1995

Depositional environments and paleogeography of the Winnipeg Group (Ordovician), Williston Basin, North Dakota

Jonathan B. Ellingson
University of North Dakota

DEPOSITIONAL ENVIRONMENTS AND PALEOGEOGRAPHY OF THE WINNIPEG GROUP (ORDOVICIAN), WILLISTON BASIN, NORTH DAKOTA

by

Jonathan B. Ellingson
Bachelor of Science, University of North Dakota, 1993

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota
May
1995

This thesis, submitted by Jonathan B. Ellingson in partial fulfillment of the requirements for the Degree of Masters of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Richard D. Lefsrud
(Chairperson)

Neil A. Forsman

Patricia H. Kelley

This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

Harvey Knull
Dean of the Graduate School

4-28-95

PERMISSION

Title Depositional Environments and Paleogeography of the Winnipeg Group (Ordovician), Williston Basin, North Dakota

Department Geology

Degree Master of Science

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the chairperson of the department or the dean of the Graduate School. It is understood that any copying or publication or other use of this thesis of part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Signature Jon Ellingson

Date 4-26-95

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ACKNOWLEDGMENTS

I would like to thank my committee members, Drs. Richard D. LeFever (chairman), Nels Forsman, and Patricia Kelley, for their advice and critical reviews of the thesis and advice during research. I would especially like to thank Dr. LeFever for the initial suggestion for this thesis, and for his constant encouragement and support.

Thanks are also extended to the North Dakota Geological Survey for the use of their facilities at the Wilson M. Laird Core and Sample Library at the University of North Dakota campus, Grand Forks, North Dakota. I would especially like to thank Julie A. LeFever for her suggestions and insights, as well as Dave Fischer, Sidney B. Anderson, and Kent Hollands.

I would like to thank Sigma Gamma Epsilon, Beta Zeta Chapter, for their financial support. Thanks are given to my family, friends, and fellow graduate students for their support, encouragement, and understanding during my graduate studies. I would especially like to thank my wife Christie for her support and encouragement throughout my graduate studies.

ABSTRACT

The Winnipeg Group (Upper Ordovician) unconformably overlies the Deadwood Formation (Cambrian - Lower Ordovician) over most of North Dakota, except in the extreme eastern part, where it lies directly on Precambrian basement rocks. The Winnipeg is conformably overlain by the Red River Formation (Upper Ordovician). The Winnipeg reaches a maximum thickness of 448 feet (136.6 m) in the center of the basin, Williams County. The Winnipeg Group consists of three formations, in ascending order, the Black Island, Icebox, and Roughlock Formations. The Black Island Formation is, herein, formally divided into the Hawkeye Valley and the Garland Members.

The Hawkeye Valley Member consists of two lithofacies: a red-bed lithofacies and a green quartz wacke lithofacies. The red-bed lithofacies consists of two lithotypes: a red quartz arenite and a red clayshale. The Hawkeye Valley Member reaches a maximum thickness of 128 feet (39 m) in Williams County and is restricted to the western half of North Dakota and the immediately surrounding areas. Abundant desiccation cracks and the distinctive red color strongly suggest that the red-bed lithofacies was deposited in a subareal environment. The red-bed lithofacies represents a fluvial/deltaic environment and the green quartz wacke lithofacies represents a nearshore marine or lagoonal environment. The Garland Member consists of two lithofacies: a quartz arenite lithofacies and a green quartz wacke lithofacies. The green quartz wacke

lithofacies is similar in character to the green quartz wacke lithofacies within the Hawkeye Valley, which represents the initial deposits of the Late Ordovician transgression. The quartz arenite lithofacies consists of three lithotypes: a bioturbated quartz arenite, a structured quartz arenite, and a structureless quartz arenite. The Garland Member reaches a maximum thickness of 169 feet (52 m) in McKenzie County. Prominent sedimentary structures and good sorting in the structured quartz arenite indicate that deposition occurred in an active foreshore or nearshore environment. The high degree of bioturbation and lack of sedimentary structures in the bioturbated quartz arenite lithotype indicate deposition in a relatively low-energy environment below normal wave base. The lithofacies found within the Garland Member thus represents a shallow marine environment.

The Icebox Formation is a fossiliferous, bioturbated shale with occasional sandstones, and represents an offshore deposit. The Icebox Formation reaches a maximum thickness of 167 feet (51 m) in Grand Forks County; the maximum thickness in the center of the basin is 156 feet (48 m) in McKenzie County. The Roughlock Formation is a fossiliferous, calcareous shale deposited in a deeper marine environment. The Roughlock reaches a maximum thickness of 95 feet (29 m) in the extreme eastern part of North Dakota and gradually thins to the west. The contacts between all of the units within the Winnipeg are intertonguing and gradational.

At the end of the Llanvirnian (Middle Ordovician) there was a major sea level drop, causing erosion of much of the Deadwood Formation. Sea level rose again during the Chazyan Stage (latest Middle Ordovician), and the Hawkeye Valley was deposited

unconformably on the Deadwood. As sea level continued to rise, the Garland was deposited, followed by offshore marine Icebox shales. Local topographic highs probably had sufficient relief to cause the formation of sand bodies during Icebox deposition. Still farther offshore, where the influx of clays was minor, the calcareous shales of the Roughlock were deposited, and finally deposition of the Red River limestones occurred.

INTRODUCTION

General

The Winnipeg Group represents the initial deposits in the Williston Basin of the Late Ordovician transgression which covered most of the North American craton. The most recent complete study of the Winnipeg Group in North Dakota (Thompson, 1984) examined approximately 300 well logs and 13 cores. Renewed interest in deeper drilling targets in the North Dakota part of the Williston Basin has produced considerable new data. This study examines all of the available well logs (380) and cores (43). This increased control has made it possible to reevaluate the Winnipeg stratigraphy and depositional interpretations.

Purpose

The purpose of this study is to describe in detail the lithologic character of the formations of the Winnipeg Group, to interpret the depositional environments of these formations, and to interpret the depositional history. This study also proposes that the lowest formation of the Winnipeg Group, the Black Island, be divided into two members, the Hawkeye Valley Member and the Garland Member.

Regional Setting and Area of Study

The geology of the northern Great Plains is dominated by the presence of the Williston Basin (Fig. 1). The Williston Basin is a relatively shallow intracratonic basin

