area. Special attention was focused on defining units in the lower and upper shale members of the Bakken Formation. Gamma ray and density curves were the two most important log curves used during correlation. The gamma ray

curve provides information regarding lithology, organic richness, and stacking patterns. The density curve provides information regarding the mineralogy and lithology. Depending on the logging tool response of the density curve, it is possible to delineate clay, carbonate and silica richness throughout the intervals of interest.

Petrophysical parameters used to define the units are listed in Table 4.1. Recognition and correlation of the stratigraphic units and subdivision of the Bakken shale intervals required the use of LAS logs that could be rescaled due to the gamma ray exceeding the standard scale of 0-200 API units on the raster log images. Typically, gamma ray LAS logs were rescaled to a 0 to 800 API units (Figure 4.1). The surfaces used to define units in the lower and upper Bakken shale units were identified by relatively low gamma-ray and relatively high density values representing regressive surfaces (increased carbonate -2.71 grams/cm³ or quartz – 2.65gm/cm³ volume as compared to decreased organic material - 1.1to 1.3 gm/cm³). Subunits within the Bakken Formation are based primarily on the gamma ray, neutron porosity, and density curves. Beginning with the Basal Bakken siltstone, the units are discussed in stratigraphic order from oldest to youngest units in the Bakken Formation.

Formation/Unit	Gamma Ray (API)	Density/Neutron gm/cm³ - %	Resistivity Ohm-meters	PhotoElectric Barns/Electron
Lodgepole Formation	10-40	2.7 and 0 Track each other	Moderate ~100	4.5
Upper Bakken Unit 3	300-450	2.25 and 40 Neut. > Den.	High	3.3-3.5
Upper Bakken Unit 2	300-550	2.5 and 35 Neut. > Den.	High	2.8-3
Upper Bakken Unit 1	350-650	2.4 and 35 Neut. > Den.	High	2.7-3.2
Middle Member Unit 5	30-90	2.6 and 10 Track each other	Variable	3-4.2
Middle Member Unit 4	25-50	2.6 and 10 Track each other	Variable	3.5-4.2
Middle Member Unit 3	30-80	2.6 and 10 Track each other	Variable	3-3.5
Middle Member Unit 2	30-80	2.6 and 10 Track each other	Variable	2.9-3.2
Middle Member Unit 1	30-80	2.6 and 10 Track each other	Variable	3-4
Lower Bakken Unit 3	300-700	2.25 and 40 Neut. > Den.	High	3.3-3.8
Lower Bakken Unit 2	300- >800	2.5 and 35 Neut. > Den.	High	2.5-3
Lower Bakken Unit 1	300-600	2.25 and 40 Neut. > Den.	High	3.4-4.5
Basal Bakken Siltstone	200-300	2.6 and 25 Neut. > Den.	Low/Variable	2.8-3.2
Three Forks Formation	30-80	2.6 and 10 Neut. > Den.	Variable	3.2
Table 4.1 Petrophysical parameters used to define the interpreted subunits in the Bakken Formation as well the overlying Lodgepole Formation and underlying Three Forks Formation.				

Basal Bakken siltstone

The first phase of lower Bakken deposition is the basal Bakken siltstone. It is present throughout the basin center and is intermediate in terms of petrophysical parameters between the Three Forks Formation and the shale of the lower Bakken Formation. The basal Bakken siltstone is defined by a lower gamma ray (200-300 API units) and lower resistivity (1-75 Ohm-

meters) signature than the overlying organic interval of the lower Bakken shale member (also Figure 4.2). The gamma ray curve reads around 150-170 API units which contrasts sharply with the overlying, more organic, lower Bakken shale member (300-600 API units). It is also easily discernible from the underlying Three Forks Formation (30-60 API units) using the gamma ray curve. Bulk density and neutron porosity read lower than the overlying, more organic, lower Bakken shale interval.

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Figure 4.2: Well log display of the lower Bakken units, the basal Bakken, and the top of the Three Forks. The basal Bakken siltstone is separated from the lower Bakken shale units by a flooding surface at the top of the interval (dashed line). Regressive surfaces and unit boundaries within the lower Bakken shale member are indicated by local gamma-ray minimums and local density maximums (dashed lines with arrows).

Lower Bakken shale

Above the basal Bakken siltstone, the lower Bakken shale has three units that are identified based on gamma ray, bulk density, neutron porosity and photo-electric curves (Figure 4.2). A maximum flooding surface (labeled as MFS within the yellow highlight in Figure 4.2) is interpreted approximately half way up the lower Bakken shale member at a gamma-ray maximum and/or bulk density minimum and a PE minimum. This interval is bound by the lowermost regressive surface and an uppermost maximum regressive surface (labeled as MRS within the yellow highlight in Figure 4.2), which is defined by a local gamma-ray minimum, density maximum, and PE increase (Figure 4.2). At the MRS the PE curve spikes and the neutron porosity and the bulk density track one another indicating that the interval is carbonate-rich. The lowermost and the uppermost regressive surfaces have a bulk density that reads higher than through the maximum flooding surface interval.

Middle Bakken units

The units in the middle Bakken were defined using primarily the gamma ray and photo-electric curves (Figure 4.3). Definition of these units followed closely with what previous research has established (Thrasher, 1985; Karma & Parslow, 1989; LeFever et al., 1991). The neutron porosity curve and the bulk density curve were intermediately useful to distinguish Middle member unit 4 due to its high porosity and limestone content as indicated by a photoelectric index moving above 4.0 (Figure 4.3). Middle member unit 1 is characterized by a very calcareous siltstone with a photoelectric index moving towards 4.0. The overlying Middle member unit 2 is interbedded gray shale and siltstone with the occasional silty sandstone thin

bed. Middle member unit 3 has a very similar lithology and what sets these two facies apart is fossil content and sedimentary structures which is not obvious in well logs. Middle member unit 4 is a reservoir quality, calcareous sandstone. Middle member unit 5 is a dolomitic, massive grey siltstone. The contact of the middle member of the Bakken Formation, with the upper shale member is sharp in all the log curves.

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Figure 4.3: Middle member units were defined using primarily the gamma ray and photo-electric curves. Middle Member unit 1 is characterized by a very calcareous siltstone with a photoelectric index moving towards 4.0. The overlying Middle member unit 2 is interbedded gray shale and siltstone with the occasional silty sandstone thin bed. Middle member unit 3 has a very similar lithology and what sets these two facies apart is fossil content which is not obvious in well logs. Middle member unit 4 is a reservoir quality, calcareous sandstone. Middle member unit 5 is a dolomitic, massive grey siltstone.

Upper Bakken shale

The upper Bakken shale member is divided into units based on the vertical variation of the gamma ray, bulk density, neutron porosity, and photo-electric curves. Within the upper Bakken shale member two regressive surfaces are defined and interpreted at the inflection point of the gamma ray curve. The MFS (maximum flooding surface) within the upper Bakken is identified as a gamma ray maximum and density minimum. The first regressive surface is the MRS (maximum regressive surface and is indicated by a drop in the gamma-ray curve, a slight increase in the bulk density curve and a PE curve increase indicating a more carbonate-rich lithology. The overall trend from both the gamma-ray, density, and PE curves is an obvious shoaling upward pattern (Figure 4.4).

A composite sequence stratigraphic representation of the Bakken Formation (focusing on the shale members) is shown in Figure 4.5. These stratigraphic units in the Bakken Formation were correlated across the study area. As mentioned previously, maximum regressive surfaces are identified by low gamma-ray and resistivity values as well as high density values (increased carbonate or quartz volume). The maximum regressive surfaces are commonly located within intervals of carbonaceous material and/or thin limestone beds and are interpreted to be related to small drops in relative sea-level affecting the stratigraphic record. The maximum flooding surfaces were identified by gamma-ray maximums and a decrease in the neutron and bulk density curves which are interpreted to represent an increase in relative sea-level.

Figure 4.5: A composite sequence stratigraphic representation of the Bakken Formation using the transgressive-regressive depositional model in Figure 3.2 is displayed above. The small-scale regressive surfaces, maximum flooding surfaces and sequence boundaries are also displayed in this figure.

Core Descriptions

Core descriptions of the Bakken Formation were completed for seven wells at the North Dakota Geological Survey core library in Grand Forks, North Dakota. This particular core library is a warehouse that is open to the public and houses several hundreds of wells with core, which penetrates the Bakken interval.

The entire interval of the Bakken Formation was described from just above the contact of the upper Bakken shale member to the top of the Three Forks Formation. Properties that were characterized include, but are not limited to: rock color, lithology, sedimentary structures, bedding thickness, lamination, fossil content, and pyrite features. A Core Lab™ grain size comparator and a Wards™ 10X hand lens were used to aid in the identification of differing lithologies. Rock color was compared to a rock color chart produced by Munsell™ color. Hydrochloric acid was used to help determine the type of matrix, grain composition, and cement found in the study interval. Core descriptions for each well including lithologic, sedimentologic, and paleontologic observations were entered into *SedLog*® to create stratigraphic columns for each cored section (Figure 4.5 and Appendix B).

Facies differentiation for both the upper and lower shale intervals in the Bakken Formation was difficult upon visual examination of the core, and at best changes in color and reaction to the hydrochloric acid revealed subtle lithologic changes. Facies in the middle member of the Bakken Formation were easier to recognize.

Figure 4.6: Core description for the entire interval of the Bakken Formation for the Nesson State 42X-36 well.

Core observations

Core descriptions were a marginally useful method in supplementing well log correlation and providing data for interpretation of the separate units. Thin limestone beds, calcareous concretions, changes in grain size, and rock color were recorded however there was very little to no correlation to the log data. These characteristics (in addition to many more) suggest a change in depositional cycles. However, based on observations the shale intervals in the Bakken Formation appear homogeneous and precise stratigraphic unit delineation was difficult through the primary intervals of interest. Appendix B displays the study wells with the gamma ray posted next to the core description, however for reasons stated above no correlation of subunits was possible.

Basal Bakken siltstone

The basal Bakken siltstone appears to be a different lithology than the rest of the lower Bakken shale member both in well logs and in core. In core the basal Bakken siltstone varied from dark gray to brown shale, a mixed lithology of gray shale and siltstone with very little evidence of sedimentary structures. In addition to these two properties the basal Bakken has numerous thin calcareous beds. The cored interval for the Sakakawea well displays the contact of the lower Bakken shale and the basal Bakken siltstone (Figure 4.6). The basal Bakken did not possess the fissile nature that was observed in the overlying lower Bakken member. Delineation of the basal Bakken siltstone from the lower Bakken member was accomplished primarily by identifying changes in lithology and color. Towards the top of the basal Bakken siltstone facies localized calcareous beds exist and suggest a facies change into the lower Bakken shale member.

Figure 4.7: Gamma Ray curve, core photo, and core description for the Sakakawea 13X-35 well showing the basal Bakken siltstone and the lower Bakken shale member contact. The basal Bakken has more numerous thin, calcareous beds and displays, generally, a lighter gray color than the overlying dark, organic lower Bakken shale member.

Lower Bakken units

Delineating the separate units in the lower Bakken shale member with the use of cored intervals was attempted but due to the homogeneous appearance of the organic intervals this was not as valuable a method as hoped. However, there were signs of lithology changes which included thin limestone beds, intervals which more readily reacted with hydrochloric acid than others, fissile versus blocky, and degrees of induration (ability to be disaggregated by the hand). The observations from core did not tie closely to well logs, however it was clear the lower Bakken possessed distinguishing properties in core.

Middle Bakken units

The five units identified in the Middle Member on well logs were also recognized in core. Descriptions for these facies were completed for the seven study wells. Table 4.2 shows a modified composite list of the lithofacies in the middle member as identified by LeFever et al. (1991), Thrasher (1985), and Karma & Parslow (1989). The facies vary from massive, calcareous siltstone with high fossil content to coarse-grained sandstone with varying forms of cross-stratification to buff to dark-gray shale with disseminated pyrite (Pitman, Price and LeFever, 2001).

Middle Bakken Lithofacies	Lithology and Major Characteristics
Middle Bakken Unit 5	Siltstone/Mudstone, buff to gray, green, dolomitic, disseminated pyrite
Middle Bakken Unit 4	Calcareous sandstone to buffy siltstone, moderate bioturbation
Middle Bakken Unit 3	Coarse-grained sandstone, massive or wavy/flaser bedded, cross-stratification, fossil lags, heavy minerals present
Middle Bakken Unit 2	Siltstone/Mudstone, dolomitic,
Middle Bakken Unit 1	Limestone/Dolomitic siltstone, massive, dense, gray/green, highly fossiliferous

Table 4.2: Lithofacies of the Middle Member of the Bakken Formation. Modified from; Pitman, Price and LeFever (2001) and LeFever (2008).

Beginning with the stratigraphically oldest unit in the middle member, middle Bakken unit1 (MBU1), is a mixed lithology of highly fossiliferous lime wackestone to a massive, dense siltstone. Middle Bakken unit 2 (MBU2) is an interbedded grey shale and dolomitic silty sandstone. Middle Bakken unit 3 (MBU3) is a dolomitic siltstone with sandstone interbeds and strong bioturbation and cross-stratification. Middle Bakken unit 4 (MBU4) is a calcareous sandstone with scour surfaces, wavy and flaser bedding. Middle Bakken unit 5 (MBU5) is a dolomitic mudstone with massive, dense siltstone interbeds. The contact with the upper Bakken shale member is sharp (Figure 4.7).

Figure 4.8: Gamma Ray curve, core photo, and core description for the Nesson 42X-36 showing the middle Bakken member units. MBU1 is a mixed lithology of highly fossiliferous lime wackestone to a massive, dense siltstone. MBU2 is an interbedded grey shale and dolomitic silty sandstone. MBU3 is a dolomitic siltstone with sandstone interbeds and strong bioturbation and cross-stratification.

Upper Bakken units

The same difficulties as experienced in the lower Bakken shale unit were experienced in describing the upper Bakken units. The separate units in the upper Bakken shale member were identified with similar methods as the lower Bakken shale. Observations included: lithology changes such as thin limestone beds, intervals of calcareous rock, fissile versus blocky bedding, and degrees of induration. Figure 4.8 shows the core photos and core description for the Sakakawea well through the upper Bakken shale member.

Figure 4.9: Gamma Ray curve, core photo, and core description for the Sakakawea 13X-35 well through the upper Bakken shale. Visual observation revealed lithology changes such as thin limestone beds, intervals of calcareous lithology, fissile versus blocky bedding, and varying degrees of induration.

Both the lower and upper shale members are finely laminated, organic-rich, hemipelagic black mudstone intervals with carbonaceous features (nodules, concretions, and thin beds). These features could be observed in both the wire-line logs and core. Core observations reveal

abundant pyrite occurring as finely disseminated particles in which some formed thin laminae, nodules, and concretions. These observations are valuable however there was not enough visual evidence seen in core to delineate separate petrofacies and correlate the subunits to the well log data with the use of core descriptions.

Lithology & Mineralogy Plots

The mineralogy and lithology of the Bakken Formation is variable from one member to another. The same may be said for the difference in mineralogy from one facies to another within each member, only on a smaller scale. Identifying small scale changes from one facies to another requires detailed analysis.

XRD Results

A number of different methods were used to distinguish variations in mineralogy and lithology within stratigraphic intervals. XRD data became available through the DOE for the Nesson State 42X-36 well, located proximal to the Nesson anticline. XRD for this well reveals mineral composition differences for the upper Bakken shale member (green shading), the middle Bakken member (blue shading), as well as for the lower Bakken shale member (red shading). Results of the semi-quantitative X-ray diffraction analysis are summarized for the bulk, or whole rock, mineralogy in relative weight percent (Table 4.3). Relative clay abundances in are also listed (Table 4.3).

The middle member of the Bakken Formation is very low in clay material (0 to 17%) with variable amounts of quartz, dolomite and calcite comprising the dominant minerals. However, in general quartz in the middle member is less dominant (mean 41%) than in the upper or lower shale units (62-73%). The clay content in the upper shale member is high, making up 20% of the lithology. However, the predominant mineral in the shale units of the Bakken

Formation is quartz, and the lower shale member has slightly higher quartz content (73%) than the upper shale member (62%).

SAMPLE ID	4	8	10	11	13	18	20	22	28	37
DEPTH (FT)	10304.50	10315.00	10319.00	10323.50	10327.80	10351.50	10365.00	10376.50	10406.80	10440.40
QUARTZ	62	40	35	24	62	44	42	41	73	19
K-FELDSPAR	6	5	5	1	4	4	6	4	4	6
PLAGIOCLASE	3	8	9	1	5	6	7	10	5	5
CALCITE	0	3	4	72	16	21	16	14	0	0
SIDERITE	0	0	0	0	0	0	0	0	0	0
ANKERITE/FE-DOLOMITE	3	0	1	0	0	1	3	3	1	0
DOLOMITE	1	33	31	2	10	11	13	9	1	52
PYRITE	6	1	1	0	0	1	1	1	3	1
TOTAL NON-CLAY	80	90	85	100	97	88	87	83	87	82
ILLITE/SMECTITE (I/S)	7	3	4	0	0	4	3	4	4	5
ILLITE+MICA	13	7	11	0	3	7	9	12	9	11
KAOLINITE	0	0	0	0	0	1	0	0	0	1
CHLORITE	0	0	0	0	0	0	1	1	0	1
TOTAL CLAY	20	10	15	0	3	12	13	17	13	18
GRAND TOTAL	100	100	100	100	100	100	100	100	100	100

Table 4.3: X-ray diffraction results for the Nesson State 42X-36 well. The mineralogy is displayed in relative weight percent and relative clay abundance. The upper shale is shaded in green and reveals greatest abundance of clay (20%). The lower shale has a clay abundance of 13% (much lower than the upper shale).

RHOMaa-Umaa Plots

Constructing RHOMaa-Umaa plots in *Microsoft Excel*® was used to delineate mineral composition with LAS digital well data collected through the interval of interest. These types of plots enable the interpreter to display mineral composition in a three mineral format (Figures 4.10 and 4.11). The matrix-identification (RHOMaa vs. Umaa) plot uses apparent matrix density (RHOMaa - grams/cm³) and apparent volumetric cross section (Umaa barns/cm³). Umaa is

calculated from a photoelectric (PE) curve, neutron porosity curve and a bulk density (RHOb) curve using the following equation:

$$U_{maa} = (PE * RHOB) - (ND \text{ Porosity} * PE \text{ absorption of fluid}) / (1 - ND \text{ Porosity}).$$

ND equals the arithmetic average of the neutron and density porosity curves.

Where the appropriate log curves are available, the RHO_{maa}-U_{maa} plot for the upper shale interval of the Bakken Formation shows distinct differences in the mineralogy between the different units defined using the log-based interpreted boundaries (Figure 4.10). For example in the Lars Rothie well, Unit 2 of the upper shale is much more quartz- and carbonate-rich and separates units 1 and 3 (Figure 4.10). Unit 1 of the upper shale also appears to have more pyrite and clay than Unit 3, while unit 3 appears to have significant free gas.

Figure 4.10: RHOMaa-Umaa plot showing the petrofacies of the upper Bakken shale for the Lars Rothie 32-29H well. Unit 2 is much more quartz-rich (blue squares) and separates units 1 (green triangles) and 3 (purple X). Unit 1 of the upper shale also appears to have more pyrite and clay than Unit 3, while unit 3 appears to have free gas.

Figure 4.11: This RHOMaa-Umaa plot shows the petrofacies of the lower Bakken shale for the Lars Rothie 32-29H well. The separate units in this interval appear to overlap one another more so on this type of plot.

Lithology composition plots

Lithology composition plots were also generated in *Microsoft Excel*® with LAS digital well data (Figure 4.12). These plots can show the relative amount of three minerals (e.g., silica, clay, carbonate) and porosity in a two dimensional format. These plots are generated as a linear combination of the neutron, density and photoelectric curves and the physical properties of the three minerals (Doveton, 1994). It should be noted that porosity is probably significantly overestimated and a better relative measure of TOC, as a result of the low density (1.1 to 1.3 gm/cm³) and low photoelectric index (0.16 to 0.20 barns/electron) of the organic content present in upper and lower shale units of the Bakken Formation.

Figure 4.12: Lithology composition plot through the Upper Bakken shale member in the Lars Rothie 32-29H well. The base of units 1 through 3 are defined by increased quartz content. The plot is generated as a linear combination of the neutron, density and photoelectric curves and the physical properties of the three minerals (Doveton, 1994). Porosity is probably significantly overestimated and a better relative measure of TOC, as a result of the low density (1.1 to 1.3 gm/cm^3) and low photoelectric index (0.16 to 0.20 barns/electron) of the organic content present in upper and lower shale units of the Bakken Formation.

The lithology plot in Figure 4.11 reveals the lithologic variations that occur vertically through the upper Bakken shale member. Unit 1 appears to have a greater amount of low Z shale and quartz content than the overlying units. Unit 2 contains appears to have the most low-Z shale content and the Unit 3 has the greatest carbonate abundance.

Using log data cross plots maximizes available data and can help control facies delineation by observing rock-type clusters (Figures 4.10 & 4.11). Establishing relationships

between log data responses, rock types, and depositional environments plays an important role in the identification of the subunits in the Bakken Formation.

Chapter 5: Interpretation of Subunits and Depositional Environments

Fluctuations in relative sea level during the Late Devonian and Early Mississippian are important because they resulted in changing depositional cycles and sedimentary subunits that can be traced across the study area. The identification of the shale subunits has implications for hydrocarbon exploration due to the variations in rock properties and mechanics that are associated with changes in lithology.

After deposition of the Three Forks carbonate and at the close of the Devonian the Williston basin floor experienced a brief exposure and lead to the deposition of the “Sanish” sandstone. Immediately following that, relative sea level increased and resulted in the deposition of the basal Bakken siltstone which was followed by the deposition of the lower Bakken shale when water levels were still rising. A forced regression occurred at the very end of the Devonian and resulted in the deposition of the mixed carbonate and clastics interval of the middle Bakken member. Relative sea level rose again at the beginning of the Mississippian and resulted in the deposition of the upper Bakken shale interval. The Lodgepole limestone was deposited during a rapid drop in relative sea level which lasted the duration of the Mississippian.

Subunits of the Shale Members and Depositional Environments

The lower shale was deposited during the latest Devonian rise in sea-level. The upper shale was deposited during another rise in sea-level during the Early Mississippian. Previous studies concluded that the shale members of the Bakken Formation were deposited under relatively deep marine anoxic conditions (>200 meters). The shale members are separated by the relatively shallow marine middle member (<10 meters) (Smith & Bustin, 2000). For this to have occurred two significant changes in sea-level, in relatively short geologic periods of time would

have had to occur. The average sedimentation rate was estimated at 1-3 m/m.y. (Smith & Bustin, 2000). The question arises as to mechanisms for relatively rapid fluctuations in water depth of up to 200 meters in a stable, cratonic setting.

As discussed in detail in Chapter 3, subunits were identified within the lower and upper shale intervals of the Bakken Formation based on response of wire-line logs. The surfaces that were picked on wire-line logs separate the subunits and are interpreted to be regressive surfaces in a cyclic transgressive-regressive environment.

The shale members of the Bakken Formation have been interpreted to have been deposited under conditions of restricted water circulation, deep-water levels, and low rates of sedimentation (Smith and Bustin, 2000). Organic carbon in both (upper and lower) Bakken shale members averages 12% volume content which would have required a combination of bottom water anoxia, high productivity and suitable organic preservation (Figure 5.1).

Figure 5.1: Depositional environments for the upper and lower Bakken shale members. These intervals were deposited in euxinic to anoxic, off-shore, highly productive, marine environment with possible traction of bottom water and accumulated mud.

Basal Bakken siltstone

The basal Bakken siltstone displays a lower gamma-ray signature than the lower Bakken shale member and the neutron-porosity curve is also higher than the density curve. This is probably due to the great amount of clay and silt in this interval.

The basal Bakken siltstone is considered a facies within the lower Bakken shale. However, it is necessary to distinguish between the less organic-rich basal Bakken siltstone interval and the overlying black, pyritic, highly organic lower Bakken shale section. Webster (1982) identified uppermost portion of the lower Bakken onlapping with the silty shale in some portions of the basin. However, in areas where the silty basal Bakken is not present an erosional surface exists, marking a possible sequence boundary.

The basal Bakken siltstone or gray shale facies is interpreted as the first phase of lower Bakken deposition. Depositional conditions were shallow marine to marine in origin. Sea level was beginning to rise and TOC content was increasing (~8%; Sesack, 2011), however the amount of silt and the infrequent observation of lag deposits present in this lowermost interval suggest storm events and initial sea-level rise created periodic mixing within the water column.

Lower Bakken shale member

Within the lower Bakken shale member three subunits were defined. Generally, the lower Bakken shale member was deposited in euxinic to anoxic, off-shore, marine environment (Figure 5.1). However, the facies picked for this research allows a more detailed approach to identifying depositional conditions. The lower Bakken shale member displays an asymmetrical stacking pattern of the subunits (LBU1 through LBU3) as defined by the wire-line logs (Figure 5.2). The

surfaces that separate the subunits represent regressive surfaces in a cyclic transgressive-regressive pattern.

LBU1 directly overlies the basal Bakken siltstone and represents deposition of black, organic-rich shale. This subunit (LBU1) contains the interval that was first deposited as a result of deeper water, increased productivity, and water column stratification during the close of the Devonian period. The top of this unit is picked as a regressive surface, where there may have been a brief drop in relative sea-level.

Figure 5.2: Lower Bakken shale member showing the asymmetrical stacking pattern (green) of the subunits defined by the logs and interpreted as regressive surfaces of transgressive-regressive cycles (LBU1 through LBU3). As indicated by the overlay of the density and neutron curves, the lower portion of LBU2 has relatively increased carbonate content compared to the lower and upper cycle. Log is from the Lars Rothie 32-29H (API 33053027890000) well.

Overlying LBU1 is the lower Bakken unit 2 (LBU2). LBU2 contains the maximum flooding surface and is bounded, stratigraphically, by the regressive surfaces at the base of LBU2 and the base of the overlying LBU3 shale units. The shale becomes more carbonate rich in the lower to middle portion of LBU2 subunit of the of the lower Bakken member. Directly above this slightly more carbonate interval is the interpreted maximum flooding surface where water depth was likely the deepest during deposition of the lower Bakken shale. The maximum flooding surface is consistently observed across the study area on wire-line logs.

LBU3 is located above LBU2 and displays a coarsening/cleaning upward log pattern which indicates a drop in sea-level resulting in the beginning of the predominantly carbonate middle member of Bakken. Additionally, both of the flooding surfaces in the lower Bakken shale show the neutron curve reading higher than the density curve suggesting carbonate production was put on hold and clay particles began to dominate in the sediment. The top of the lower Bakken unit 3 (LBU3), which is the base of the middle Bakken member, represents the sequence boundary and a marked forced regression. This was a result of a rapid drop on relative sea level.

Middle Bakken

The middle Bakken member is interpreted as deposited in a coastal ramp setting (Figure 5.3) following a rapid relative sea-level drop. The presence of argillaceous, greenish-gray, highly fossiliferous, pyritic siltstones in the lower part of the member suggest an offshore, moderately oxygenated marine environment that was dysaerobic at times. Oolitic shoals are thought to have been present during the time of deposition of the middle member of the Bakken Formation, when base level was relatively high and forced shoreline regression was occurring. Evidence of a forced regression is recorded in the abrupt shift to low-stand deposits in the interior of the

Williston basin and the absence of channel-fill or basin-margin deposits (Smith & Bustin, 2000). Progradation of the shoreline basinward is indicated by interbeds of highly bioturbated shale and sandstone higher in the interval. On the basis of flaser and wavy-bedded silty sandstones and disarticulated brachiopods it suggested that the upper part of the member was deposited in a marine environment with frequent and at times strong wave action.

Figure 5.3: Large-scale depositional features of the middle Bakken member. This figure displays a schematic of shoal formation and the deepest off-shore portion of the Williston basin during the latest Devonian and early Mississippian periods when the middle Bakken member was deposited.

Upper Bakken shale member

The upper Bakken shale member displays an asymmetrical stacking pattern of the subunits (UBU1 through UBU3) as defined by the wire-line logs (Figure 5.4). Surfaces separating subunits are interpreted as regressive surfaces of transgressive-regressive cycles. The overall trend of the upper Bakken shale member is a coarsening/cleaning upward log pattern, which is interpreted as shoaling upward.

Upper Bakken unit 1 (UBU1) overlies the middle Bakken member and was deposited as a result of the second rapid rise in relative sea-level during the deposition of the Bakken Formation. This flooding surface marks one last episode of transgression. The maximum flooding surface is interpreted near the base of this subunit (UBU1).

Figure 5.4: Upper Bakken shale member showing the asymmetrical stacking pattern (green) of the subunits defined by the logs and interpreted as regressive surfaces of transgressive-regressive cycles (UBU1 through UBU3). The overall trend of the upper Bakken shale member is a coarsening/cleaning upward log pattern, which is interpreted as shoaling upward. As indicated by the overlay of the density and neutron curves, the middle cycle has relatively increased carbonate content compared to the lower and upper cycle. Log is from the Lars Rothie 32-29H (API: 33053027890000) well.

The top of UBU1 (the base of UBU2) is picked as a regressive surface, where there may have been a sudden drop in relative sea-level causing differences in water chemistry and productivity thus affecting a change in lithology and sedimentary response. UBU2 (the middle

cycle) has relatively increased carbonate content compared to the lower and upper cycles (Figure 5.4).

Upper Bakken unit 3 (UBU3) shows one last increase in the gamma ray curve, which indicates that sea-level once again could have increased slightly changing lithology and sedimentary response. UBU3 displays a coarsening/cleaning upward log pattern which indicates a drop in sea-level resulting in the beginning of the dominantly carbonate Lodgepole limestone. The upper boundary UBU3 is a sharp contact with the Lodgepole Formation and is interpreted as a sequence boundary.

Similar to the lower Bakken shale, the upper Bakken shale member was deposited in a euxinic to anoxic, off-shore, marine environment where current action was minimal and organic preservation was optimal. However there were environmental conditions that were likely different during the deposition of these shale intervals; conditions which would have created varying lithologies, changing sedimentary responses and diverse organic content within the shale members. With that said it is believed that the upper and lower Bakken shale members are not identical and do possess distinct rock characteristics.

Chapter 6 Regional Mapping and Cross-sections

Cross-sections

Following definition of the members and shale units within the Bakken Formation, a series of cross-sections were generated to correlate the individual units across the study area (Appendix E). Digital well logs were necessary in the definition and correlation of individual units within the shale members due to the extremely high gamma-ray values. Each cross-section color shades the gamma-ray curve based on API value (Figure 6.1). The location of the cross-section is highlighted on a small inset map of the top structure of the Three Forks Formation.

Isopach maps of the separate facies were generated from a database containing approximately 100 wells for the study area (See Appendix F). The maps in this section show thickness and lateral extent of the upper and lower shale members, and individual shale subunits of the Bakken Formation.

Figure 6.1: Cross-section running from the south to north along the Nesson anticline in the center of the basin. Color shading is based on the API value of the gamma-ray curve.

Regional Mapping

The structure map on the top of the underlying Three Forks Formation shows the general elliptical shape of the depositional basin with the north-south Nesson anticline down the center (Figure 6.2). The map was useful in determining paleo-lows at the time of accumulation of the various members and units of the Bakken Formation. Formation tops used to create this map are a combination of North Dakota Geological Survey tops and my picks. The top of the Three Forks surface reaches a maximum depth of approximately 12,000 feet (~3,700 meters) in the basin center west of the Nesson anticline and shallows towards the basin margins to approximately 8,500 feet (~2,600 meters).

All three members of the Bakken Formation are spatially continuous throughout the study area and reach their respective maximum thicknesses proximal to the flanks of the Nesson and Antelope anticlines and basin depocenter. All three members thin towards the basin edges to zero thickness from either erosional or depositional processes. An on-lapping relationship has been documented for the lower, middle, and upper members with the older, underlying stratigraphic units (Smith & Bustin, 1997)

Figure 6.2: Three Forks structure map showing the elliptical shape of the Williston basin in North Dakota with red dashed lines showing lows separated by the north-south Nesson anticline (white dashed line). The Antelope anticline, a secondary positive structural feature, branches off to the southeast of the Nesson anticline. Contour interval of structural depth is 500 feet (~150 meters) and uses a sea-level datum. The gray dashed line is the extent of the study area and the yellow cross-hatches are Bakken Formation picks from my tops and the tops provided by the North Dakota Geological Survey.

Lower Bakken Gross Thickness

The gross isopach for the lower shale member of the Bakken Formation includes the interval from the base of the basal Bakken siltstone to the base of the middle member (top of the lower Bakken unit 3 (LBU3) (Figure 6.3). The lower shale member reaches a maximum thickness of approximately 30-40 feet (9.1-12 meters) adjacent to the western and eastern flanks of the Nesson anticline, which could indicate the existence of paleotopographic lows along the flanks of the anticline during the time of deposition or erosion across this positive feature by the overlying middle member of the Bakken Formation. The lower Bakken shale thins concentrically towards the edges of the Williston basin.

As defined by log response, the lower Bakken shale member displays a deepening stacking pattern from the lowest subunit (LBU1) through the maximum flooding surface interpreted near the top of subunit LBU2 (Figure 5.2). The upper subunit of the lower Bakken shale member (LBU3) shows a shoaling upwards pattern until the contact with the carbonate and sandstone units of the middle member of the Bakken Formation. Surfaces separating lower shale subunits are interpreted as regressive surfaces of transgressive-regressive cycles.

Deposition of the lower Bakken shale is interpreted to have occurred during a rise in relative sea level at the close of the Devonian period. During the time of deposition of the lower shale member in the Williston Basin, it appears that the Nesson anticline was a positive feature, influencing accumulation of the thickest deposits to the west and east of the structure (Figure 6.3).

Figure 6.3: Gross isopach of the lower shale member of the Bakken Formation consisting of units LBU1 through LBU3. The map shows the thickest accumulation in the center of the Williston basin and off the flanks of the Nesson anticline. The yellow cross-hatches are datapoints. Contour interval is 5 feet (1.5 meters).