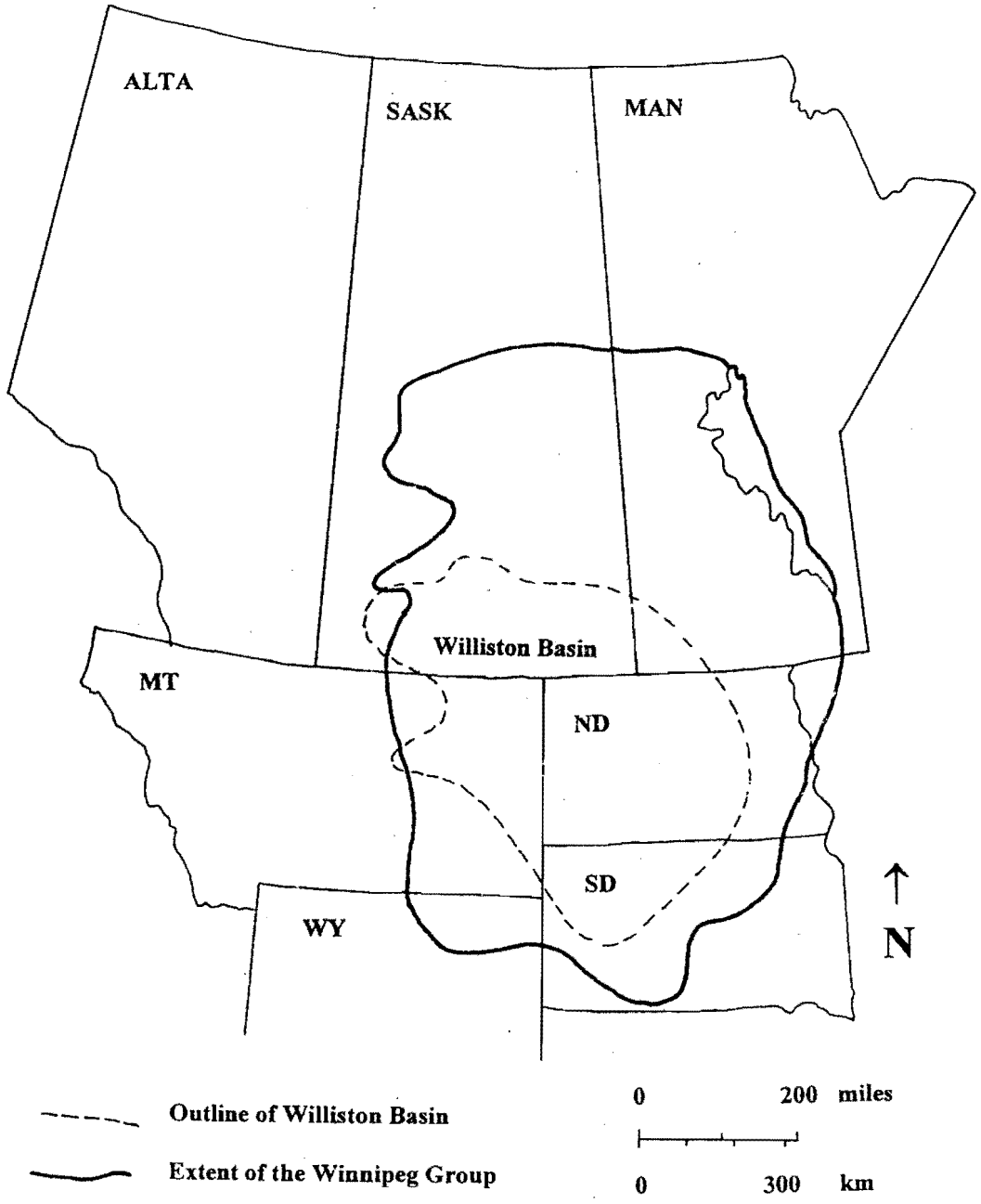

Figure 1. The position and extent of the Williston Basin and areal extent of the Winnipeg Group.

covering approximately 50,000 square miles (129,500 square km) and is centered in northwestern North Dakota, where Phanerozoic strata reach a maximum thickness of approximately 16,000 feet (4900 m) (Carlson and Anderson, 1965). The sediment which makes up the Williston Basin ranges in age from Late Cambrian to Recent. The outline of the Williston Basin shown on Figure 1 is drawn at the zero elevation line of the Dakota Group due to its distinctive and easily recognizable character on well logs (Laird, 1956).

The Canadian Shield extends beneath the Williston Basin and is exposed at the surface in northern Minnesota, northeastern Manitoba, and northern Saskatchewan (Thompson, 1984). Ballard (1963) recognized the north-south trending boundary between the Precambrian Superior and Churchill Provinces, which extends through central North Dakota (Fig. 2). This boundary had an important influence in the development of the Williston Basin during the Phanerozoic (Gerhard et al., 1982).

The Williston Basin includes many structures that range in size from large anticlines, such as the Nesson and Cedar Creek, to smaller-scale anticlines, lineaments, faults, and impact structures, such as the Red Wing Creek (Gerhard et al., 1982) and the Newporte structures (Gerlach, 1994). Figure 2 illustrates the major structural features of the Williston Basin (Gerhard et al., 1982).

The areal distribution of the Winnipeg Group extends well beyond the boundaries of the Williston Basin. The Winnipeg occurs throughout most of North Dakota and portions of South Dakota, Wyoming, Montana, Saskatchewan, Manitoba, and the northwestern corner of Minnesota (Fig. 1). The study area, however, is confined to the North Dakota part of the Williston Basin and the immediately surrounding area.

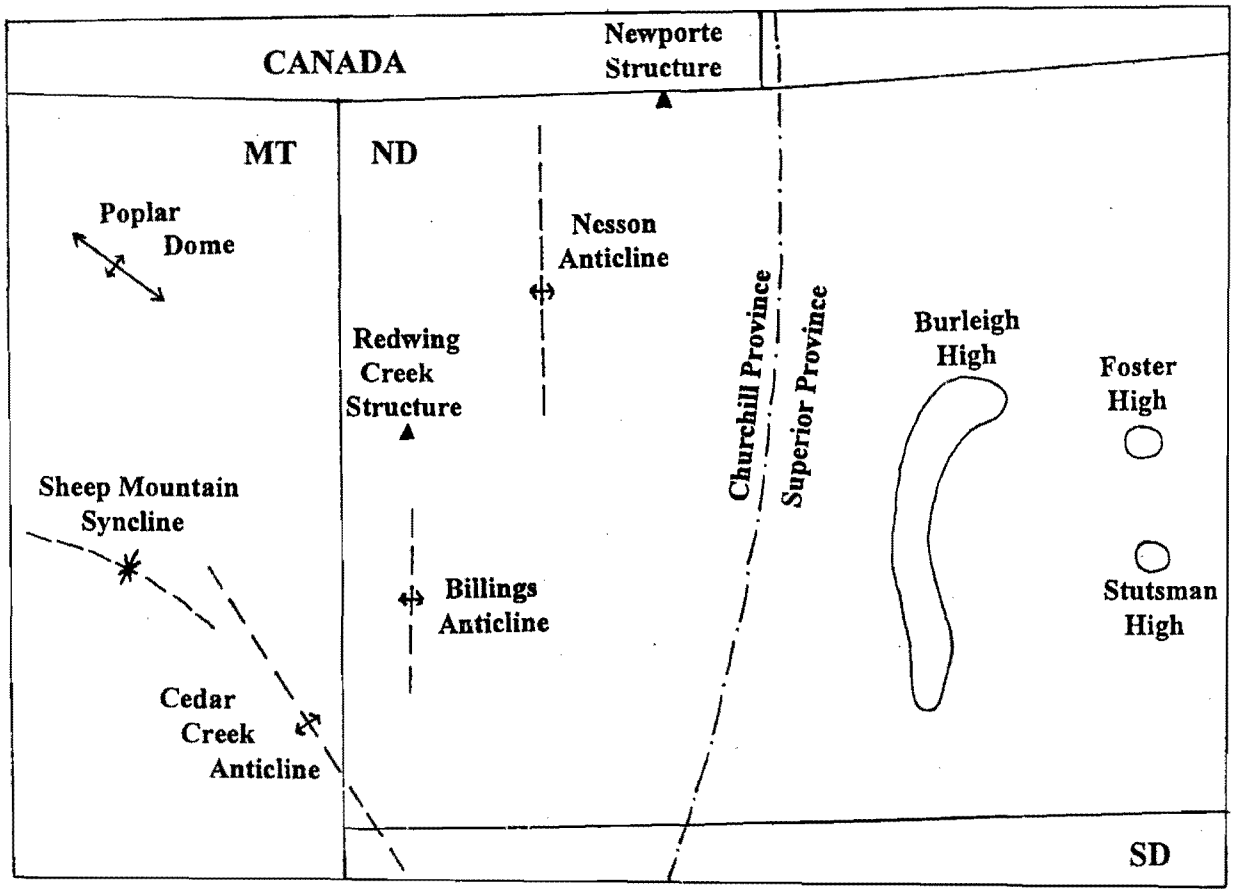

Figure 2. Major structural features in western North Dakota and eastern Montana (Modified slightly from Gerhard et al., 1982).