Lower Bakken shale unit 1 – LBU1

As defined in well logs, the lower Bakken shale unit 1 (LBU1) is the high gamma ray “organic” shale interval above the basal Bakken siltstone (Figure 5.2). The top of LBU1 is defined by a decrease in the gamma ray values and is interpreted as a regressive surface. The isopach for this interval shows the thickest area to be along the eastern flank of the Nesson anticline (Figure 6.4). Maximum thickness for LBU1 is 13 feet (~ 4 meters) and thins to zero at the depositional or erosional edges of the Williston basin. The thickest accumulation of LBU1 trends in a north-south and slight northwest-southeast direction just to the east of the Nesson anticline. The strong north-south orientation is interpreted to indicate that the ancestral Nesson anticline was a positive structural feature at time of deposition creating trough-like depressions along each flank.

Figure 6.4: Isopach of Lower Bakken shale unit 1 (LBU1) displaying north-south oriented trends and a large thick trend off the eastern flanks of the Nesson and Antelope anticlines. Contour interval is 5 feet (1.5 meters).

Lower Bakken shale unit 2 – LBU2

As defined the lower Bakken shale unit 2 (LBU2) includes the highest observed gamma-ray values in the lower shale member (Figure 5.2). The highest gamma-ray values are observed near the top of LBU2, and are interpreted as the maximum flooding surface in the lower shale member of the Bakken Formation. This suggests an asymmetric deepening transgressive-regressive cycle. The top and base of LBU2 are interpreted as regressive surfaces within the lower Bakken shale member. The thickness of LBU2 is highly variable, especially in the eastern Williston basin, but the thickest trends have a general northwest-southeast orientation (Figure 6.5). Maximum thickness for LBU2 occurs along the flanks of the Nesson anticline and is approximately 20 feet (~6 meters) and the minimum thickness in the study area is approximately 2 feet (~.5 meter). Changes in gross thickness of the lower shale member of the Bakken Formation have been attributed to the collapse of the underlying Middle Devonian Prairie evaporite (Webster, 1984). The change in orientation of isopach thick intervals between LBU1 and LBU2, along with the highly variable thickness of LBU2 may be the result of salt dissolution and constrain the timing of dissolution of the Prairie evaporite.

Figure 6.5: Isopach of the lower Bakken shale unit 2 (LBU2) displays dramatic changes in thickness due to pale lows created by salt collapse of the Prairie evaporite. Contour interval is 5 feet (1.5 meters).

Lower Bakken shale unit 3 – LBU3

The uppermost unit of the lower shale member of the Bakken Formation is the lower Bakken shale unit 3 (LBU3). The base of LBU3 is interpreted as a regressive surface. The top of LBU3 is defined by significant changes in log response resulting from the deposition of the carbonate and sandstone units of the middle member of the Bakken Formation (Figure 5.2). The boundary between LBU3 and the base of the middle member is interpreted as a sequence boundary. LBU3 has a highly variable thickness similar to the underlying LBU2. In the study area, the maximum thickness for LBU3 is approximately 14 feet (~4.2 meters) and the minimum thickness is about 2 feet (~.5 meter) (Figure 6.6). The variable thickness and northwest-southeast trends in the isopach for LBU3 are similar to LBU2 and could indicate the continued influence of the ancestral Nesson anticline and collapse of the underlying Prairie evaporite (Figures 6.5, 6.6).

Figure 6.6: Isopach of the lower Bakken shale unit 3 (LBU3). Maximum thickness for LBU3 is approximately 14 feet (~4.2 meters) and the minimum thickness is about 2 feet (~.5 meter). The orientation and variable thickness of LBU3 isopachs are similar to the underlying LBU2 interval. Contour interval is 5 feet (1.5 meters).

Upper Bakken Gross Thickness

The gross isopach for the upper shale member of the Bakken Formation includes the high gamma ray organic-rich shale interval from the top of the carbonate and sand beds of middle member (interpreted to be a flooding surface) to the overlying carbonate units of the Lodgepole Formation (interpreted as a sequence boundary) defining the top of the Bakken Formation (Figure 5.4). The upper shale member reaches a maximum thickness of approximately 68 feet (20.6 meters) along the Nesson anticline, which is interpreted as the location of the Williston basin depocenter (Figure 6.7). During the time of the upper Bakken shale deposition it appears that the Nesson anticline was no longer a significant positive feature, and had less influence on sedimentation patterns. Isopach trends for the entire upper shale member and individual units run across the anticline (Figures 6.7-6.10). The upper Bakken shale member covers a greater lateral extent in the Williston basin than the Middle Member and the lower shale member of the Bakken Formation.

The upper Bakken shale member displays asymmetrical stacking pattern of the subunits (UBU1 through UBU3) as defined by the wireline logs (Figure 5.4). Surfaces separating subunits are interpreted as regressive surfaces of transgressive-regressive cycles. The overall trend of the upper Bakken shale member is a coarsening/cleaning upward log pattern, which is interpreted as shoaling upward. The middle unit of the upper shale member has relatively increased carbonate content compared to the lower and upper units and a maximum flooding surface between two regressive surfaces.

Deposition of the upper Bakken shale is interpreted to have occurred during another rise in relative sea level during the Early Mississippian. Evidence of this continued rise in sea level is evident by the on-lapping relationship with the underlying units (Smith & Bustin, 2000).

Figure 6.7: Upper Bakken gross isopach reaches a maximum thickness of approximately 68 feet (20.6 meters) in the vicinity of the Nesson anticline. Contour interval is 10 feet (3 meters).

Upper Bakken shale unit 1 – UBU1

The upper Bakken shale unit 1 (UBU1) includes the interval from the contact with the carbonate and sandstone units at the top of the middle Bakken member, which is interpreted as a flooding surface, to a decrease in the gamma-ray values and change in lithology marking the base of the upper Bakken shale unit 2 (UBU2). UBU1 contains the maximum flooding surface of the upper Bakken shale member, resulting in an overall asymmetrical shoaling upward pattern to the units comprising the upper shale member (Figure 5.4). The surface separating UBU1 from UBU2 is interpreted as the first regressive surface in the upper Bakken shale member. Maximum thickness of UBU1 is approximately 10 feet (3 meters) and is oriented northwest-southeast and appears to cross the Nesson anticline. The isopach thick of UBU1 thins to the northeast and southwest of the study area. UBU1 may begin to increase in thickness in the southwest corner of the study area (Figure 6.8).

UBU1 is interpreted as the initial shale interval of the upper Bakken shale member which was deposited as a result of a significant rise in relative sea level during the accumulation of the Bakken Formation. Neither the Nesson nor Antelope anticlines appear to have been a significant positive features affecting deposition of UBU1.

Figure 6.8: Isopach of the upper Bakken shale unit 1(UBU1). Maximum thickness is observed on the flanks of the Nesson anticline and is approximately 10 feet (3 meters). Contour interval is 1 foot (.3 meter).

Upper Bakken shale unit 2 – UBU2

The upper Bakken shale unit 2 (UBU2) includes an interval marked by increased carbonate and shale content compared to the lower and upper cycle. The upper and lower boundaries of UBU2 are marked by decreased gamma ray API values and are interpreted as regressive surfaces (Figure 5.4). UBU2 is the second shoaling upward transgressive-regressive cycle in the overall shoaling upward trend of the upper Bakken shale member. As in the underlying UBU1, UBU2 shows a prominent east-west thick trend in the middle of the study area which suggests the north-south Nesson anticline was no longer influencing sedimentation during this time. Just to the southwest of the Nesson Anticline, in the vicinity as the trend of the isopach thin observed in the underlying UBU1 (Figure 6.8), UBU2 shows a northwest-southeast thick trend (Figure 6.9). The patterns of isopach thickness, suggest “traction” or reciprocal sedimentation patterns.

Figure 6.9: Isopach of the upper Bakken shale unit 2 (UBU2). An east-west thick trend in the middle of the study area is observed and maximum thickness is 11 feet (3.3 meters), located on the Antelope anticline and crossing the axis of the Nesson anticline.

Upper Bakken shale unit 3 – UBU3

The base of Upper Bakken shale unit 3 (UBU3) is marked by a decrease in the gamma ray values and is interpreted as the second regressive surface (Figure 5.4). UBU3 continues to the top of the upper Bakken shale member. Isopach trends for UBU3 are oriented predominantly in a northwest-southeast direction with a large isopach thick located off the western flank of the Nesson anticline in the area of isopach thins for the underlying upper shale units. The maximum thickness reaches just over 10 feet (~3 meters) and thins towards the depositional limits of the basin and where the underlying upper shale units are thickening (Figure 6.10). The UBU3 depositional cycle is interpreted to be the last of a sequence of coarsening and shallowing upward units as relative sea level was beginning to drop. The overlying Lodgepole Limestone was deposited in relatively shallow water with an oxygenated water column.

Figure 6.10: Isopach of the upper Bakken shale unit 3 (UBU3). Maximum thickness reaches just over 10 feet (~3 meters) and thins towards the depositional limits of the basin. Contour interval is 2 feet (~.5 meter).

Chapter 7 Discussion & Conclusions

The carbonate and sandstone middle member of the Bakken Formation in the Williston basin of North Dakota is the major target for horizontal drilling in addition to the Sanish and the Three Forks intervals due to great permeability and porosity that these sections possess. As a result, the middle member has received extensive study and been subdivided into numerous subunits and petrofacies. However, the surrounding organic-rich lower and upper shale members of the Bakken Formation, which are the hydrocarbon source rocks have not received extensive study, and are treated as single, homogeneous units. The goal of this research was to better understand the internal stratigraphy of the upper and lower shale members using well logs and cores to define and map transgressive-regressive subunits.

In general, depositional conditions for the upper and lower Bakken shale members have been defined by restricted water circulation, limited terrigenous input, which resulted in increased preservation of organic matter. In combination with the middle member, the upper and lower shale units are a major source for oil produced in the Williston Basin and form a world-class reservoir system.

Approximately 100 wells with LAS logs distributed across the Williston basin of North Dakota were used to define and map subunits in the lower and upper shale intervals of the Late Devonian and Early Mississippian Bakken Formation. Selected wells with core data was used to calibrate log responses and better understand depositional environments. A network of regional cross-sections was built to correlate the Bakken stratigraphic units. Gross isopach maps for the upper and lower Bakken shale members were constructed. The upper and lower Bakken shale members is divided into transgressive-regressive subunits that can be recognized by changes in

lithology and sedimentologic properties, and are attributed to fluctuating depositional conditions. Isopach maps were constructed for individual subunits in the lower and upper Bakken shale members to improve our understanding of factors that influenced sedimentation and depositional systems during the Late Devonian and Early Mississippian and the evolution of the Williston basin.

The lower Bakken shale member was divided into three subunits (LBU1 – LBU3). Boundaries between subunits were defined by changes in log response and interpreted as regressive surfaces of transgressive-regressive cycles. The subunits show an asymmetry with the highest gamma-ray value near the top of each subunit. This asymmetry suggests a deepening upwards stacking pattern until the maximum flooding surface (highest gamma-ray value) in the upper part of LBU2. The upper boundary LBU3 is a sharp contact with the carbonate and mixed clastics units of the middle member of the Bakken Formation, and is interpreted as a shore-face regressive surface or sequence boundary. Thickness trends for the lower shale member and the individual subunits indicate that the Nesson anticline was a positive feature that influenced accumulation patterns. The increase in local variability of isopach thickness in LBU2 and LBU3 may be attributable to dissolution and local collapse of the underlying Middle Devonian Prairie evaporite.

The upper Bakken shale member was divided into three subunits (UBU1 – UBU3). Boundaries between subunits were defined by changes in log response and interpreted as regressive surfaces of transgressive-regressive cycles. The subunits show an asymmetry with the highest gamma-ray value near the base of each subunit. This asymmetry suggests a shoaling upwards stacking pattern and is also displayed by the overall trend of decrease in gamma-ray values upwards to the top of the member. The maximum flooding surface is interpreted near the

base of the lowest subunit (UBU1). The upper boundary UBU3 is a sharp contact with the Lodgepole Formation and is interpreted as a sequence boundary. Thickness trends for the upper shale member and the individual subunits indicate that the Nesson anticline no longer acted as a positive feature that influenced accumulation patterns. Isopach trends in individual subunits indicate reciprocal sedimentation and the possibility of deposition by traction processes.

The lower Bakken unit 2 and the upper Bakken unit 2 were observed to have greater amounts of quartz and calcite than their overlying and underlying counterparts. The brittle nature of rock intervals rich in silica and carbonate could have important implications for the understanding of the rock properties and mechanics of the shale members in the Bakken Formation. This is especially important if these shale members are a drilling target or thought to be contributing to the outstanding production in the Bakken interval. Implementation of a transgressive-regressive stratigraphic framework in the Bakken subunits harbors a better understanding of the changing depositional conditions such as fluctuating sea level and complicated sediment accumulation patterns. Thus the improved understanding of the dynamics of the depositional facies in the Bakken Formation, including the shale units, is important to further explore and develop this unconventional reservoir to its best potential.

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Appendix A

Definition of Bakken Shale Facies Based on Log Response

33053027690000
 HESS CORPORATION
 LARS ROTHIE 32-29H

- ← Upper Bakken Unit 3
- ← Upper Bakken Unit 2
- ← Upper Bakken Unit 1
- ← Lower Bakken Unit 3
- ← Lower Bakken Unit 2
- ← Lower Bakken Unit 1
- ← Basal Bakken siltstone
- ← Three Forks

TD=20166

33061006410000
WHITING OIL AND GAS CORPORATION
BRAAFAT 11-11H

33105015270000
 HESS CORPORATION
 STATE 36-31H 36-31H

33105016670000
XTO ENERGY INC.
NESSON STATE 42X-36

33061004900000
 HESS CORPORATION
 SARAG. BARSTAD 6-44H 6-44H

Appendix B

Gamma Ray Curve plotted alongside Core Descriptions

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Appendix C

Core Photos

33105016670000

XTO ENERGY INC

NESSON STATE 42X-36

33105016670000

XTO ENERGY INC

NESSON STATE 42X-36

(continued)

C

33053028580000

XTO ENERGY INC.

SAKAKAWEA FEDERAL 13X-35

33053027690000

HESS CORPORATION

LARS ROTHIE 32-29H

33105015270000

HESS CORPORATION

STATE 36-31H

33061006410000

WHITING OIL AND GAS CORPORATION

BRAAFLAT 11-11H

33061006800000
OASIS PETROLEUM NORTH AMERICA LLC
FARHART 11-11H

33061004900000

HESS CORPORATION

SARA G. BARSTAD

Appendix D

Selected RHOMaa-Umaa Plots and Lithology Composition Plots

33053027690000

HESS CORPORATION

LARS ROTHIE 32-29H

33053027690000

HESS CORPORATION

LARS ROTHIE 32-29H

33053027690000

HESS CORPORATION

LARS ROTHIE 32-29H

33053027690000

HESS CORPORATION

LARS ROTHIE 32-29H

Appendix E

Regional Cross-sections

North-South Regional Cross-section

Northwest-Southeast Regional Cross-section

Southwest-Northeast Regional Cross-section

Appendix F

Formation Tops

<u>Well ID</u>	<u>Well Name and Number</u>	<u>Formation</u>	<u>Top MD</u>
33053027780000	A. GRIMESTAD 6-32	Basal Bakken	10396.4
33053027780000	A. GRIMESTAD 6-32	Lower Shale Unit 1	10393
33053027780000	A. GRIMESTAD 6-32	Lower Shale Unit 2	10380.7
33053027780000	A. GRIMESTAD 6-32	Lower Shale Unit 3	10374.5
33053027780000	A. GRIMESTAD 6-32	Middle Member Unit 3	10339
33053027780000	A. GRIMESTAD 6-32	Middle Member Unit 4	10336.1
33053027780000	A. GRIMESTAD 6-32	Middle Member Unit 5	10328.9
33053027780000	A. GRIMESTAD 6-32	Upper Shale Unit 1	10322.8
33053027780000	A. GRIMESTAD 6-32	Upper Shale Unit 2	10314
33053027780000	A. GRIMESTAD 6-32	Upper Shale Unit 3	10307.5
33053019310000	A. N. NELSON (NCT-1) 3	Middle Member Unit 3	10574.2
33053019310000	A. N. NELSON (NCT-1) 3	Middle Member Unit 4	10571.5
33053019310000	A. N. NELSON (NCT-1) 3	Middle Member Unit 5	10564
33053019310000	A. N. NELSON (NCT-1) 3	Upper Shale Unit 1	10555.6
33053023080000	AHEL ET AL GRASSEY BUTTE 12-31 H3	Basal Bakken	11285.3
33053023080000	AHEL ET AL GRASSEY BUTTE 12-31 H3	Lower Shale Unit 3	11279.6
33053023080000	AHEL ET AL GRASSEY BUTTE 12-31 H3	Middle Member Unit 5	11250.6
33053023080000	AHEL ET AL GRASSEY BUTTE 12-31 H3	Upper Shale Unit 1	11244.1
33053023080000	AHEL ET AL GRASSEY BUTTE 12-31 H3	Upper Shale Unit 2	11240.3
33053005590000	AMU H-517HR	Basal Bakken	10310.4
33053005590000	AMU H-517HR	Lower Shale Unit 3	10287.5
33053005590000	AMU H-517HR	Middle Member Unit 1	10285.1
33053005590000	AMU H-517HR	Middle Member Unit 2	10273.5
33053005590000	AMU H-517HR	Middle Member Unit 3	10258.5
33053005590000	AMU H-517HR	Middle Member Unit 4	10254.9
33053005590000	AMU H-517HR	Middle Member Unit 5	10246.5
33053005590000	AMU H-517HR	Upper Shale Unit 2	10229.8
33053005590000	AMU H-517HR	Upper Shale Unit 3	10223.6
33105015570000	ANDERSON SMITH 1-26H	Basal Bakken	9795.74
33105015570000	ANDERSON SMITH 1-26H	Lower Shale Unit 1	9791.97
33105015570000	ANDERSON SMITH 1-26H	Lower Shale Unit 2	9781.88
33105015570000	ANDERSON SMITH 1-26H	Lower Shale Unit 3	9773.59