Regional Stratigraphy

The Winnipeg Group (Upper Ordovician) consists of three formations, in ascending order, the Black Island Formation, the Icebox Formation, and the Roughlock Formation (Fig. 3). This study proposes names for previously unnamed members of the Black Island Formation, the Hawkeye Valley and the Garland Members (Ellingson and LeFever, in press, 1995). The Winnipeg Group reaches a maximum thickness of 448 ft (137 m) in the center of the basin, in Williams County. The Black Island reaches a maximum thickness of 265 feet (81 m) in the center of the basin. The Black Island consists of two members, the Hawkeye Valley, which reaches a maximum thickness of 128 feet (39 m), and the Garland, which reaches a maximum thickness of 169 feet (52m). The Hawkeye Valley Member consists of two lithofacies: a red-bed lithofacies consisting of sand and clay and a green quartz wacke lithofacies. The Garland Member also consists of two lithofacies: a quartz arenite lithofacies and a green quartz wacke lithofacies. The quartz arenite lithofacies consists of three lithotypes: a bioturbated quartz arenite, a structured quartz arenite, and a structureless quartz arenite. Overlying the Black Island Formation is the noncalcareous, green to gray, fossiliferous in areas, bioturbated clayshale of the Icebox Formation. The Icebox reaches a maximum thickness of 167 feet (51 m). The argillaceous, fossiliferous, nodular limestone of the Roughlock Formation conformably overlies the Icebox. The Roughlock reaches a maximum thickness of 95 feet (29 m).

The Winnipeg Group unconformably overlies the Deadwood Formation (Cambrian - Lower Ordovician) over most of North Dakota, except in the extreme eastern

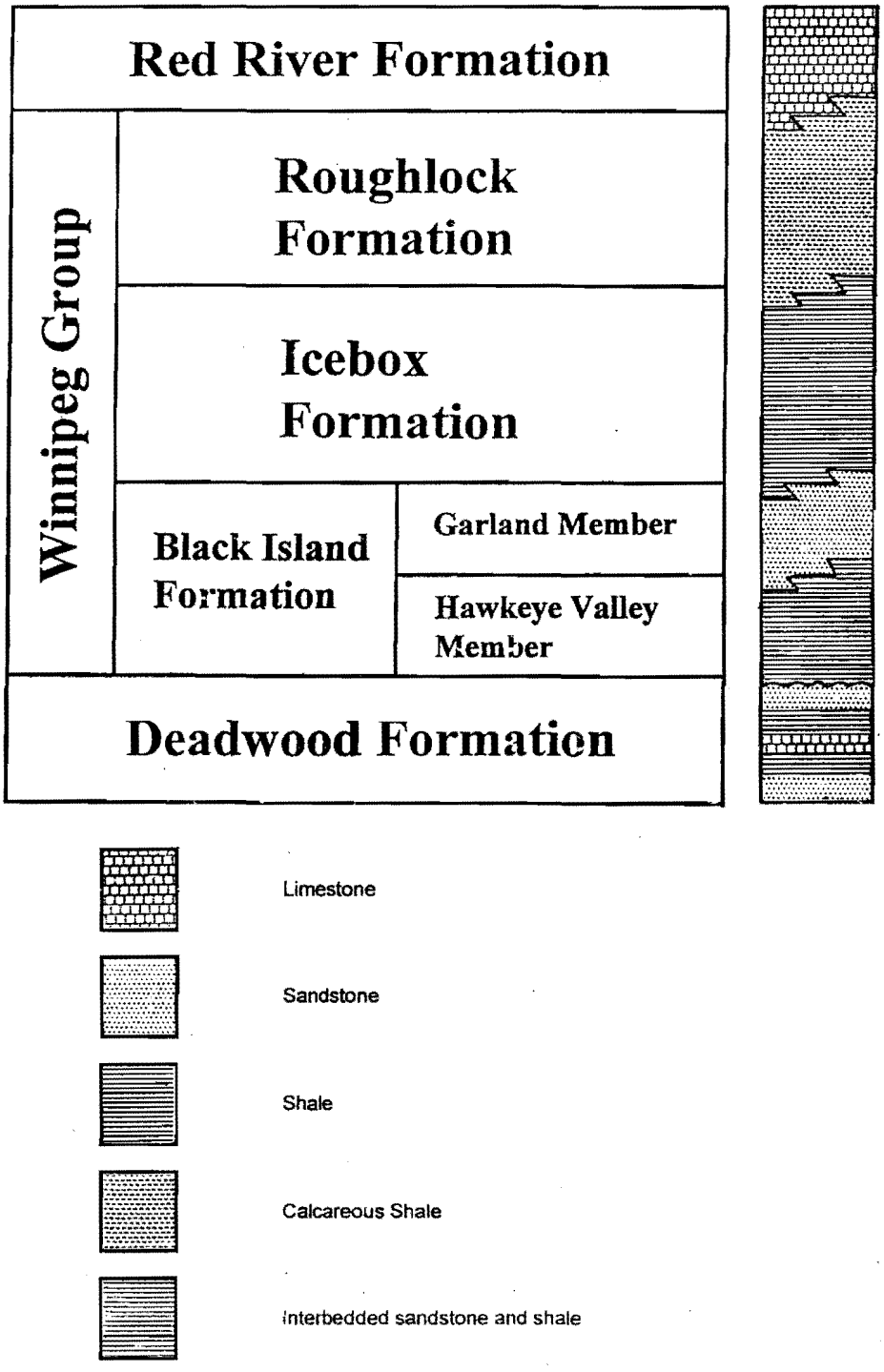

Figure 3. Diagrammatic lithologic column of the Winnipeg Group and adjacent formations.

part, where it lies directly on Precambrian basement rocks. The Winnipeg is conformably overlain by the dolomitic limestones of the Red River Formation. Figure 4 illustrates two cross-sections (north-south and east-west) running through the deepest part of the Williston Basin. These cross-sections illustrate the relationships between the units of the Winnipeg Group and the relations to the overlying and underlying formations.

Methods

The primary sources of data for this study were well logs and cores maintained by the North Dakota Geological Survey at the Wilson M. Laird Core and Sample Library at the University of North Dakota campus, Grand Forks, North Dakota. A total of 380 logs (Fig. 5) and 43 cores (Fig. 6) were examined, representing all of the available cores and logs in North Dakota. Ninety logs from Montana, South Dakota, Saskatchewan, and Manitoba were examined for additional control, although these wells are not depicted on the location map.