<u>Well ID</u>	<u>Well Name and Number</u>	<u>Formation</u>	<u>Top MD</u>
33105015570000	ANDERSON SMITH 1-26H	Middle Member Unit 1	9768.91
33105015570000	ANDERSON SMITH 1-26H	Middle Member Unit 2	9749.78
33105015570000	ANDERSON SMITH 1-26H	Middle Member Unit 3	9739.44
33105015570000	ANDERSON SMITH 1-26H	Middle Member Unit 4	9728.47
33105015570000	ANDERSON SMITH 1-26H	Middle Member Unit 5	9722.12
33105015570000	ANDERSON SMITH 1-26H	Upper Shale Unit 1	9713.03
33105015570000	ANDERSON SMITH 1-26H	Upper Shale Unit 2	9708.57
33105015570000	ANDERSON SMITH 1-26H	Upper Shale Unit 3	9702
33053028730000	AN-EVENSON-152-95- 0310H-1	Basal Bakken	10794.1
33053028730000	AN-EVENSON-152-95- 0310H-1	Lower Shale Unit 1	10770.7
33053028730000	AN-EVENSON-152-95- 0310H-1	Lower Shale Unit 2	10733.2
33053028730000	AN-EVENSON-152-95- 0310H-1	Lower Shale Unit 3	10704.9
33053028730000	AN-EVENSON-152-95- 0310H-1	Middle Member Unit 1	10692.2
33053028730000	AN-EVENSON-152-95- 0310H-1	Middle Member Unit 2	10630.2
33053028730000	AN-EVENSON-152-95- 0310H-1	Middle Member Unit 3	10602.7
33053028730000	AN-EVENSON-152-95- 0310H-1	Middle Member Unit 4	10596.6
33053028730000	AN-EVENSON-152-95- 0310H-1	Middle Member Unit 5	10582.3
33053028730000	AN-EVENSON-152-95- 0310H-1	Upper Shale Unit 1	10569.4
33053028730000	AN-EVENSON-152-95- 0310H-1	Upper Shale Unit 2	10548.3
33053028730000	AN-EVENSON-152-95- 0310H-1	Upper Shale Unit 3	10534.4
33053026470000	ANN 1	Basal Bakken	11237.8
33053026470000	ANN 1	Lower Shale Unit 1	11235.6
33053026470000	ANN 1	Lower Shale Unit 2	11227
33053026470000	ANN 1	Lower Shale Unit 3	11220.4
33053026470000	ANN 1	Middle Member Unit 5	11178.9
33053026470000	ANN 1	Upper Shale Unit 1	11175.9
33053026470000	ANN 1	Upper Shale Unit 2	11169.9
33053026470000	ANN 1	Upper Shale Unit 3	11161.2
33061005780000	ANNALA 11-36H	Basal Bakken	10488.1
33061005780000	ANNALA 11-36H	Middle Member Unit 5	10390.5
33061005780000	ANNALA 11-36H	Upper Shale Unit 1	10387.4
33061005780000	ANNALA 11-36H	Upper Shale Unit 2	10383.1
33061005780000	ANNALA 11-36H	Upper Shale Unit 3	10370.9
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Basal Bakken	10346.8
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Lower Shale Unit 3	10331.2
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Middle Member Unit 1	10327.9
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Middle Member Unit 2	10310.3
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Middle Member Unit 3	10299.1
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Middle Member Unit 4	10290.9
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Middle Member Unit 5	10288

<u>Well ID</u>	<u>Well Name and Number</u>	<u>Formation</u>	<u>Top MD</u>
33053002730000	ANTELOPE-MADISON UNIT D-519HR	Upper Shale Unit 3	10264.3
33053002240000	ANTELOPE-MADISON UNIT M-511	Lower Shale Unit 3	10393.5
33053002240000	ANTELOPE-MADISON UNIT M-511	Middle Member Unit 5	10355.1
33053027600000	ARNEGARD STATE 1	Basal Bakken	11168.4
33053027600000	ARNEGARD STATE 1	Lower Shale Unit 3	11164.8
33053027600000	ARNEGARD STATE 1	Middle Member Unit 3	11147.9
33053027600000	ARNEGARD STATE 1	Middle Member Unit 4	11143.9
33053027600000	ARNEGARD STATE 1	Middle Member Unit 5	11136
33053027600000	ARNEGARD STATE 1	Upper Shale Unit 1	11132.1
33053027600000	ARNEGARD STATE 1	Upper Shale Unit 2	11129.8
33053027600000	ARNEGARD STATE 1	Upper Shale Unit 3	11125.1
33061005960000	AUSTIN 8-26H	Basal Bakken	9435.99
33061005960000	AUSTIN 8-26H	Lower Shale Unit 1	9431.86
33061005960000	AUSTIN 8-26H	Lower Shale Unit 2	9410.87
33061005960000	AUSTIN 8-26H	Lower Shale Unit 3	9405.85
33061005960000	AUSTIN 8-26H	Middle Member Unit 5	9369.44
33061005960000	AUSTIN 8-26H	Upper Shale Unit 1	9366.16
33061005960000	AUSTIN 8-26H	Upper Shale Unit 2	9359.6
33061005960000	AUSTIN 8-26H	Upper Shale Unit 3	9354.01
33061004950000	BARTLESON 44-1H	Basal Bakken	10326
33061004950000	BARTLESON 44-1H	Lower Shale Unit 1	10317.6
33061004950000	BARTLESON 44-1H	Lower Shale Unit 2	10299.7
33061004950000	BARTLESON 44-1H	Lower Shale Unit 3	10288.6
33061004950000	BARTLESON 44-1H	Middle Member Unit 3	10250
33061004950000	BARTLESON 44-1H	Middle Member Unit 4	10243.1
33061004950000	BARTLESON 44-1H	Middle Member Unit 5	10232.5
33061004950000	BARTLESON 44-1H	Upper Shale Unit 1	10229.3
33061004950000	BARTLESON 44-1H	Upper Shale Unit 2	10224.4
33061004950000	BARTLESON 44-1H	Upper Shale Unit 3	10213.5
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Basal Bakken	9920.27
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Lower Shale Unit 1	9912.7
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Lower Shale Unit 2	9899.38
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Lower Shale Unit 3	9892.41
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Middle Member Unit 1	9882.25
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Middle Member Unit 2	9864.65
33105005560000	BEAVER LODGE-SILURIAN UNIT G-	Middle Member Unit 3	9856.74

<u>Well ID</u>	<u>Well Name and Number</u>	<u>Formation</u>	<u>Top MD</u>
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Middle Member Unit 4	9849.26
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Middle Member Unit 5	9841.78
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Upper Shale Unit 1	9834.27
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Upper Shale Unit 2	9827.31
33105005560000	BEAVER LODGE-SILURIAN UNIT G-405ST	Upper Shale Unit 3	9822.62
33053014880000	BECKEN 1	Basal Bakken	11085.3
33053014880000	BECKEN 1	Lower Shale Unit 1	11083.9
33053014880000	BECKEN 1	Lower Shale Unit 3	11060.6
33053014880000	BECKEN 1	Middle Member Unit 1	11055.9
33053014880000	BECKEN 1	Middle Member Unit 2	11044.5
33053014880000	BECKEN 1	Middle Member Unit 3	11025.2
33053014880000	BECKEN 1	Middle Member Unit 4	11020.3
33053014880000	BECKEN 1	Middle Member Unit 5	11019
33053014880000	BECKEN 1	Upper Shale Unit 3	11001
33105018200000	BERGSTROM 15-23H	Basal Bakken	11030
33105018200000	BERGSTROM 15-23H	Lower Shale Unit 1	11023.3
33105018200000	BERGSTROM 15-23H	Lower Shale Unit 2	11011
33105018200000	BERGSTROM 15-23H	Lower Shale Unit 3	11004.4
33105018200000	BERGSTROM 15-23H	Middle Member Unit 5	10953.2
33105018200000	BERGSTROM 15-23H	Upper Shale Unit 1	10946.7
33105018200000	BERGSTROM 15-23H	Upper Shale Unit 2	10941.4
33105018200000	BERGSTROM 15-23H	Upper Shale Unit 3	10933
33105015100000	BLDU DD-307	Basal Bakken	9777.94
33105015100000	BLDU DD-307	Lower Shale Unit 1	9770.99
33105015100000	BLDU DD-307	Lower Shale Unit 2	9760.51
33105015100000	BLDU DD-307	Lower Shale Unit 3	9752.4
33105015100000	BLDU DD-307	Middle Member Unit 1	9747.22
33105015100000	BLDU DD-307	Middle Member Unit 2	9725.52
33105015100000	BLDU DD-307	Middle Member Unit 3	9717.41
33105015100000	BLDU DD-307	Middle Member Unit 4	9706.63
33105015100000	BLDU DD-307	Middle Member Unit 5	9699.49
33105015100000	BLDU DD-307	Upper Shale Unit 1	9691.53
33105015100000	BLDU DD-307	Upper Shale Unit 2	9686.12
33105015100000	BLDU DD-307	Upper Shale Unit 3	9680.93
33105015160000	BLDU H-315	Basal Bakken	9827.5
33105015160000	BLDU H-315	Lower Shale Unit 1	9817.76
33105015160000	BLDU H-315	Lower Shale Unit 2	9807.89

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33105015160000	BLDU H-315	Lower Shale Unit 3	9798.33
33105015160000	BLDU H-315	Middle Member Unit 3	9759.68
33105015160000	BLDU H-315	Middle Member Unit 4	9749.38
33105015160000	BLDU H-315	Middle Member Unit 5	9740.18
33105015160000	BLDU H-315	Upper Shale Unit 1	9732.26
33105015160000	BLDU H-315	Upper Shale Unit 3	9726.56
33061005870000	BLOOM SWD 1	Basal Bakken	8867.23
33061005870000	BLOOM SWD 1	Lower Shale Unit 1	8862.2
33061005870000	BLOOM SWD 1	Lower Shale Unit 2	8852.17
33061005870000	BLOOM SWD 1	Lower Shale Unit 3	8848.65
33061005870000	BLOOM SWD 1	Middle Member Unit 5	8820.42
33061005870000	BLOOM SWD 1	Upper Shale Unit 1	8816.51
33061005870000	BLOOM SWD 1	Upper Shale Unit 2	8808.68
33061005870000	BLOOM SWD 1	Upper Shale Unit 3	8802.97
33061005480000	BOTTLESON 34-22H	Middle Member Unit 1	10818.9
33061005480000	BOTTLESON 34-22H	Middle Member Unit 2	10742.7
33061005480000	BOTTLESON 34-22H	Middle Member Unit 3	10704.8
33061005480000	BOTTLESON 34-22H	Middle Member Unit 4	10692.6
33061005480000	BOTTLESON 34-22H	Middle Member Unit 5	10659
33061005480000	BOTTLESON 34-22H	Upper Shale Unit 1	10641
33061005480000	BOTTLESON 34-22H	Upper Shale Unit 2	10630
33061005480000	BOTTLESON 34-22H	Upper Shale Unit 3	10609
33061006410000	BRAAFLAT 11-11H	Basal Bakken	9970.04
33061006410000	BRAAFLAT 11-11H	Lower Shale Unit 1	9962.85
33061006410000	BRAAFLAT 11-11H	Lower Shale Unit 2	9948.41
33061006410000	BRAAFLAT 11-11H	Lower Shale Unit 3	9934.42
33061006410000	BRAAFLAT 11-11H	Middle Member Unit 1	9917.62
33061006410000	BRAAFLAT 11-11H	Middle Member Unit 2	9905.33
33061006410000	BRAAFLAT 11-11H	Middle Member Unit 3	9898.1
33061006410000	BRAAFLAT 11-11H	Middle Member Unit 4	9889.38
33061006410000	BRAAFLAT 11-11H	Middle Member Unit 5	9878.41
33061006410000	BRAAFLAT 11-11H	Upper Shale Unit 1	9874.48
33061006410000	BRAAFLAT 11-11H	Upper Shale Unit 2	9871.13
33061006410000	BRAAFLAT 11-11H	Upper Shale Unit 3	9865.09
33053015120000	BRODERSON 29-1	Basal Bakken	11073.3
33053015120000	BRODERSON 29-1	Lower Shale Unit 3	11044.9
33053015120000	BRODERSON 29-1	Middle Member Unit 1	11042.3
33053015120000	BRODERSON 29-1	Middle Member Unit 2	11024.5
33053015120000	BRODERSON 29-1	Middle Member Unit 3	11013.4
33053015120000	BRODERSON 29-1	Middle Member Unit 4	11006.4
33053015120000	BRODERSON 29-1	Middle Member Unit 5	11002

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33053015120000	BRODERSON 29-1	Upper Shale Unit 3	10980.6
33053004490000	CHARLSON SWD 2	Basal Bakken	9800.34
33053004490000	CHARLSON SWD 2	Lower Shale Unit 2	9784.43
33053004490000	CHARLSON SWD 2	Lower Shale Unit 3	9774.18
33053004490000	CHARLSON SWD 2	Middle Member Unit 1	9770.4
33053004490000	CHARLSON SWD 2	Middle Member Unit 2	9748.34
33053004490000	CHARLSON SWD 2	Middle Member Unit 3	9743.7
33053004490000	CHARLSON SWD 2	Middle Member Unit 4	9737.03
33053004490000	CHARLSON SWD 2	Middle Member Unit 5	9731.8
33053004490000	CHARLSON SWD 2	Upper Shale Unit 3	9706.85
33053014110000	COOPER PETROLEUM SHAFER 1	Lower Shale Unit 1	10944.6
33053014110000	COOPER PETROLEUM SHAFER 1	Lower Shale Unit 2	10938.3
33053014110000	COOPER PETROLEUM SHAFER 1	Lower Shale Unit 3	10929
33053014110000	COOPER PETROLEUM SHAFER 1	Middle Member Unit 1	10920.4
33053014110000	COOPER PETROLEUM SHAFER 1	Middle Member Unit 2	10905.7
33053014110000	COOPER PETROLEUM SHAFER 1	Middle Member Unit 3	10892.8
33053014110000	COOPER PETROLEUM SHAFER 1	Middle Member Unit 4	10887
33053014110000	COOPER PETROLEUM SHAFER 1	Middle Member Unit 5	10884.8
33053014110000	COOPER PETROLEUM SHAFER 1	Upper Shale Unit 3	10866.7
33025011170000	CORRINE OLSON 34-20	Basal Bakken	10900.4
33025011170000	CORRINE OLSON 34-20	Lower Shale Unit 1	10897.4
33025011170000	CORRINE OLSON 34-20	Lower Shale Unit 2	10890
33025011170000	CORRINE OLSON 34-20	Lower Shale Unit 3	10883.5
33025011170000	CORRINE OLSON 34-20	Middle Member Unit 1	10877.5
33025011170000	CORRINE OLSON 34-20	Middle Member Unit 2	10870.4
33025011170000	CORRINE OLSON 34-20	Middle Member Unit 3	10858.3
33025011170000	CORRINE OLSON 34-20	Middle Member Unit 4	10843.7
33025011170000	CORRINE OLSON 34-20	Middle Member Unit 5	10839.1
33025011170000	CORRINE OLSON 34-20	Upper Shale Unit 1	10834.8
33025011170000	CORRINE OLSON 34-20	Upper Shale Unit 2	10830.6
33025011170000	CORRINE OLSON 34-20	Upper Shale Unit 3	10824.1
33105007700000	DAVIDSON SWD	Middle Member Unit 1	9856.14
33105007700000	DAVIDSON SWD	Middle Member Unit 2	9840.29
33105007700000	DAVIDSON SWD	Middle Member Unit 3	9819.62
33105007700000	DAVIDSON SWD	Middle Member Unit 4	9805.93
33105007700000	DAVIDSON SWD	Middle Member Unit 5	9797.07
33105007700000	DAVIDSON SWD	Upper Shale Unit 3	9779.67
33061005900000	DEADWOOD CANYON RANCH 11-5H	Basal Bakken	10268.2
33061005900000	DEADWOOD CANYON RANCH 11-5H	Lower Shale Unit 1	10252
33061005900000	DEADWOOD CANYON RANCH 11-5H	Lower Shale Unit 2	10242.6
33061005900000	DEADWOOD CANYON RANCH 11-5H	Lower Shale Unit 3	10223.1

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33061005900000	DEADWOOD CANYON RANCH 11-5H	Middle Member Unit 1	10220.7
33061005900000	DEADWOOD CANYON RANCH 11-5H	Middle Member Unit 3	10182
33061005900000	DEADWOOD CANYON RANCH 11-5H	Middle Member Unit 4	10162.4
33061005900000	DEADWOOD CANYON RANCH 11-5H	Middle Member Unit 5	10156.7
33061005900000	DEADWOOD CANYON RANCH 11-5H	Upper Shale Unit 1	10149.8
33061005900000	DEADWOOD CANYON RANCH 11-5H	Upper Shale Unit 2	10140.5
33105017910000	EIDE 5-13H	Basal Bakken	11135.6
33105017910000	EIDE 5-13H	Lower Shale Unit 1	11126.5
33105017910000	EIDE 5-13H	Lower Shale Unit 2	11116
33105017910000	EIDE 5-13H	Lower Shale Unit 3	11107.9
33105017910000	EIDE 5-13H	Middle Member Unit 5	11064.3
33105017910000	EIDE 5-13H	Upper Shale Unit 1	11061.2
33105017910000	EIDE 5-13H	Upper Shale Unit 2	11053.6
33105017910000	EIDE 5-13H	Upper Shale Unit 3	11044.1
33105000120000	ELMER TANK 1	Basal Bakken	10173.5
33105000120000	ELMER TANK 1	Lower Shale Unit 3	10128.1
33105000120000	ELMER TANK 1	Middle Member Unit 1	10124
33105000120000	ELMER TANK 1	Middle Member Unit 2	10108.1
33105000120000	ELMER TANK 1	Middle Member Unit 3	10096.7
33105000120000	ELMER TANK 1	Middle Member Unit 4	10089.9
33105000120000	ELMER TANK 1	Middle Member Unit 5	10084
33105000120000	ELMER TANK 1	Upper Shale Unit 3	10061.6
33061008470000	EN-D CVANCARA-154-93- 0409H-1	Middle Member Unit 4	10674.2
33061008470000	EN-D CVANCARA-154-93- 0409H-1	Middle Member Unit 5	10655.8
33061008470000	EN-D CVANCARA-154-93- 0409H-1	Upper Shale Unit 1	10650.7
33061008470000	EN-D CVANCARA-154-93- 0409H-1	Upper Shale Unit 2	10638.3
33061008470000	EN-D CVANCARA-154-93- 0409H-1	Upper Shale Unit 3	10619.2
33061006820000	EN-PEDERSON-154-94- 0409H-1	Basal Bakken	10646.2
33061006820000	EN-PEDERSON-154-94- 0409H-1	Lower Shale Unit 1	10602.4
33061006820000	EN-PEDERSON-154-94- 0409H-1	Lower Shale Unit 2	10571.7
33061006820000	EN-PEDERSON-154-94- 0409H-1	Lower Shale Unit 3	10538.8
33061006820000	EN-PEDERSON-154-94- 0409H-1	Middle Member Unit 3	10437.2
33061006820000	EN-PEDERSON-154-94- 0409H-1	Middle Member Unit 4	10419.8
33061006820000	EN-PEDERSON-154-94- 0409H-1	Middle Member Unit 5	10401.1
33061006820000	EN-PEDERSON-154-94- 0409H-1	Upper Shale Unit 1	10384.9
33061006820000	EN-PEDERSON-154-94- 0409H-1	Upper Shale Unit 2	10374.7
33061006820000	EN-PEDERSON-154-94- 0409H-1	Upper Shale Unit 3	10368.6
33025008840000	ERICKSON 11-1H	Basal Bakken	11322.9
33025008840000	ERICKSON 11-1H	Lower Shale Unit 1	11320.3
33025008840000	ERICKSON 11-1H	Lower Shale Unit 2	11313.8
33025008840000	ERICKSON 11-1H	Lower Shale Unit 3	11306.2

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33025008840000	ERICKSON 11-1H	Middle Member Unit 3	11275.2
33025008840000	ERICKSON 11-1H	Middle Member Unit 4	11274.1
33025008840000	ERICKSON 11-1H	Middle Member Unit 5	11268.1
33025008840000	ERICKSON 11-1H	Upper Shale Unit 1	11265.5
33025008840000	ERICKSON 11-1H	Upper Shale Unit 2	11259.9
33025008840000	ERICKSON 11-1H	Upper Shale Unit 3	11252.5
33061007490000	ERIE 44-19H	Basal Bakken	10059.4
33061007490000	ERIE 44-19H	Lower Shale Unit 3	10014.5
33061007490000	ERIE 44-19H	Middle Member Unit 5	9957.78
33061007490000	ERIE 44-19H	Upper Shale Unit 1	9955.25
33061007490000	ERIE 44-19H	Upper Shale Unit 2	9949.66
33061007490000	ERIE 44-19H	Upper Shale Unit 3	9945.1
33053026690000	FANCY BUTTE 14-32	Basal Bakken	10826.2
33053026690000	FANCY BUTTE 14-32	Lower Shale Unit 1	10822.6
33053026690000	FANCY BUTTE 14-32	Lower Shale Unit 2	10807.9
33053026690000	FANCY BUTTE 14-32	Lower Shale Unit 3	10801.2
33053026690000	FANCY BUTTE 14-32	Middle Member Unit 1	10791.3
33053026690000	FANCY BUTTE 14-32	Middle Member Unit 2	10775.7
33053026690000	FANCY BUTTE 14-32	Middle Member Unit 3	10764.8
33053026690000	FANCY BUTTE 14-32	Middle Member Unit 4	10761.8
33053026690000	FANCY BUTTE 14-32	Middle Member Unit 5	10760.7
33053026690000	FANCY BUTTE 14-32	Upper Shale Unit 1	10754.2
33053026690000	FANCY BUTTE 14-32	Upper Shale Unit 2	10749.6
33053026690000	FANCY BUTTE 14-32	Upper Shale Unit 3	10742.1
33061006800000	FARHART 11-11H	Basal Bakken	9721.22
33061006800000	FARHART 11-11H	Lower Shale Unit 1	9718.08
33061006800000	FARHART 11-11H	Lower Shale Unit 2	9704.21
33061006800000	FARHART 11-11H	Lower Shale Unit 3	9686.94
33061006800000	FARHART 11-11H	Middle Member Unit 1	9683.74
33061006800000	FARHART 11-11H	Middle Member Unit 2	9664.84
33061006800000	FARHART 11-11H	Middle Member Unit 3	9662.4
33061006800000	FARHART 11-11H	Middle Member Unit 5	9643.18
33061006800000	FARHART 11-11H	Upper Shale Unit 1	9640.86
33061006800000	FARHART 11-11H	Upper Shale Unit 2	9636.75
33061006800000	FARHART 11-11H	Upper Shale Unit 3	9629.96
33053012030000	FEDERAL 15-1	Lower Shale Unit 1	10077.7
33053012030000	FEDERAL 15-1	Lower Shale Unit 2	10075.3
33053012030000	FEDERAL 15-1	Lower Shale Unit 3	10067.6
33053012030000	FEDERAL 15-1	Middle Member Unit 1	10062.1
33053012030000	FEDERAL 15-1	Middle Member Unit 2	10045.7
33053012030000	FEDERAL 15-1	Middle Member Unit 3	10030.8

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33053012030000	FEDERAL 15-1	Middle Member Unit 4	10025.5
33053012030000	FEDERAL 15-1	Middle Member Unit 5	10017.9
33053012030000	FEDERAL 15-1	Upper Shale Unit 3	9997.67
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Basal Bakken	10666.6
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Lower Shale Unit 1	10650.9
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Lower Shale Unit 2	10640.7
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Lower Shale Unit 3	10633.2
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Middle Member Unit 3	10592.1
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Middle Member Unit 4	10587.2
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Middle Member Unit 5	10575.6
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Upper Shale Unit 1	10567.1
33053031410000	FORT BERTHOLD 152-94-13B-24-1H	Upper Shale Unit 2	10555.6
33105015730000	FOSS 12-11	Basal Bakken	10240.8
33105015730000	FOSS 12-11	Lower Shale Unit 1	10237.7
33105015730000	FOSS 12-11	Lower Shale Unit 2	10225.5
33105015730000	FOSS 12-11	Lower Shale Unit 3	10218.9
33105015730000	FOSS 12-11	Middle Member Unit 3	10173.7
33105015730000	FOSS 12-11	Middle Member Unit 4	10166
33105015730000	FOSS 12-11	Middle Member Unit 5	10162.4
33105015730000	FOSS 12-11	Upper Shale Unit 1	10154.8
33105015730000	FOSS 12-11	Upper Shale Unit 2	10150.4
33105015730000	FOSS 12-11	Upper Shale Unit 3	10146.3
33053014490000	G. V. LEVANG 1 HR	Lower Shale Unit 3	10736.1
33053014490000	G. V. LEVANG 1 HR	Middle Member Unit 1	10713.7
33053014490000	G. V. LEVANG 1 HR	Middle Member Unit 2	10708.6
33053014490000	G. V. LEVANG 1 HR	Middle Member Unit 3	10705.1
33053014490000	G. V. LEVANG 1 HR	Middle Member Unit 4	10703
33053014490000	G. V. LEVANG 1 HR	Middle Member Unit 5	10695.9
33053014490000	G. V. LEVANG 1 HR	Upper Shale Unit 3	10679.4
33053015350000	G. V. LEVANG B 1	Lower Shale Unit 1	10718.2
33053015350000	G. V. LEVANG B 1	Lower Shale Unit 2	10709.8
33053015350000	G. V. LEVANG B 1	Lower Shale Unit 3	10700.2
33053015350000	G. V. LEVANG B 1	Middle Member Unit 1	10691.1
33053015350000	G. V. LEVANG B 1	Middle Member Unit 2	10682.4
33053015350000	G. V. LEVANG B 1	Middle Member Unit 3	10674.9
33053015350000	G. V. LEVANG B 1	Middle Member Unit 4	10668.1
33053015350000	G. V. LEVANG B 1	Middle Member Unit 5	10661.4
33053015350000	G. V. LEVANG B 1	Upper Shale Unit 3	10643.7
33053025770000	GREEN 12-6	Basal Bakken	10707.7
33053025770000	GREEN 12-6	Lower Shale Unit 3	10703.3
33053025770000	GREEN 12-6	Middle Member Unit 3	10687.3

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33053025770000	GREEN 12-6	Middle Member Unit 4	10682.7
33053025770000	GREEN 12-6	Middle Member Unit 5	10672.4
33053025770000	GREEN 12-6	Upper Shale Unit 1	10665.5
33053025770000	GREEN 12-6	Upper Shale Unit 2	10663.2
33053025770000	GREEN 12-6	Upper Shale Unit 3	10658.7
33053014210000	H AND M GIERKE 1-20-1D	Middle Member Unit 1	11023.3
33053014210000	H AND M GIERKE 1-20-1D	Middle Member Unit 2	11010.5
33053014210000	H AND M GIERKE 1-20-1D	Middle Member Unit 3	10997.8
33053014210000	H AND M GIERKE 1-20-1D	Middle Member Unit 4	10992.7
33053014210000	H AND M GIERKE 1-20-1D	Middle Member Unit 5	10988
33105007320000	H. BORSTAD 1	Basal Bakken	9722.31
33105007320000	H. BORSTAD 1	Lower Shale Unit 3	9696.17
33105007320000	H. BORSTAD 1	Middle Member Unit 1	9690.07
33105007320000	H. BORSTAD 1	Middle Member Unit 2	9681.91
33105007320000	H. BORSTAD 1	Middle Member Unit 3	9659.74
33105007320000	H. BORSTAD 1	Middle Member Unit 4	9648.75
33105007320000	H. BORSTAD 1	Middle Member Unit 5	9641.01
33105007320000	H. BORSTAD 1	Upper Shale Unit 1	9634.81
33105007320000	H. BORSTAD 1	Upper Shale Unit 3	9624.36
33061004940000	H. JUMA 1-9H	Basal Bakken	10123.6
33061004940000	H. JUMA 1-9H	Lower Shale Unit 1	10114.8
33061004940000	H. JUMA 1-9H	Lower Shale Unit 2	10089.7
33061004940000	H. JUMA 1-9H	Lower Shale Unit 3	10075.8
33061004940000	H. JUMA 1-9H	Middle Member Unit 1	10051.6
33061004940000	H. JUMA 1-9H	Middle Member Unit 2	10037.2
33061004940000	H. JUMA 1-9H	Middle Member Unit 3	10025.7
33061004940000	H. JUMA 1-9H	Middle Member Unit 4	10020.6
33061004940000	H. JUMA 1-9H	Middle Member Unit 5	10010.1
33061004940000	H. JUMA 1-9H	Upper Shale Unit 1	10007.4
33061004940000	H. JUMA 1-9H	Upper Shale Unit 2	10000.7
33061004940000	H. JUMA 1-9H	Upper Shale Unit 3	9996.66
33053020760000	HAGEN 1-13	Basal Bakken	10402.8
33053020760000	HAGEN 1-13	Lower Shale Unit 3	10377.1
33053020760000	HAGEN 1-13	Middle Member Unit 5	10330
33053020760000	HAGEN 1-13	Upper Shale Unit 1	10320
33053020760000	HAGEN 1-13	Upper Shale Unit 3	10309
33053026140000	HANSEN 2-23	Basal Bakken	10795.9
33053026140000	HANSEN 2-23	Lower Shale Unit 3	10790.1
33053026140000	HANSEN 2-23	Middle Member Unit 3	10773.2
33053026140000	HANSEN 2-23	Middle Member Unit 4	10771.3
33053026140000	HANSEN 2-23	Middle Member Unit 5	10760.7

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33053026140000	HANSEN 2-23	Upper Shale Unit 1	10753.9
33053026140000	HANSEN 2-23	Upper Shale Unit 2	10750.9
33053026140000	HANSEN 2-23	Upper Shale Unit 3	10746
33053004060000	HARRY MENDENHALL 1	Basal Bakken	10155.4
33053004060000	HARRY MENDENHALL 1	Lower Shale Unit 3	10123
33053004060000	HARRY MENDENHALL 1	Middle Member Unit 1	10115.1
33053004060000	HARRY MENDENHALL 1	Middle Member Unit 2	10102.6
33053004060000	HARRY MENDENHALL 1	Middle Member Unit 3	10092.7
33053004060000	HARRY MENDENHALL 1	Middle Member Unit 4	10089.9
33053004060000	HARRY MENDENHALL 1	Middle Member Unit 5	10082
33053004060000	HARRY MENDENHALL 1	Upper Shale Unit 3	10052.7
33105007550000	HARTSOCH 33-33	Basal Bakken	9693.53
33105007550000	HARTSOCH 33-33	Lower Shale Unit 1	9685.07
33105007550000	HARTSOCH 33-33	Lower Shale Unit 3	9667.57
33105007550000	HARTSOCH 33-33	Middle Member Unit 1	9661.36
33105007550000	HARTSOCH 33-33	Middle Member Unit 2	9649.65
33105007550000	HARTSOCH 33-33	Middle Member Unit 3	9632.91
33105007550000	HARTSOCH 33-33	Middle Member Unit 4	9624.31
33105007550000	HARTSOCH 33-33	Middle Member Unit 5	9613.08
33105007550000	HARTSOCH 33-33	Upper Shale Unit 3	9594.64
33053025760000	HAUGEN COATES 2-4	Basal Bakken	10965
33053025760000	HAUGEN COATES 2-4	Lower Shale Unit 3	10960.8
33053025760000	HAUGEN COATES 2-4	Middle Member Unit 5	10935.7
33053025760000	HAUGEN COATES 2-4	Upper Shale Unit 2	10931.7
33053025760000	HAUGEN COATES 2-4	Upper Shale Unit 3	10926.2
33105017560000	HEIDI 1-4H	Basal Bakken	10765
33105017560000	HEIDI 1-4H	Lower Shale Unit 1	10762.5
33105017560000	HEIDI 1-4H	Lower Shale Unit 2	10745.4
33105017560000	HEIDI 1-4H	Lower Shale Unit 3	10739.7
33105017560000	HEIDI 1-4H	Middle Member Unit 3	10703.8
33105017560000	HEIDI 1-4H	Middle Member Unit 4	10699.9
33105017560000	HEIDI 1-4H	Middle Member Unit 5	10692
33105017560000	HEIDI 1-4H	Upper Shale Unit 1	10688.4
33105017560000	HEIDI 1-4H	Upper Shale Unit 2	10684
33105017560000	HEIDI 1-4H	Upper Shale Unit 3	10672.9
33105016130000	HIGGINS 34-33D	Basal Bakken	10823.1
33105016130000	HIGGINS 34-33D	Lower Shale Unit 1	10818.7
33105016130000	HIGGINS 34-33D	Lower Shale Unit 2	10804.1
33105016130000	HIGGINS 34-33D	Lower Shale Unit 3	10797.6
33105016130000	HIGGINS 34-33D	Middle Member Unit 5	10752.7
33105016130000	HIGGINS 34-33D	Upper Shale Unit 1	10750.1