A total of 470 well logs were studied (Appendix A), for which the tops and thicknesses of the Deadwood Formation, the Black Island Formation, the Hawkeye Valley Member, the Garland Member, the Icebox Formation, and the Roughlock Formations were recorded (Appendices B and C). Using the thickness data, isopach maps were constructed for each of the units using SURFER for Windows (Golden Software, 1994). Typical gamma ray and resistivity log responses for the Winnipeg's units in the Williston Basin are illustrated in Figure 7. This log shows the typical log responses, the gradational contacts between the Winnipeg units and the overlying Red River Formation, as well as the abrupt contact with the underlying Deadwood Formation

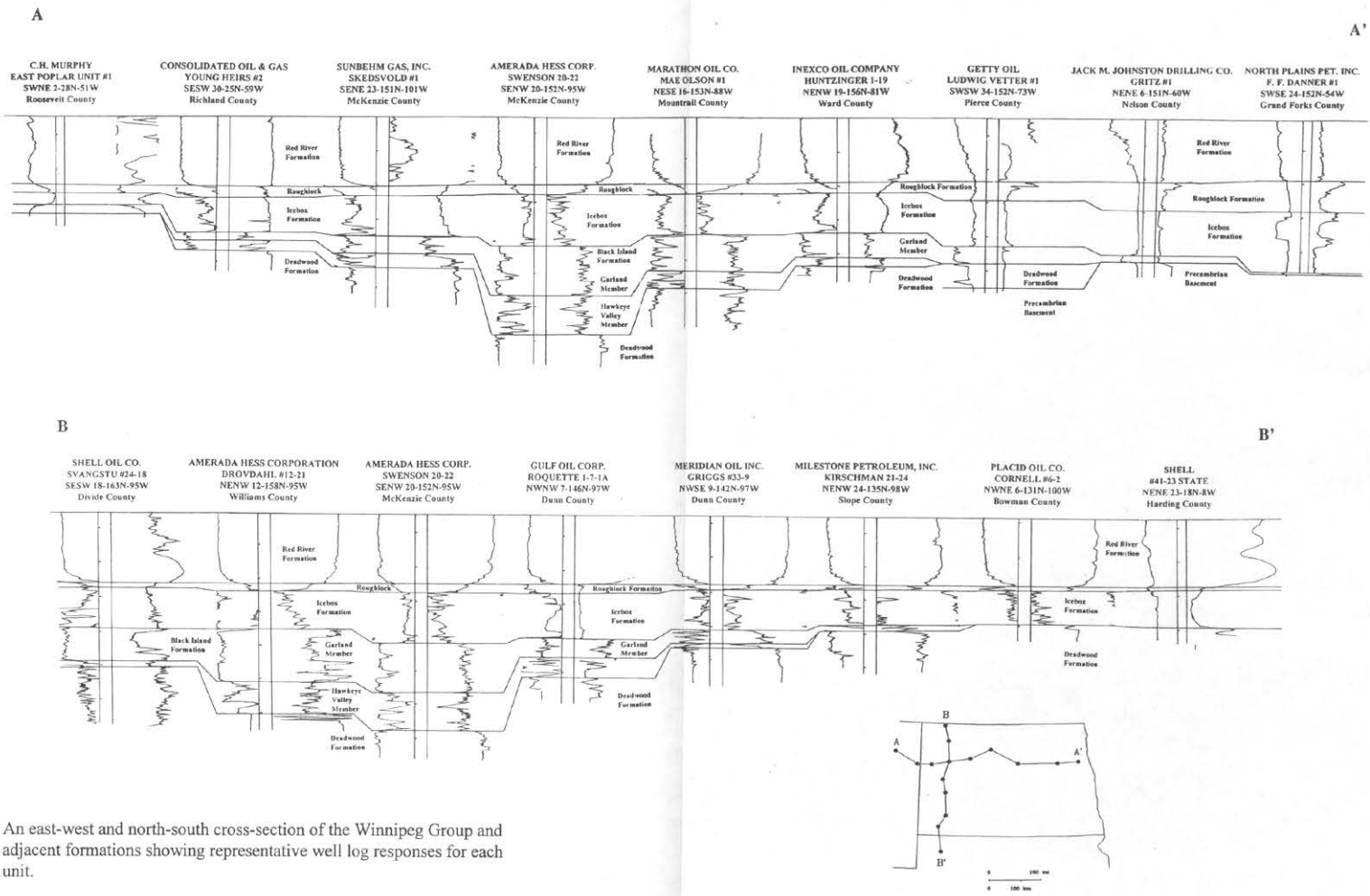

Figure 4. An east-west and north-south cross-section of the Winnipeg Group and adjacent formations showing representative well log responses for each unit.

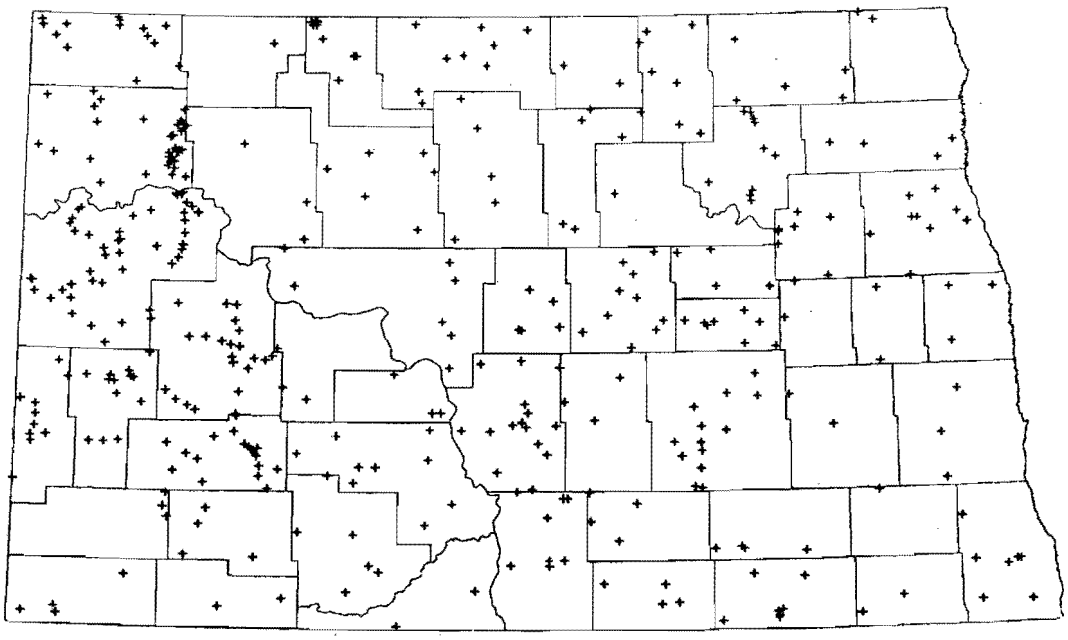

Figure 5. Location of wells from which well logs were examined.