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33105016130000	HIGGINS 34-33D	Upper Shale Unit 2	10741.2
33105016130000	HIGGINS 34-33D	Upper Shale Unit 3	10733.1
33061011960000	HOWARD USA 11-1H	Middle Member Unit 3	10865.9
33061011960000	HOWARD USA 11-1H	Middle Member Unit 4	10826.9
33061011960000	HOWARD USA 11-1H	Middle Member Unit 5	10795.8
33061011960000	HOWARD USA 11-1H	Upper Shale Unit 1	10773.6
33061011960000	HOWARD USA 11-1H	Upper Shale Unit 1	10777.7
33061011960000	HOWARD USA 11-1H	Upper Shale Unit 2	10760.3
33061011960000	HOWARD USA 11-1H	Upper Shale Unit 2	10767.1
33061011960000	HOWARD USA 11-1H	Upper Shale Unit 3	10743.2
33061004930000	J. HORST 1-11H	Basal Bakken	10668.7
33061004930000	J. HORST 1-11H	Lower Shale Unit 1	10661.5
33061004930000	J. HORST 1-11H	Lower Shale Unit 3	10624.5
33061004930000	J. HORST 1-11H	Middle Member Unit 1	10619.6
33061004930000	J. HORST 1-11H	Middle Member Unit 2	10605
33061004930000	J. HORST 1-11H	Middle Member Unit 3	10574
33061004930000	J. HORST 1-11H	Middle Member Unit 4	10562.4
33061004930000	J. HORST 1-11H	Middle Member Unit 5	10551.6
33061004930000	J. HORST 1-11H	Upper Shale Unit 3	10534.3
33061012940000	JERICHO 2-5H-TF	Basal Bakken	10208.8
33061012940000	JERICHO 2-5H-TF	Lower Shale Unit 1	10203.9
33061012940000	JERICHO 2-5H-TF	Lower Shale Unit 2	10187.2
33061012940000	JERICHO 2-5H-TF	Lower Shale Unit 3	10175.4
33061012940000	JERICHO 2-5H-TF	Middle Member Unit 5	10129.6
33061012940000	JERICHO 2-5H-TF	Upper Shale Unit 1	10127.2
33061012940000	JERICHO 2-5H-TF	Upper Shale Unit 2	10122
33061012940000	JERICHO 2-5H-TF	Upper Shale Unit 3	10110.1
33025007290000	JORGENSEN 1-15H	Basal Bakken	11032.7
33025007290000	JORGENSEN 1-15H	Lower Shale Unit 1	11023.7
33025007290000	JORGENSEN 1-15H	Lower Shale Unit 2	11017.3
33025007290000	JORGENSEN 1-15H	Lower Shale Unit 3	11010.3
33025007290000	JORGENSEN 1-15H	Middle Member Unit 3	10982.5
33025007290000	JORGENSEN 1-15H	Middle Member Unit 4	10975.9
33025007290000	JORGENSEN 1-15H	Middle Member Unit 5	10968.7
33025007290000	JORGENSEN 1-15H	Upper Shale Unit 1	10966.5
33025007290000	JORGENSEN 1-15H	Upper Shale Unit 2	10961.3
33025007290000	JORGENSEN 1-15H	Upper Shale Unit 3	10951.2
33061004810000	JORSTAD 10-9	Basal Bakken	9675.53
33061004810000	JORSTAD 10-9	Lower Shale Unit 1	9663.49
33061004810000	JORSTAD 10-9	Lower Shale Unit 2	9649.87
33061004810000	JORSTAD 10-9	Lower Shale Unit 3	9640.82

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33061004810000	JORSTAD 10-9	Middle Member Unit 3	9594.9
33061004810000	JORSTAD 10-9	Middle Member Unit 4	9587.76
33061004810000	JORSTAD 10-9	Middle Member Unit 5	9576.51
33061004810000	JORSTAD 10-9	Upper Shale Unit 1	9574.3
33061004810000	JORSTAD 10-9	Upper Shale Unit 2	9568.12
33061004810000	JORSTAD 10-9	Upper Shale Unit 3	9560.79
33053027690000	LARS ROTHIE 32-29H	Basal Bakken	10697.7
33053027690000	LARS ROTHIE 32-29H	Lower Shale Unit 1	10694
33053027690000	LARS ROTHIE 32-29H	Lower Shale Unit 2	10680.1
33053027690000	LARS ROTHIE 32-29H	Lower Shale Unit 3	10675
33053027690000	LARS ROTHIE 32-29H	Middle Member Unit 3	10650.6
33053027690000	LARS ROTHIE 32-29H	Middle Member Unit 4	10648.8
33053027690000	LARS ROTHIE 32-29H	Middle Member Unit 5	10634.9
33053027690000	LARS ROTHIE 32-29H	Upper Shale Unit 1	10632.1
33053027690000	LARS ROTHIE 32-29H	Upper Shale Unit 2	10626.6
33053027690000	LARS ROTHIE 32-29H	Upper Shale Unit 3	10617.1
33053028530000	LARSEN 1-16H	Basal Bakken	10572.6
33053028530000	LARSEN 1-16H	Lower Shale Unit 1	10567.8
33053028530000	LARSEN 1-16H	Lower Shale Unit 2	10557.9
33053028530000	LARSEN 1-16H	Lower Shale Unit 3	10551.1
33053028530000	LARSEN 1-16H	Middle Member Unit 3	10516.9
33053028530000	LARSEN 1-16H	Middle Member Unit 4	10511.4
33053028530000	LARSEN 1-16H	Middle Member Unit 5	10504.6
33053028530000	LARSEN 1-16H	Upper Shale Unit 2	10494.5
33053028530000	LARSEN 1-16H	Upper Shale Unit 3	10489.4
33053028060000	LEVANG 3-22H	Basal Bakken	10730.5
33053028060000	LEVANG 3-22H	Lower Shale Unit 1	10724.4
33053028060000	LEVANG 3-22H	Lower Shale Unit 2	10710.5
33053028060000	LEVANG 3-22H	Lower Shale Unit 3	10707.5
33053028060000	LEVANG 3-22H	Middle Member Unit 1	10703
33053028060000	LEVANG 3-22H	Middle Member Unit 2	10697.1
33053028060000	LEVANG 3-22H	Middle Member Unit 3	10679
33053028060000	LEVANG 3-22H	Middle Member Unit 4	10673.1
33053028060000	LEVANG 3-22H	Middle Member Unit 5	10666.2
33053028060000	LEVANG 3-22H	Upper Shale Unit 1	10663
33053028060000	LEVANG 3-22H	Upper Shale Unit 2	10657.1
33053028060000	LEVANG 3-22H	Upper Shale Unit 3	10647.1
33061991880000	LIBERTY 22-12M	Basal Bakken	9725.6
33061991880000	LIBERTY 22-12M	Lower Shale Unit 1	9718.71
33061991880000	LIBERTY 22-12M	Lower Shale Unit 2	9705.46
33061991880000	LIBERTY 22-12M	Lower Shale Unit 3	9691.01

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33061991880000	LIBERTY 22-12M	Middle Member Unit 5	9653.37
33061991880000	LIBERTY 22-12M	Upper Shale Unit 1	9650.19
33061991880000	LIBERTY 22-12M	Upper Shale Unit 2	9641.98
33061991880000	LIBERTY 22-12M	Upper Shale Unit 3	9634.69
33025009990000	LIND 2-1H	Basal Bakken	11199.1
33025009990000	LIND 2-1H	Lower Shale Unit 2	11196.2
33025009990000	LIND 2-1H	Lower Shale Unit 3	11189.7
33025009990000	LIND 2-1H	Middle Member Unit 1	11187.3
33025009990000	LIND 2-1H	Middle Member Unit 2	11177.7
33025009990000	LIND 2-1H	Middle Member Unit 3	11167.5
33025009990000	LIND 2-1H	Middle Member Unit 4	11164.9
33025009990000	LIND 2-1H	Middle Member Unit 5	11157.7
33025009990000	LIND 2-1H	Upper Shale Unit 1	11155
33025009990000	LIND 2-1H	Upper Shale Unit 2	11149.7
33025009990000	LIND 2-1H	Upper Shale Unit 3	11143.5
33053025880000	LYNN 1	Basal Bakken	10771.9
33053025880000	LYNN 1	Lower Shale Unit 1	10769.6
33053025880000	LYNN 1	Lower Shale Unit 2	10767.3
33053025880000	LYNN 1	Lower Shale Unit 3	10764.1
33053025880000	LYNN 1	Middle Member Unit 3	10737.8
33053025880000	LYNN 1	Middle Member Unit 5	10728.9
33053025880000	LYNN 1	Upper Shale Unit 1	10725
33053025880000	LYNN 1	Upper Shale Unit 2	10719.2
33053025880000	LYNN 1	Upper Shale Unit 3	10714
33053030370000	MANTA RAY 1-12H	Basal Bakken	11193.5
33053030370000	MANTA RAY 1-12H	Lower Shale Unit 2	11189.8
33053030370000	MANTA RAY 1-12H	Lower Shale Unit 3	11184.4
33053030370000	MANTA RAY 1-12H	Middle Member Unit 3	11165.3
33053030370000	MANTA RAY 1-12H	Middle Member Unit 4	11162.8
33053030370000	MANTA RAY 1-12H	Middle Member Unit 5	11149.9
33053030370000	MANTA RAY 1-12H	Upper Shale Unit 1	11143.9
33053030370000	MANTA RAY 1-12H	Upper Shale Unit 2	11140.6
33053030370000	MANTA RAY 1-12H	Upper Shale Unit 3	11134.7
33053010840000	MATTHEW 1-20	Lower Shale Unit 1	10784.2
33053010840000	MATTHEW 1-20	Lower Shale Unit 2	10776.4
33053010840000	MATTHEW 1-20	Lower Shale Unit 3	10773.6
33053010840000	MATTHEW 1-20	Middle Member Unit 1	10769.1
33053010840000	MATTHEW 1-20	Middle Member Unit 2	10756.4
33053010840000	MATTHEW 1-20	Middle Member Unit 3	10747.4
33053010840000	MATTHEW 1-20	Middle Member Unit 4	10743.8
33053010840000	MATTHEW 1-20	Middle Member Unit 5	10734.7

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33053010840000	MATTHEW 1-20	Upper Shale Unit 3	10719.2
33105007510000	MATTSON 1-20	Middle Member Unit 1	9825.6
33105007510000	MATTSON 1-20	Middle Member Unit 2	9809.19
33105007510000	MATTSON 1-20	Middle Member Unit 3	9800.5
33105007510000	MATTSON 1-20	Middle Member Unit 4	9796.95
33105007510000	MATTSON 1-20	Middle Member Unit 5	9786.65
33055001140000	MHA 1-18H-150-90	Basal Bakken	9825.05
33055001140000	MHA 1-18H-150-90	Lower Shale Unit 1	9820.58
33055001140000	MHA 1-18H-150-90	Lower Shale Unit 2	9805.72
33055001140000	MHA 1-18H-150-90	Lower Shale Unit 3	9793.1
33055001140000	MHA 1-18H-150-90	Middle Member Unit 3	9775.29
33055001140000	MHA 1-18H-150-90	Middle Member Unit 4	9762.24
33055001140000	MHA 1-18H-150-90	Middle Member Unit 5	9751.54
33055001140000	MHA 1-18H-150-90	Upper Shale Unit 2	9744.66
33055001140000	MHA 1-18H-150-90	Upper Shale Unit 3	9736.76
33053005670000	MOGEN 1	Lower Shale Unit 2	10065.2
33053005670000	MOGEN 1	Lower Shale Unit 3	10054.4
33053005670000	MOGEN 1	Middle Member Unit 5	10006
33053027130000	MORK 24-8	Basal Bakken	11018.3
33053027130000	MORK 24-8	Lower Shale Unit 1	11016.8
33053027130000	MORK 24-8	Lower Shale Unit 3	11012
33053027130000	MORK 24-8	Middle Member Unit 5	10978.3
33053027130000	MORK 24-8	Upper Shale Unit 1	10974.1
33053027130000	MORK 24-8	Upper Shale Unit 2	10970.1
33053027130000	MORK 24-8	Upper Shale Unit 3	10963.8
33053028540000	MYRMIDON 1-2H	Basal Bakken	11143.6
33053028540000	MYRMIDON 1-2H	Lower Shale Unit 1	11064.3
33053028540000	MYRMIDON 1-2H	Lower Shale Unit 2	10989.7
33053028540000	MYRMIDON 1-2H	Lower Shale Unit 3	10960.2
33053028540000	MYRMIDON 1-2H	Middle Member Unit 1	10888.2
33053028540000	MYRMIDON 1-2H	Middle Member Unit 2	10871.8
33053028540000	MYRMIDON 1-2H	Middle Member Unit 3	10862.2
33053028540000	MYRMIDON 1-2H	Middle Member Unit 4	10857.2
33053028540000	MYRMIDON 1-2H	Middle Member Unit 5	10854.5
33053028540000	MYRMIDON 1-2H	Upper Shale Unit 1	10838.7
33053028540000	MYRMIDON 1-2H	Upper Shale Unit 2	10822.7
33053028540000	MYRMIDON 1-2H	Upper Shale Unit 3	10812.7
33061005210000	N&D 1-05H	Basal Bakken	9497.57
33061005210000	N&D 1-05H	Lower Shale Unit 1	9491.38
33061005210000	N&D 1-05H	Lower Shale Unit 2	9475.52
33061005210000	N&D 1-05H	Lower Shale Unit 3	9466.32

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33061005210000	N&D 1-05H	Middle Member Unit 5	9428.57
33061005210000	N&D 1-05H	Upper Shale Unit 1	9424.45
33061005210000	N&D 1-05H	Upper Shale Unit 2	9420.17
33061005210000	N&D 1-05H	Upper Shale Unit 3	9413.03
33105007450000	N.D.C. A DEEP UNIT 1	Basal Bakken	9685.6
33105007450000	N.D.C. A DEEP UNIT 1	Lower Shale Unit 3	9660.75
33105007450000	N.D.C. A DEEP UNIT 1	Middle Member Unit 1	9654.27
33105007450000	N.D.C. A DEEP UNIT 1	Middle Member Unit 2	9639.78
33105007450000	N.D.C. A DEEP UNIT 1	Middle Member Unit 3	9619.14
33105007450000	N.D.C. A DEEP UNIT 1	Middle Member Unit 4	9605.67
33105007450000	N.D.C. A DEEP UNIT 1	Middle Member Unit 5	9599.71
33105007450000	N.D.C. A DEEP UNIT 1	Upper Shale Unit 3	9585.81
33105007310000	NELSON 43-29	Lower Shale Unit 3	9656
33105007310000	NELSON 43-29	Middle Member Unit 1	9647.99
33105007310000	NELSON 43-29	Middle Member Unit 2	9633.79
33105007310000	NELSON 43-29	Middle Member Unit 3	9619.77
33105007310000	NELSON 43-29	Middle Member Unit 4	9608.74
33105007310000	NELSON 43-29	Middle Member Unit 5	9600.33
33105007310000	NELSON 43-29	Upper Shale Unit 3	9584.15
33061004980000	NELSON 1-11H	Basal Bakken	9529.25
33061004980000	NELSON 1-11H	Lower Shale Unit 1	9523.18
33061004980000	NELSON 1-11H	Lower Shale Unit 2	9504.63
33061004980000	NELSON 1-11H	Lower Shale Unit 3	9490
33061004980000	NELSON 1-11H	Middle Member Unit 5	9439.52
33061004980000	NELSON 1-11H	Upper Shale Unit 1	9436.55
33061004980000	NELSON 1-11H	Upper Shale Unit 2	9431.86
33061004980000	NELSON 1-11H	Upper Shale Unit 3	9423.45
33061004890000	NELSON FARMS 1-24H	Basal Bakken	9687.19
33061004890000	NELSON FARMS 1-24H	Lower Shale Unit 1	9684.5
33061004890000	NELSON FARMS 1-24H	Lower Shale Unit 2	9672.2
33061004890000	NELSON FARMS 1-24H	Lower Shale Unit 3	9650.65
33061004890000	NELSON FARMS 1-24H	Middle Member Unit 3	9628.32
33061004890000	NELSON FARMS 1-24H	Middle Member Unit 4	9622.69
33061004890000	NELSON FARMS 1-24H	Middle Member Unit 5	9608.3
33061004890000	NELSON FARMS 1-24H	Upper Shale Unit 1	9605.1
33061004890000	NELSON FARMS 1-24H	Upper Shale Unit 3	9595.83
33105016670000	NESSON STATE 42X-36	Basal Bakken	10433.2
33105016670000	NESSON STATE 42X-36	Lower Shale Unit 1	10415.1
33105016670000	NESSON STATE 42X-36	Lower Shale Unit 2	10399.2
33105016670000	NESSON STATE 42X-36	Lower Shale Unit 3	10387.5
33105016670000	NESSON STATE 42X-36	Middle Member Unit 1	10380

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33105016670000	NESSON STATE 42X-36	Middle Member Unit 2	10355.9
33105016670000	NESSON STATE 42X-36	Middle Member Unit 3	10335.8
33105016670000	NESSON STATE 42X-36	Middle Member Unit 4	10321.4
33105016670000	NESSON STATE 42X-36	Middle Member Unit 5	10314.2
33105016670000	NESSON STATE 42X-36	Upper Shale Unit 1	10310.9
33105016670000	NESSON STATE 42X-36	Upper Shale Unit 2	10304.1
33105016670000	NESSON STATE 42X-36	Upper Shale Unit 3	10294.2
33105007540000	OLSON 32-28	Basal Bakken	9640.8
33105007540000	OLSON 32-28	Lower Shale Unit 3	9612.45
33105007540000	OLSON 32-28	Middle Member Unit 1	9607.48
33105007540000	OLSON 32-28	Middle Member Unit 2	9601.27
33105007540000	OLSON 32-28	Middle Member Unit 3	9577.46
33105007540000	OLSON 32-28	Middle Member Unit 4	9565.45
33105007540000	OLSON 32-28	Middle Member Unit 5	9558.75
33105007540000	OLSON 32-28	Upper Shale Unit 3	9541.41
33105015980000	PEGASUS 2-17H	Basal Bakken	10218.5
33105015980000	PEGASUS 2-17H	Lower Shale Unit 1	10214.8
33105015980000	PEGASUS 2-17H	Lower Shale Unit 2	10194.8
33105015980000	PEGASUS 2-17H	Lower Shale Unit 3	10187.6
33105015980000	PEGASUS 2-17H	Middle Member Unit 3	10146.6
33105015980000	PEGASUS 2-17H	Middle Member Unit 4	10144.3
33105015980000	PEGASUS 2-17H	Middle Member Unit 5	10129.9
33105015980000	PEGASUS 2-17H	Upper Shale Unit 2	10121.8
33105015980000	PEGASUS 2-17H	Upper Shale Unit 3	10116.6
33053030490000	PITTSBURGH 1-3H	Basal Bakken	10256.9
33053030490000	PITTSBURGH 1-3H	Lower Shale Unit 1	10251.4
33053030490000	PITTSBURGH 1-3H	Lower Shale Unit 2	10240.5
33053030490000	PITTSBURGH 1-3H	Lower Shale Unit 3	10229.9
33053030490000	PITTSBURGH 1-3H	Middle Member Unit 3	10192.9
33053030490000	PITTSBURGH 1-3H	Middle Member Unit 4	10191.2
33053030490000	PITTSBURGH 1-3H	Middle Member Unit 5	10181.3
33053030490000	PITTSBURGH 1-3H	Upper Shale Unit 1	10175.6
33053030490000	PITTSBURGH 1-3H	Upper Shale Unit 2	10166
33053030490000	PITTSBURGH 1-3H	Upper Shale Unit 3	10161
33025006690000	PRAIRIE ROSE 24-31H	Basal Bakken	11128.4
33025006690000	PRAIRIE ROSE 24-31H	Lower Shale Unit 2	11119.8
33025006690000	PRAIRIE ROSE 24-31H	Lower Shale Unit 3	11113.3
33025006690000	PRAIRIE ROSE 24-31H	Middle Member Unit 2	11097.8
33025006690000	PRAIRIE ROSE 24-31H	Middle Member Unit 4	11083.3
33025006690000	PRAIRIE ROSE 24-31H	Middle Member Unit 5	11077.4
33025006690000	PRAIRIE ROSE 24-31H	Upper Shale Unit 1	11073.8

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33025006690000	PRAIRIE ROSE 24-31H	Upper Shale Unit 2	11067.2
33025006690000	PRAIRIE ROSE 24-31H	Upper Shale Unit 3	11061.1
33053025400000	QUALE 31A-1-2	Basal Bakken	10251.5
33053025400000	QUALE 31A-1-2	Lower Shale Unit 1	10247.7
33053025400000	QUALE 31A-1-2	Lower Shale Unit 2	10235.8
33053025400000	QUALE 31A-1-2	Lower Shale Unit 3	10229.5
33053025400000	QUALE 31A-1-2	Middle Member Unit 2	10207
33053025400000	QUALE 31A-1-2	Middle Member Unit 3	10193.7
33053025400000	QUALE 31A-1-2	Middle Member Unit 4	10190.8
33053025400000	QUALE 31A-1-2	Middle Member Unit 5	10185.7
33053025400000	QUALE 31A-1-2	Upper Shale Unit 1	10179.5
33053025400000	QUALE 31A-1-2	Upper Shale Unit 2	10171.3
33053010510000	QUALE 3X	Middle Member Unit 1	10285.5
33053010510000	QUALE 3X	Middle Member Unit 2	10265
33053010510000	QUALE 3X	Middle Member Unit 3	10257.3
33053010510000	QUALE 3X	Middle Member Unit 4	10252.8
33053010510000	QUALE 3X	Middle Member Unit 5	10245.6
33053010510000	QUALE 3X	Upper Shale Unit 3	10230.2
33053002360000	R. A. HENDRICKSON 1	Lower Shale Unit 3	10418.8
33053002360000	R. A. HENDRICKSON 1	Middle Member Unit 1	10414.5
33053002360000	R. A. HENDRICKSON 1	Middle Member Unit 2	10397.9
33053002360000	R. A. HENDRICKSON 1	Middle Member Unit 3	10383.7
33053002360000	R. A. HENDRICKSON 1	Middle Member Unit 4	10375.3
33053002360000	R. A. HENDRICKSON 1	Middle Member Unit 5	10371.8
33061007730000	REUM 11-32H	Basal Bakken	9890.5
33061007730000	REUM 11-32H	Lower Shale Unit 1	9887.64
33061007730000	REUM 11-32H	Lower Shale Unit 2	9870.4
33061007730000	REUM 11-32H	Lower Shale Unit 3	9853.2
33061007730000	REUM 11-32H	Middle Member Unit 5	9807.33
33061007730000	REUM 11-32H	Upper Shale Unit 1	9804.01
33061007730000	REUM 11-32H	Upper Shale Unit 2	9798.16
33061007730000	REUM 11-32H	Upper Shale Unit 3	9793.09
33025009820000	ROBERTS TRUST 1-13H	Basal Bakken	10738.4
33025009820000	ROBERTS TRUST 1-13H	Lower Shale Unit 1	10734.4
33025009820000	ROBERTS TRUST 1-13H	Lower Shale Unit 2	10728.5
33025009820000	ROBERTS TRUST 1-13H	Lower Shale Unit 3	10721.8
33025009820000	ROBERTS TRUST 1-13H	Middle Member Unit 3	10692.8
33025009820000	ROBERTS TRUST 1-13H	Middle Member Unit 4	10688.6
33025009820000	ROBERTS TRUST 1-13H	Middle Member Unit 5	10678.7
33025009820000	ROBERTS TRUST 1-13H	Upper Shale Unit 1	10674.1
33025009820000	ROBERTS TRUST 1-13H	Upper Shale Unit 2	10665.3

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33025009820000	ROBERTS TRUST 1-13H	Upper Shale Unit 3	10655.8
33053013590000	ROLFSON 1	Lower Shale Unit 3	11102.3
33053013590000	ROLFSON 1	Middle Member Unit 5	11060
33053013980000	ROLFSRUD 11-17	Basal Bakken	10681.5
33053013980000	ROLFSRUD 11-17	Lower Shale Unit 3	10658.6
33053013980000	ROLFSRUD 11-17	Middle Member Unit 1	10655.6
33053013980000	ROLFSRUD 11-17	Middle Member Unit 2	10645.6
33053013980000	ROLFSRUD 11-17	Middle Member Unit 3	10628.8
33053013980000	ROLFSRUD 11-17	Middle Member Unit 4	10617.4
33053013980000	ROLFSRUD 11-17	Middle Member Unit 5	10613
33053013980000	ROLFSRUD 11-17	Upper Shale Unit 3	10595.8
33053021630000	ROSE 1	Basal Bakken	10604.4
33053021630000	ROSE 1	Lower Shale Unit 1	10596.7
33053021630000	ROSE 1	Lower Shale Unit 2	10590.5
33053021630000	ROSE 1	Lower Shale Unit 3	10580
33053021630000	ROSE 1	Middle Member Unit 3	10542
33053021630000	ROSE 1	Middle Member Unit 4	10540.9
33053021630000	ROSE 1	Middle Member Unit 5	10537.5
33053021630000	ROSE 1	Upper Shale Unit 1	10527.6
33053021630000	ROSE 1	Upper Shale Unit 2	10520.8
33053021630000	ROSE 1	Upper Shale Unit 3	10517.3
33053003910000	ROSE HOPKINS HAND 2 SWD	Lower Shale Unit 1	10693.6
33053003910000	ROSE HOPKINS HAND 2 SWD	Lower Shale Unit 2	10673.2
33053003910000	ROSE HOPKINS HAND 2 SWD	Middle Member Unit 3	10642.1
33053003910000	ROSE HOPKINS HAND 2 SWD	Middle Member Unit 4	10628.1
33061007220000	ROSENCRANS 44-21H	Basal Bakken	9466.14
33061007220000	ROSENCRANS 44-21H	Lower Shale Unit 1	9462.87
33061007220000	ROSENCRANS 44-21H	Lower Shale Unit 2	9440.59
33061007220000	ROSENCRANS 44-21H	Lower Shale Unit 3	9431.41
33061007220000	ROSENCRANS 44-21H	Middle Member Unit 5	9396.46
33061007220000	ROSENCRANS 44-21H	Upper Shale Unit 1	9392.96
33061007220000	ROSENCRANS 44-21H	Upper Shale Unit 2	9388.16
33061007220000	ROSENCRANS 44-21H	Upper Shale Unit 3	9380.73
33061005770000	RS-NELSON-156-91 1423H-1	Basal Bakken	9286.07
33061005770000	RS-NELSON-156-91 1423H-1	Lower Shale Unit 1	9279.98
33061005770000	RS-NELSON-156-91 1423H-1	Lower Shale Unit 2	9267.52
33061005770000	RS-NELSON-156-91 1423H-1	Lower Shale Unit 3	9255.98
33061005770000	RS-NELSON-156-91 1423H-1	Middle Member Unit 3	9238.56
33061005770000	RS-NELSON-156-91 1423H-1	Middle Member Unit 4	9225.46
33061005770000	RS-NELSON-156-91 1423H-1	Middle Member Unit 5	9215.09
33061005770000	RS-NELSON-156-91 1423H-1	Upper Shale Unit 1	9210.74

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33061005770000	RS-NELSON-156-91 1423H-1	Upper Shale Unit 2	9202.26
33061005770000	RS-NELSON-156-91 1423H-1	Upper Shale Unit 3	9197.38
33061006660000	RS-STATE C-157-90- 3603H-1	Basal Bakken	8843.44
33061006660000	RS-STATE C-157-90- 3603H-1	Lower Shale Unit 1	8841.05
33061006660000	RS-STATE C-157-90- 3603H-1	Lower Shale Unit 2	8831.08
33061006660000	RS-STATE C-157-90- 3603H-1	Lower Shale Unit 3	8822.44
33061006660000	RS-STATE C-157-90- 3603H-1	Middle Member Unit 5	8792.37
33061006660000	RS-STATE C-157-90- 3603H-1	Upper Shale Unit 1	8788.56
33061006660000	RS-STATE C-157-90- 3603H-1	Upper Shale Unit 2	8781.47
33061006660000	RS-STATE C-157-90- 3603H-1	Upper Shale Unit 3	8773.16
33061006850000	RYSTEDT 4-11H	Basal Bakken	9302.83
33061006850000	RYSTEDT 4-11H	Lower Shale Unit 1	9294.22
33061006850000	RYSTEDT 4-11H	Lower Shale Unit 2	9280.51
33061006850000	RYSTEDT 4-11H	Lower Shale Unit 3	9269.82
33061006850000	RYSTEDT 4-11H	Middle Member Unit 5	9234.37
33061006850000	RYSTEDT 4-11H	Upper Shale Unit 1	9231.21
33061006850000	RYSTEDT 4-11H	Upper Shale Unit 2	9225.48
33061006850000	RYSTEDT 4-11H	Upper Shale Unit 3	9216.87
33053026840000	SAETZ FEDERAL 6-25	Middle Member Unit 5	11120.4
33053026840000	SAETZ FEDERAL 6-25	Upper Shale Unit 1	11117.9
33053026840000	SAETZ FEDERAL 6-25	Upper Shale Unit 2	11111.6
33053026840000	SAETZ FEDERAL 6-25	Upper Shale Unit 3	11105.8
33053028580000	SAKAKAWEA FEDERAL 13X-35	Basal Bakken	9869.68
33053028580000	SAKAKAWEA FEDERAL 13X-35	Lower Shale Unit 1	9859.9
33053028580000	SAKAKAWEA FEDERAL 13X-35	Lower Shale Unit 2	9849.11
33053028580000	SAKAKAWEA FEDERAL 13X-35	Lower Shale Unit 3	9840.85
33053028580000	SAKAKAWEA FEDERAL 13X-35	Middle Member Unit 2	9823.14
33053028580000	SAKAKAWEA FEDERAL 13X-35	Middle Member Unit 3	9800.73
33053028580000	SAKAKAWEA FEDERAL 13X-35	Middle Member Unit 4	9794
33053028580000	SAKAKAWEA FEDERAL 13X-35	Middle Member Unit 5	9789.69
33053028580000	SAKAKAWEA FEDERAL 13X-35	Upper Shale Unit 1	9778.57
33053028580000	SAKAKAWEA FEDERAL 13X-35	Upper Shale Unit 2	9772.18
33053028580000	SAKAKAWEA FEDERAL 13X-35	Upper Shale Unit 3	9765.93
33053032240000	SANDIE 1-28H	Basal Bakken	11202.3
33053032240000	SANDIE 1-28H	Lower Shale Unit 1	11188.7
33053032240000	SANDIE 1-28H	Lower Shale Unit 2	11164.3
33053032240000	SANDIE 1-28H	Lower Shale Unit 3	11151.9
33053032240000	SANDIE 1-28H	Middle Member Unit 5	11087.4
33053032240000	SANDIE 1-28H	Upper Shale Unit 1	11083.4
33053032240000	SANDIE 1-28H	Upper Shale Unit 2	11072.9
33053032240000	SANDIE 1-28H	Upper Shale Unit 3	11060.9

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33061004900000	SARA G. BARSTAD 6-44H	Basal Bakken	10601
33061004900000	SARA G. BARSTAD 6-44H	Lower Shale Unit 1	10592.1
33061004900000	SARA G. BARSTAD 6-44H	Lower Shale Unit 2	10567.8
33061004900000	SARA G. BARSTAD 6-44H	Lower Shale Unit 3	10556.7
33061004900000	SARA G. BARSTAD 6-44H	Middle Member Unit 1	10549.2
33061004900000	SARA G. BARSTAD 6-44H	Middle Member Unit 2	10527
33061004900000	SARA G. BARSTAD 6-44H	Middle Member Unit 3	10507
33061004900000	SARA G. BARSTAD 6-44H	Middle Member Unit 4	10500.1
33061004900000	SARA G. BARSTAD 6-44H	Middle Member Unit 5	10490
33061004900000	SARA G. BARSTAD 6-44H	Upper Shale Unit 1	10478.7
33061004900000	SARA G. BARSTAD 6-44H	Upper Shale Unit 2	10471
33061004900000	SARA G. BARSTAD 6-44H	Upper Shale Unit 3	10466.7
33105018030000	SCANLAN 3-5H	Basal Bakken	11099.4
33105018030000	SCANLAN 3-5H	Lower Shale Unit 1	11095.3
33105018030000	SCANLAN 3-5H	Lower Shale Unit 2	11082.4
33105018030000	SCANLAN 3-5H	Lower Shale Unit 3	11075.4
33105018030000	SCANLAN 3-5H	Middle Member Unit 1	11070.6
33105018030000	SCANLAN 3-5H	Middle Member Unit 2	11055.5
33105018030000	SCANLAN 3-5H	Middle Member Unit 3	11045.1
33105018030000	SCANLAN 3-5H	Middle Member Unit 4	11040.4
33105018030000	SCANLAN 3-5H	Middle Member Unit 5	11031.3
33105018030000	SCANLAN 3-5H	Upper Shale Unit 1	11026.7
33105018030000	SCANLAN 3-5H	Upper Shale Unit 2	11019.9
33105018030000	SCANLAN 3-5H	Upper Shale Unit 3	11013.2
33105007460000	SCHMIDT 42-30	Basal Bakken	9727.66
33105007460000	SCHMIDT 42-30	Lower Shale Unit 3	9702.12
33105007460000	SCHMIDT 42-30	Middle Member Unit 1	9699.43
33105007460000	SCHMIDT 42-30	Middle Member Unit 2	9682.45
33105007460000	SCHMIDT 42-30	Middle Member Unit 3	9671.48
33105007460000	SCHMIDT 42-30	Middle Member Unit 4	9660.91
33105007460000	SCHMIDT 42-30	Middle Member Unit 5	9653.87
33105007460000	SCHMIDT 42-30	Upper Shale Unit 3	9638.82
33053019150000	SILURIAN UNIT 32 1	Basal Bakken	10174.7
33053019150000	SILURIAN UNIT 32 1	Lower Shale Unit 3	10151.3
33053019150000	SILURIAN UNIT 32 1	Middle Member Unit 5	10105.8
33053019150000	SILURIAN UNIT 32 1	Upper Shale Unit 3	10092.4
33053020160000	SIVERTSON 15-33	Middle Member Unit 1	10767.4
33053020160000	SIVERTSON 15-33	Middle Member Unit 2	10756.5
33053020160000	SIVERTSON 15-33	Middle Member Unit 3	10745.8
33053020160000	SIVERTSON 15-33	Middle Member Unit 4	10742
33053020160000	SIVERTSON 15-33	Middle Member Unit 5	10736