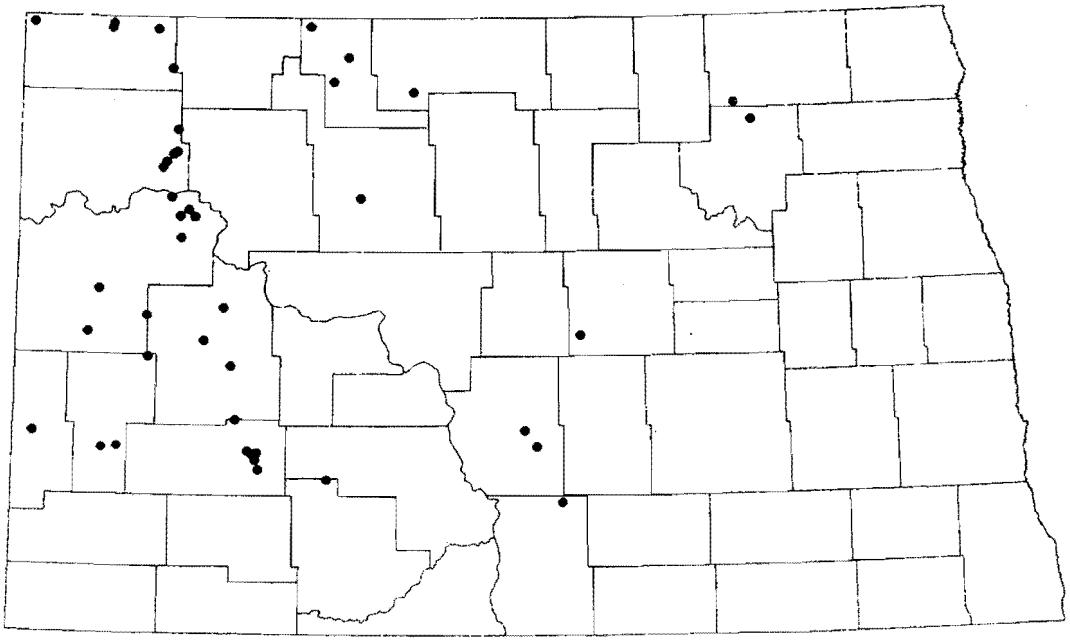

Figure 6. Location of wells from which cores were examined during this study.

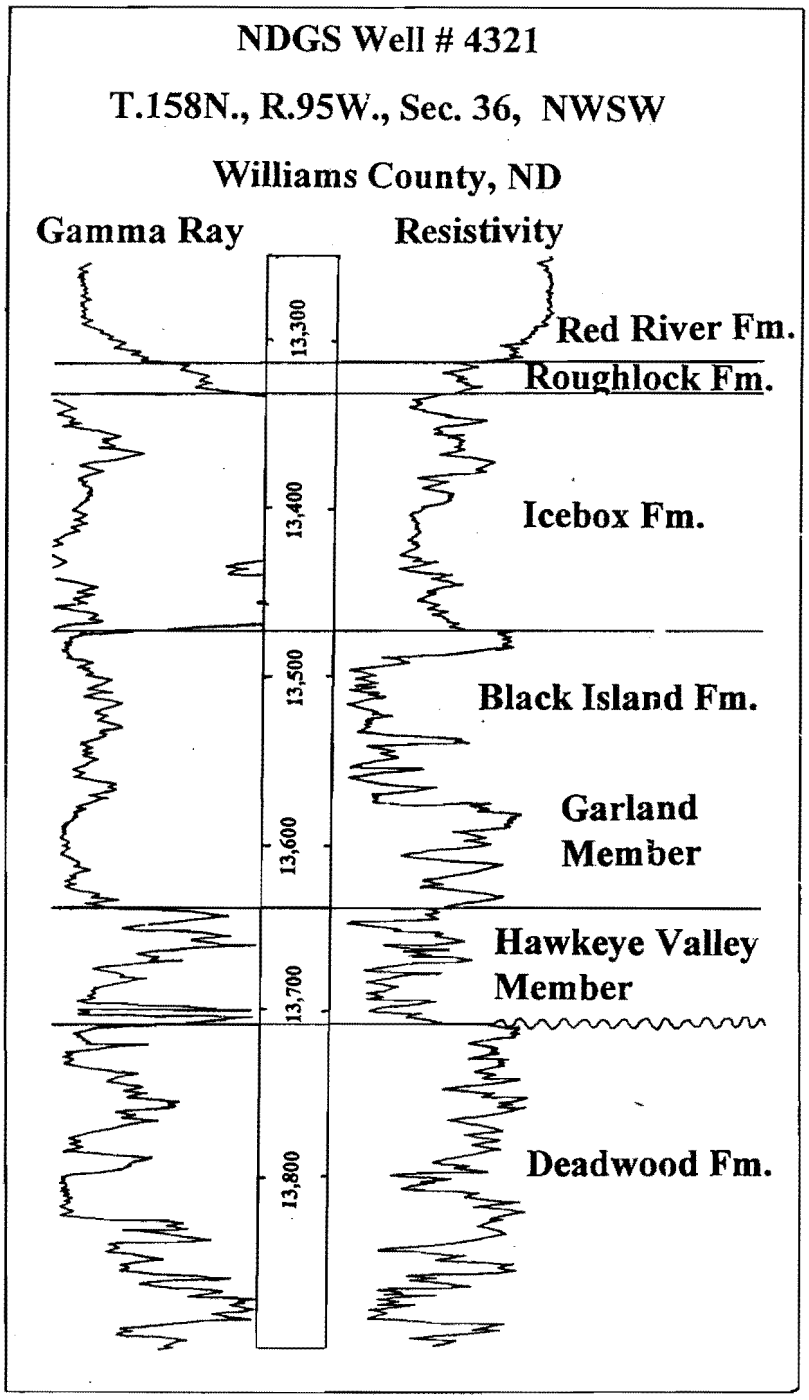

Figure 7. Sample well log response of the Winnipeg Group from the Amerada Oil Company - N.D. "C" No.9 (NDGS Well #4321), NW1/4, SW1/4, Sec.36, T.158N., R.95W., Williams County, North Dakota.

in Williams County, North Dakota, where the Winnipeg reaches its maximum thickness. Comparison of cores to the corresponding well log sections indicates that the lithologies, interpreted from logs, have been picked accurately and consistently throughout the study. Thus, for the Winnipeg Group, well logs can probably be used to complete detailed lithologic interpretations and lithologic correlations throughout the state where cores are not present.

All of the available cores (43) of the Winnipeg Group in North Dakota were examined for this study, totaling over 2,400 feet (732 m). Core descriptions (Appendix D) were made using a hand lens and a 10x binocular microscope and were classified according to Gilbert (1954; sandstones), Potter et al.(1980; shales), and Folk (1959; carbonates). The rock color chart (Goddard et al., 1963) was used as the standard for color description. Angularity, sorting, and grain size classification were determined using Tucker (1980). The information obtained from these core descriptions was used to determine general lithologic trends of the Winnipeg's units, interpret the depositional environments, and determine the depositional history.

Previous Work

Dowling (1895) was the first to describe strata which are now a part of the Winnipeg Group. Dowling (1895) assigned the name "Winnipeg sandstone" to the rocks underlying the Ordovician limestones and overlying the Precambrian rocks on islands of Lake Winnipeg, Manitoba. He described the unit as a fine-grained, friable sandstone with minor amounts of shale towards the top of the exposure (Dowling, 1895). Dowling (1900) studied exposures on four other islands in Lake Winnipeg and referred to these

rocks as the "Winnipeg formation." Dowling (1900) estimated the thickness of the Winnipeg formation to be about 100 feet and assigned a "Black River" age to the Winnipeg Group (Fig. 8).