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33053011730000	SIVERTSON 29-23 R#1	Lower Shale Unit 1	10649
33053011730000	SIVERTSON 29-23 R#1	Lower Shale Unit 2	10644.2
33053011730000	SIVERTSON 29-23 R#1	Lower Shale Unit 3	10635.6
33053011730000	SIVERTSON 29-23 R#1	Middle Member Unit 1	10624
33053011730000	SIVERTSON 29-23 R#1	Middle Member Unit 2	10615.2
33053011730000	SIVERTSON 29-23 R#1	Middle Member Unit 3	10606.8
33053011730000	SIVERTSON 29-23 R#1	Middle Member Unit 4	10600.3
33053011730000	SIVERTSON 29-23 R#1	Middle Member Unit 5	10592.2
33053011730000	SIVERTSON 29-23 R#1	Upper Shale Unit 3	10575.3
33105015270000	STATE 36-31H	Basal Bakken	9862.77
33105015270000	STATE 36-31H	Lower Shale Unit 1	9857.96
33105015270000	STATE 36-31H	Lower Shale Unit 2	9845.2
33105015270000	STATE 36-31H	Lower Shale Unit 3	9834.71
33105015270000	STATE 36-31H	Middle Member Unit 1	9832.55
33105015270000	STATE 36-31H	Middle Member Unit 2	9814.81
33105015270000	STATE 36-31H	Middle Member Unit 3	9799.18
33105015270000	STATE 36-31H	Middle Member Unit 4	9789.54
33105015270000	STATE 36-31H	Middle Member Unit 5	9780.92
33105015270000	STATE 36-31H	Upper Shale Unit 1	9772.7
33105015270000	STATE 36-31H	Upper Shale Unit 2	9767.79
33105015270000	STATE 36-31H	Upper Shale Unit 3	9762.46
33105018900000	STATE 36-1 2H	Basal Bakken	10812.8
33105018900000	STATE 36-1 2H	Lower Shale Unit 1	10807
33105018900000	STATE 36-1 2H	Lower Shale Unit 2	10798.5
33105018900000	STATE 36-1 2H	Lower Shale Unit 3	10792.9
33105018900000	STATE 36-1 2H	Middle Member Unit 5	10750.1
33105018900000	STATE 36-1 2H	Upper Shale Unit 1	10742.4
33105018900000	STATE 36-1 2H	Upper Shale Unit 2	10737.8
33105018900000	STATE 36-1 2H	Upper Shale Unit 3	10732.1
33025005970000	STOHLER 21-3H	Basal Bakken	10926.2
33025005970000	STOHLER 21-3H	Lower Shale Unit 2	10916.7
33025005970000	STOHLER 21-3H	Lower Shale Unit 3	10909.8
33025005970000	STOHLER 21-3H	Middle Member Unit 1	10902.6
33025005970000	STOHLER 21-3H	Middle Member Unit 2	10894.9
33025005970000	STOHLER 21-3H	Middle Member Unit 3	10885.1
33025005970000	STOHLER 21-3H	Middle Member Unit 4	10880.2
33025005970000	STOHLER 21-3H	Middle Member Unit 5	10871.1
33025005970000	STOHLER 21-3H	Upper Shale Unit 1	10866.6
33025005970000	STOHLER 21-3H	Upper Shale Unit 2	10860.2
33025005970000	STOHLER 21-3H	Upper Shale Unit 3	10854.6
33053019370000	SWENSON 20-22ST2	Basal Bakken	10601.3

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33053019370000	SWENSON 20-22ST2	Lower Shale Unit 2	10578
33053019370000	SWENSON 20-22ST2	Lower Shale Unit 3	10578.9
33053019370000	SWENSON 20-22ST2	Middle Member Unit 1	10568.3
33053019370000	SWENSON 20-22ST2	Middle Member Unit 2	10554.9
33053019370000	SWENSON 20-22ST2	Middle Member Unit 3	10542.2
33053019370000	SWENSON 20-22ST2	Middle Member Unit 4	10539.6
33053019370000	SWENSON 20-22ST2	Middle Member Unit 5	10536.9
33053019370000	SWENSON 20-22ST2	Upper Shale Unit 3	10517.6
33053015950000	TANK 24-15	Basal Bakken	10759.3
33053015950000	TANK 24-15	Lower Shale Unit 1	10757.2
33053015950000	TANK 24-15	Lower Shale Unit 3	10738.2
33053015950000	TANK 24-15	Middle Member Unit 1	10732.5
33053015950000	TANK 24-15	Middle Member Unit 2	10720.2
33053015950000	TANK 24-15	Middle Member Unit 3	10706.6
33053015950000	TANK 24-15	Middle Member Unit 4	10698.3
33053015950000	TANK 24-15	Middle Member Unit 5	10691.5
33053015950000	TANK 24-15	Upper Shale Unit 1	10682.1
33053015950000	TANK 24-15	Upper Shale Unit 3	10674.5
33053031820000	TAT USA 34-22H	Middle Member Unit 1	11001.3
33053031820000	TAT USA 34-22H	Middle Member Unit 2	10977.3
33053031820000	TAT USA 34-22H	Middle Member Unit 3	10953.3
33053031820000	TAT USA 34-22H	Middle Member Unit 4	10942.3
33053031820000	TAT USA 34-22H	Middle Member Unit 5	10934.2
33053031820000	TAT USA 34-22H	Upper Shale Unit 1	10920.8
33053031820000	TAT USA 34-22H	Upper Shale Unit 2	10912.1
33053031820000	TAT USA 34-22H	Upper Shale Unit 3	10893.6
33025007160000	TEKAKWITHA 9-24H	Basal Bakken	10832.1
33025007160000	TEKAKWITHA 9-24H	Lower Shale Unit 1	10830.4
33025007160000	TEKAKWITHA 9-24H	Lower Shale Unit 2	10816.4
33025007160000	TEKAKWITHA 9-24H	Lower Shale Unit 3	10808.6
33025007160000	TEKAKWITHA 9-24H	Middle Member Unit 3	10777.9
33025007160000	TEKAKWITHA 9-24H	Middle Member Unit 4	10772.4
33025007160000	TEKAKWITHA 9-24H	Middle Member Unit 5	10763.4
33025007160000	TEKAKWITHA 9-24H	Upper Shale Unit 2	10757.8
33025007160000	TEKAKWITHA 9-24H	Upper Shale Unit 3	10748.8
33053004260000	THOMAS YELLOWFACE 1	Basal Bakken	10715.3
33053004260000	THOMAS YELLOWFACE 1	Lower Shale Unit 3	10695.6
33053004260000	THOMAS YELLOWFACE 1	Middle Member Unit 1	10690.7
33053004260000	THOMAS YELLOWFACE 1	Middle Member Unit 2	10666.9
33053004260000	THOMAS YELLOWFACE 1	Middle Member Unit 3	10660.9
33053004260000	THOMAS YELLOWFACE 1	Middle Member Unit 4	10654.6

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33053004260000	THOMAS YELLOWFACE 1	Middle Member Unit 5	10650.7
33053004260000	THOMAS YELLOWFACE 1	Upper Shale Unit 3	10635.3
33053026720000	TITAN E-GIERKE 20-1-H	Basal Bakken	11076.4
33053026720000	TITAN E-GIERKE 20-1-H	Lower Shale Unit 1	11074.1
33053026720000	TITAN E-GIERKE 20-1-H	Lower Shale Unit 2	11058
33053026720000	TITAN E-GIERKE 20-1-H	Lower Shale Unit 3	11050.6
33053026720000	TITAN E-GIERKE 20-1-H	Middle Member Unit 1	11046.6
33053026720000	TITAN E-GIERKE 20-1-H	Middle Member Unit 2	11025.8
33053026720000	TITAN E-GIERKE 20-1-H	Middle Member Unit 3	11015.1
33053026720000	TITAN E-GIERKE 20-1-H	Middle Member Unit 4	11009.8
33053026720000	TITAN E-GIERKE 20-1-H	Middle Member Unit 5	11004.6
33053026720000	TITAN E-GIERKE 20-1-H	Upper Shale Unit 1	11002
33053026720000	TITAN E-GIERKE 20-1-H	Upper Shale Unit 2	10994.3
33053026720000	TITAN E-GIERKE 20-1-H	Upper Shale Unit 3	10984.9
33053009610000	TOBACCO GARDEN 16-12	Basal Bakken	11050.9
33053009610000	TOBACCO GARDEN 16-12	Lower Shale Unit 2	11031.9
33053009610000	TOBACCO GARDEN 16-12	Lower Shale Unit 3	11022.2
33053009610000	TOBACCO GARDEN 16-12	Middle Member Unit 1	11018.5
33053009610000	TOBACCO GARDEN 16-12	Middle Member Unit 2	11001.6
33053009610000	TOBACCO GARDEN 16-12	Middle Member Unit 5	10978.3
33053009610000	TOBACCO GARDEN 16-12	Upper Shale Unit 1	10973.2
33053009610000	TOBACCO GARDEN 16-12	Upper Shale Unit 2	10965.7
33053009610000	TOBACCO GARDEN 16-12	Upper Shale Unit 3	10958.1
33025010010000	TWO SHIELDS BUTTE 14-21H	Basal Bakken	10522
33025010010000	TWO SHIELDS BUTTE 14-21H	Lower Shale Unit 1	10520.1
33025010010000	TWO SHIELDS BUTTE 14-21H	Lower Shale Unit 2	10508.2
33025010010000	TWO SHIELDS BUTTE 14-21H	Lower Shale Unit 3	10497.7
33025010010000	TWO SHIELDS BUTTE 14-21H	Middle Member Unit 3	10478.7
33025010010000	TWO SHIELDS BUTTE 14-21H	Middle Member Unit 4	10460.6
33025010010000	TWO SHIELDS BUTTE 14-21H	Middle Member Unit 5	10452.1
33025010010000	TWO SHIELDS BUTTE 14-21H	Upper Shale Unit 1	10447.9
33025010010000	TWO SHIELDS BUTTE 14-21H	Upper Shale Unit 2	10443.3
33025010010000	TWO SHIELDS BUTTE 14-21H	Upper Shale Unit 3	10438
33061011350000	URAN 31-2H	Middle Member Unit 5	10544
33061011350000	URAN 31-2H	Upper Shale Unit 1	10530.4
33061011350000	URAN 31-2H	Upper Shale Unit 2	10519.8
33061011350000	URAN 31-2H	Upper Shale Unit 3	10498.4
33061006300000	VAN HOOK 1-13H	Basal Bakken	9587.27
33061006300000	VAN HOOK 1-13H	Lower Shale Unit 1	9574.36
33061006300000	VAN HOOK 1-13H	Lower Shale Unit 2	9565.84
33061006300000	VAN HOOK 1-13H	Lower Shale Unit 3	9553.43

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33061006300000	VAN HOOK 1-13H	Middle Member Unit 5	9508.27
33061006300000	VAN HOOK 1-13H	Upper Shale Unit 1	9505.98
33061006300000	VAN HOOK 1-13H	Upper Shale Unit 2	9500.08
33105016910000	VIALL 30-1	Basal Bakken	10288.7
33105016910000	VIALL 30-1	Lower Shale Unit 1	10284.6
33105016910000	VIALL 30-1	Lower Shale Unit 2	10271.9
33105016910000	VIALL 30-1	Lower Shale Unit 3	10265.1
33105016910000	VIALL 30-1	Middle Member Unit 3	10222.6
33105016910000	VIALL 30-1	Middle Member Unit 4	10216
33105016910000	VIALL 30-1	Middle Member Unit 5	10206.2
33105016910000	VIALL 30-1	Upper Shale Unit 1	10201.5
33105016910000	VIALL 30-1	Upper Shale Unit 2	10194.9
33105016910000	VIALL 30-1	Upper Shale Unit 3	10190.6
33105015510000	VIOLET OLSON 31-29H	Basal Bakken	10046.2
33105015510000	VIOLET OLSON 31-29H	Lower Shale Unit 1	10041.9
33105015510000	VIOLET OLSON 31-29H	Lower Shale Unit 2	10030.3
33105015510000	VIOLET OLSON 31-29H	Lower Shale Unit 3	10023.6
33105015510000	VIOLET OLSON 31-29H	Middle Member Unit 5	9972.84
33105015510000	VIOLET OLSON 31-29H	Upper Shale Unit 1	9964.85
33105015510000	VIOLET OLSON 31-29H	Upper Shale Unit 2	9959.4
33105015510000	VIOLET OLSON 31-29H	Upper Shale Unit 3	9955.42
33053020180000	W.C. DODGE TRUST ESTATE 1	Basal Bakken	10683.2
33053020180000	W.C. DODGE TRUST ESTATE 1	Lower Shale Unit 3	10660.4
33053020180000	W.C. DODGE TRUST ESTATE 1	Middle Member Unit 1	10656.6
33053020180000	W.C. DODGE TRUST ESTATE 1	Middle Member Unit 2	10645.1
33053020180000	W.C. DODGE TRUST ESTATE 1	Middle Member Unit 3	10629.2
33053020180000	W.C. DODGE TRUST ESTATE 1	Middle Member Unit 4	10620.2
33053020180000	W.C. DODGE TRUST ESTATE 1	Middle Member Unit 5	10616.3
33053020180000	W.C. DODGE TRUST ESTATE 1	Upper Shale Unit 3	10597.2
33061005540000	WAYZETTA 100-26 SWD	Basal Bakken	9465.24
33061005540000	WAYZETTA 100-26 SWD	Lower Shale Unit 1	9455.88
33061005540000	WAYZETTA 100-26 SWD	Lower Shale Unit 2	9445.41
33061005540000	WAYZETTA 100-26 SWD	Lower Shale Unit 3	9436.85
33061005540000	WAYZETTA 100-26 SWD	Middle Member Unit 3	9416.23
33061005540000	WAYZETTA 100-26 SWD	Middle Member Unit 4	9413.69
33061005540000	WAYZETTA 100-26 SWD	Middle Member Unit 5	9397.35
33061005540000	WAYZETTA 100-26 SWD	Upper Shale Unit 1	9393.55
33061005540000	WAYZETTA 100-26 SWD	Upper Shale Unit 2	9386.88
33061005540000	WAYZETTA 100-26 SWD	Upper Shale Unit 3	9381.02
33105007560000	WHEELER 21-6	Basal Bakken	10689
33105007560000	WHEELER 21-6	Lower Shale Unit 3	10662.4

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33105007560000	WHEELER 21-6	Middle Member Unit 1	10649.9
33105007560000	WHEELER 21-6	Middle Member Unit 2	10637.8
33105007560000	WHEELER 21-6	Middle Member Unit 3	10625.7
33105007560000	WHEELER 21-6	Middle Member Unit 4	10621.7
33105007560000	WHEELER 21-6	Middle Member Unit 5	10608.6
33105007560000	WHEELER 21-6	Upper Shale Unit 3	10591.4
33053016910000	WHITE EAGLE 42-22	Lower Shale Unit 1	10785.2
33053016910000	WHITE EAGLE 42-22	Lower Shale Unit 2	10779.2
33053016910000	WHITE EAGLE 42-22	Lower Shale Unit 3	10771.2
33053016910000	WHITE EAGLE 42-22	Middle Member Unit 1	10763.6
33053016910000	WHITE EAGLE 42-22	Middle Member Unit 2	10754.3
33053016910000	WHITE EAGLE 42-22	Middle Member Unit 3	10743.9
33053016910000	WHITE EAGLE 42-22	Middle Member Unit 4	10736
33053016910000	WHITE EAGLE 42-22	Middle Member Unit 5	10729.9
33053016910000	WHITE EAGLE 42-22	Upper Shale Unit 3	10710.7
33053019740000	WISNESS A 27-13	Basal Bakken	10550.2
33053019740000	WISNESS A 27-13	Lower Shale Unit 3	10529.9
33053019740000	WISNESS A 27-13	Middle Member Unit 1	10524.1
33053019740000	WISNESS A 27-13	Middle Member Unit 2	10516.3
33053019740000	WISNESS A 27-13	Middle Member Unit 3	10494.9
33053019740000	WISNESS A 27-13	Middle Member Unit 4	10488.5
33053019740000	WISNESS A 27-13	Middle Member Unit 5	10482.9
33053019740000	WISNESS A 27-13	Upper Shale Unit 3	10464.5