The term Winnipeg was first used in the subsurface of northeastern North Dakota by Laird (1941). From three wells Laird (1941) described up to 155 feet of gray shale, which he designated Winnipeg, and up to 5 feet of white sandstone underlying the Winnipeg, which he called Deadwood. Genik (1951, unpublished thesis), who studied outcrops in Manitoba and the subsurface of the Williston Basin, divided the Winnipeg formation into three members, in ascending order, Black Island, Grindstone Point, and Deer Island Members (from Carlson, 1960). Baillie (1952) defined the Winnipeg as all the rocks underlying the carbonates of the Red River Formation and overlying the Precambrian basement rocks in the Lake Winnipeg area. He also divided the Winnipeg formation into two units, a basal sandstone unit and an upper unit consisting of shale and sandstone. McCoy (1952) described 150 feet of Middle Ordovician sediment that lies conformably between the overlying Englewood dolomitic shale and the underlying Cambrian Deadwood strata in the northern Black Hills. He called these formations, in ascending order, the Aladdin sandstone, the Ice Box shale, the Roughlock, and the Whitewood. He described the Aladdin sandstone-Ice Box shale contact as being very sharp (McCoy, 1950). He named the *Skolithos* sandstone the "Aladdin sandstone," the overlying shale the Ice Box Formation, and the overlying siltstone the Roughlock Formation. Kupsch (1953) used Genik's three members for describing strata of the Winnipeg formation in outcrop patterns in Saskatchewan. Later, Genik (1954) divided

Dowling 1900 Man.	Laird 1941 N.D.	Genik 1951 Man.		Baillie 1952 Man.		McCoy 1952 S.D.		Genik 1954 Man.		Carlson 1958 1960 N.D.	
Red River formation	Red River formation	Red River formation		Red River formation		Whitewood formation		Red River formation		Red River formation	
Winnipeg formation	Winnipeg formation	Winnipeg formation	Deer Island member	Winnipeg formation	upper unit	Winnipeg group	Roughlock formation	Winnipeg formation	Deer Island member	Winnipeg formation	Roughlock member
			Grindstone Point member				Icebox formation				Icebox member
			Black Island member		basal sandstone unit		Aladdin sandstone		Black Island member		Black Island member
Precambrian	Deadwood formation	Deadwood formation		Precambrian		Deadwood formation		Deadwood formation		Deadwood formation	

Figure 8. Stratigraphic nomenclature from 1900 to 1958.

the Winnipeg formation into two members, the Black Island and Deer Island members. The Deer Island member is equivalent to the Grindstone Point and Deer Island members.

Carlson (1958) stated that the Winnipeg formation lies unconformably above the Deadwood formation and is overlain conformably and gradationally by the Red River formation. Carlson (1958) studied all the available logs in North Dakota in an attempt to clear up the nomenclature for the Deadwood-Winnipeg interval in North Dakota because nomenclature had been derived from outcrop areas of the Black Hills, South Dakota, and Lake Winnipeg, Manitoba. He divided the Winnipeg formation into three members, the Black Island, the Icebox, and the Roughlock. Carlson (1958) stated that the Black Island of Manitoba and the subsurface of North Dakota do not have an equivalent in the Black Hills. Because the Winnipeg formation overlies the Deadwood formation unconformably in North Dakota and northwestern South Dakota, the Aladdin sandstone of McCoy is not part of the Winnipeg, but rather the Deadwood (Carlson, 1958) (Fig. 8).

Andrichuk (1959) arbitrarily divided the Winnipeg into two portions, the upper 100 feet (30 m) and the remaining portion lying beneath (Fig. 9). He also noted an elongated, east-west trending sandstone body within the shale of the Winnipeg. He called this lithosome the Carman sand body and suggested that it was deposited as an offshore bar.

Fuller (1961) referred to the Winnipeg as a group rather than a formation and split this group into two units: a basal sandstone unit and an upper unit. Fuller (1961) objected to the use of Carlson's (1958 and 1960) "Black Island member" and instead used the name "Burgen sandstone" for the basal sandstone of the Winnipeg group. Fuller

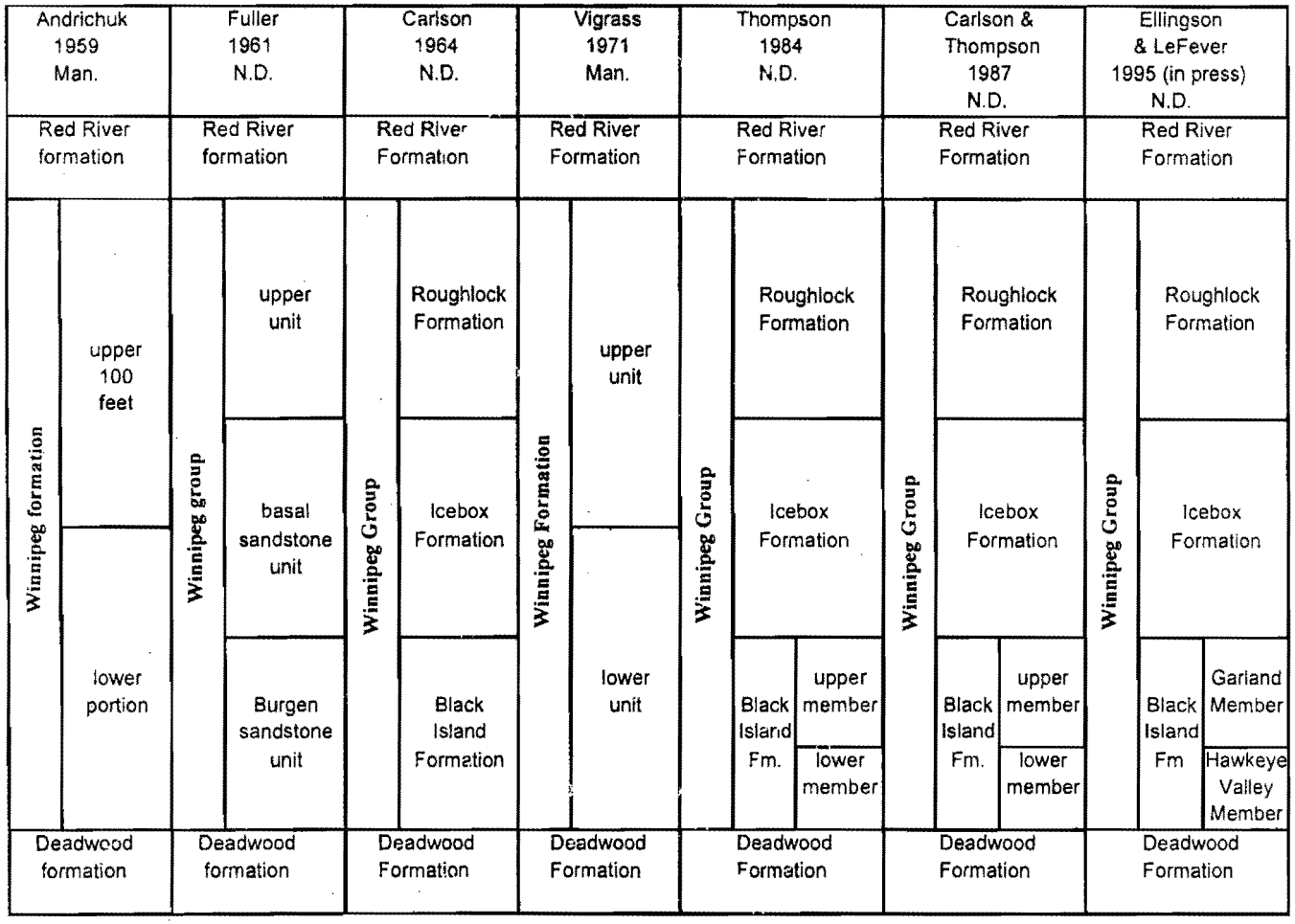

Figure 9. Stratigraphic nomenclature from 1959 to 1995.

(1961) believed the lowest sandstone of the Winnipeg group in the Williston Basin to be at a different stratigraphic level than the basal sandstone in Manitoba and that Carlson's (1960) correlation was incorrect. He believed that Carlson's (1960) sandstone unit, the Black Island, was confined to the center of the basin.

In 1964, Carlson formally changed the status of the Winnipeg from formation to group. He based the subdivisions of the Winnipeg Group on lithologic units through the subsurface of the Williston Basin to the outcrop areas in South Dakota and Manitoba (Carlson, 1964). Carlson (1964) named the three formations of the Winnipeg Group, in ascending order, the Black Island Formation, the Icebox Formation, and the Roughlock Formation.

Vigrass (1971) divided the Winnipeg into upper and lower units using mechanical logs, chips from samples, and cores from 50 wells in Manitoba and Saskatchewan. He stated that the Winnipeg consists of terrigeneous material transported from slightly uplifted margins into a marine depositional basin, distributed by current action and laid down in a variety of depositional environments. He defined three facies belts for each unit: an offshore mudstone facies, a transitional facies separating the mudstones from the basin margin sandstone facies, and a sandstone facies. The lower Winnipeg has a rather restricted distribution, whereas the upper Winnipeg is a unit of more transgressive character. Vigrass (1971) also suggested that many smaller regressions occurred within the major transgression that took place. Winnipeg deposition was complete when the sources of Winnipeg clastics were covered by the Red River limestones due to the Ordovician transgression (Vigrass, 1971). Vigrass (1971) also suggested that the Carman

Sandstone is similar to the modern outer-shelf sand bodies deposited 100 miles offshore by the tractive action of a coastal current (Thompson, 1984).

Foster (1972) adopted the nomenclature suggested by Carlson (1964) by dividing the Winnipeg Group into the Black Island, Icebox, and Roughlock Formations. Foster (1972) supported Carlson's ideas that the basal unit could be traced from Manitoba into the subsurface of North Dakota and that it had no equivalent in South Dakota. He also suggested that the Middle Ordovician rocks of the Bighorns in Montana should be referred to as the Winnipeg rather than the Harding Formation. The Winnipeg in Montana has been erosionally separated from the Winnipeg of North Dakota (Foster, 1972).

In 1976, Ross examined the Ordovician sedimentation in the western United States and concluded that the Transcontinental Arch was a major barrier during Middle Ordovician time. The Transcontinental Arch may have extended unbroken from northeastern Minnesota to southwestern Nebraska (Ross, 1976).

The most recent complete study of the Winnipeg Group in North Dakota was done by Thompson (1984). Thompson (1984) studied approximately 300 well logs and 13 cores in the North Dakota part of the Williston Basin to determine the depositional environments and history of the Winnipeg Group. Thompson (1984) was the first to informally divide the Black Island Formation into lower and upper members. He defined the strata of the lower member of the Black Island Formation as consisting of a red-bed lithofacies, containing reddish brown and dark greenish gray clayshale and reddish brown, hematite-cemented quartz arenite, and a green quartz wacke lithofacies, composed

of greenish gray, friable, quartz wacke. The upper member of the Black Island Formation was divided into a quartz arenite lithofacies, composed of thickly bedded, medium to light gray, quartz arenite and bioturbated quartz wacke, and a green quartz wacke similar in lithology to the green quartz wacke of the lower member. The lower member of the Black Island Formation was interpreted to have been deposited on a deltaic plain. The upper member was interpreted to be a nearshore deposit.

LeFever et al. (1987) studied the earliest Paleozoic history of the Williston Basin of North Dakota, including the Deadwood Formation and Winnipeg Group. LeFever et al. (1987) accepted the nomenclature of Thompson (1984) and also informally divided the Black Island Formation into upper and lower members. The lower member was again interpreted to represent a deltaic deposit and the upper member was interpreted as a nearshore deposit. Carlson and Thompson (1987) described the stratigraphy of the Deadwood Formation and Winnipeg Group and informally divided the Deadwood into lower and upper members and again divided the Black Island Formation into upper and lower members. They described the lower member as a reddish brown and green sandstone and shale and the upper member primarily as a quartzitic sandstone (Carlson and Thompson, 1987). The lower member reaches a maximum thickness of 100 feet (30 m) and is confined to the center of the basin and the upper member reaches a maximum thickness of 160 feet (49 m) in the center of the basin (Carlson and Thompson, 1987) (Fig. 9).

Kessler (1991) recognized three large elongated east-west trending sand bodies located in southern Manitoba and eastern North Dakota, all within the Icebox Formation.

The largest of these sand bodies, the Carman sand, is approximately 30 meters thick, 250 km long, and 45 km wide. Kessler (1991) suggested that this sand body consists of at least five sand ridges which accreted in a N to NNW direction. Kessler further suggested that these sand bodies, of probable storm and tidal-current origin, are the result of slow basin margin subsidence and sediment input.

Nomenclature

As described above, the nomenclature of the Winnipeg Group has been a continuing problem throughout the years (Fig. 8 & 9). Much of the problem came from early studies of the Winnipeg, which only examined outcrops on islands of Lake Winnipeg, Manitoba, and in the Black Hills of South Dakota. Although the observations were correct and thorough, the sections were not always complete and could not be correlated from South Dakota to Manitoba. It was known that these outcrops were not suitable as type sections (Dowling, 1900), because the thicknesses were expected to increase toward the center of the basin as well as undergo facies changes. For these reasons, many geologists have objected to the use of these outcrop locations to describe strata in the subsurface.

In the last 20 to 25 years, there has been an interest in deeper drilling targets in the North Dakota part of the Williston Basin, which has produced considerable amounts of new data and made it possible to reevaluate the Winnipeg Group. Due to this increase in well control, the Winnipeg can be correlated from outcrops in Manitoba, through the deepest parts of the basin in North Dakota, to the outcrops in the Black Hills. This increase in confidence of the correlation of the Winnipeg has produced a relatively

uniform and well-accepted nomenclature. The Winnipeg Group's formations, in ascending order, the Black Island, the Icebox, and the Roughlock, meet the criteria necessary by the North American Commission on Stratigraphic Nomenclature to be formations in rank. Some of these criteria include: distinct lithologic character (defined by composition, texture, color, sedimentary structures, and fossils), distinct log properties, and they are all mappable units (North American Commission on Stratigraphic Nomenclature, 1983).

Many studies in the past 10 years (Thompson, 1984; LeFever et al., 1987; Carlson and Thompson, 1987) have informally divided the Black Island Formation into lower and upper members based on very distinct lithologic changes. This study proposes that the Black Island Formation formally be divided into the Hawkeye Valley Member and the Garland Member. The proposed members meet all criteria necessary in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) to warrant member status. The Hawkeye Valley Member and Garland Member have formally been proposed in "The Seventh International Williston Basin Symposium Volume" (Ellingson and LeFever, in press, 1995).

Age

The Winnipeg Group strata are generally thought to be Late Ordovician as well as Middle Ordovician in age (Thompson, 1984). More accurately, the Winnipeg may range in age from the Chazyan, of the Champlanian, to the Edenian, of the early Cincinnatian (Fig. 10). As illustrated in Figure 10, the Winnipeg Group is time-transgressive due to the gradual transgression which occurred during Late Ordovician time (Sweet, 1982).

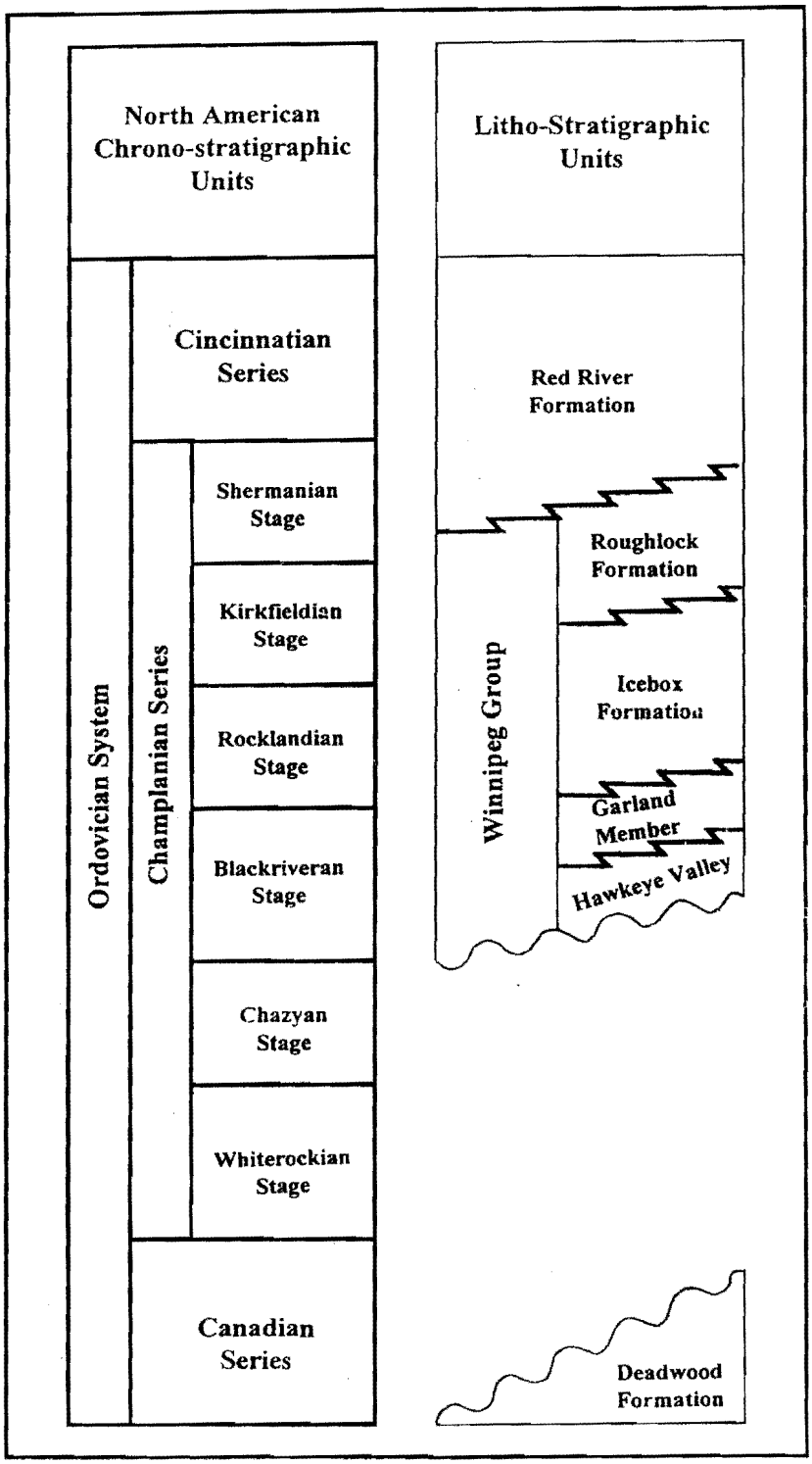

Figure 10. Generalized age relationships of Winnipeg Group strata in North Dakota and South Dakota (modified slightly from Thompson, 1984).

Most of the age determinations of the Winnipeg Group have been based on conodont studies. Conodonts are a good index fossil for many reasons: they are relatively abundant, they have widespread occurrence, and they come in a variety of forms (lots of species) due to rapid phases of evolution (Lindstrom, 1964). The conodonts of the Winnipeg Group are amber in color, easily identifiable (Carlson, 1960), and range in size from 0.2 mm to 5 mm (Higgins and Austin, 1985).

The Black Island Formation is not as fossiliferous as the overlying Icebox and Roughlock Formations, and thus is not as well documented. Holland and Waldren (1955) completed a conodont study from a core taken from the lower Winnipeg in Ward County, North Dakota. They concluded that the basal sandstone unit of the Winnipeg Group in North Dakota is older than Cincinnatian and may be Blackriveran or Chazyan in age (Holland and Waldren, 1955). Carlson (1960) completed a study at seven locations throughout the Williston Basin, three of which were in eastern North Dakota. This study compared the conodont fauna of the Winnipeg Group with the conodont fauna of Middle Ordovician rocks of the Upper Mississippi Valley, and concluded, from the three wells in eastern North Dakota, that the Icebox Formation is probably Blackriveran to Trentonian in age and the Roughlock Formation is probably Trentonian in age. Oberg (1966) completed a conodont study of the Winnipeg Group at Lake Winnipeg, Manitoba and concluded that the Deer Island (Icebox and Roughlock) may be Trentonian in age.

In 1982, Sweet studied conodonts from Winnipeg Group outcrops in the Black Hills of South Dakota. Sweet (1982) concluded that the Icebox was Rocklandian and early Kirkfieldian in age, and the Roughlock was Kirkfieldian and early Shermanian in

age. In 1984, Sweet completed another study, where he examined conodont suites collected by Clarence G. Carlson in the early 1960's (Thompson, 1984). Sweet determined the Icebox Formation in eastern North Dakota to be equivalent in age (Trentonian) to the Icebox and Roughlock Formations in the Black Hills of South Dakota. From the results of previous studies, it seems evident that the Winnipeg Group varies in age between localities. This may be due to a time-transgressive character discussed above.

LITHOLOGIC DESCRIPTIONS

Introduction

The Winnipeg Group in North Dakota has been divided into four distinct lithostratigraphic units based on core descriptions and interpretations of well log responses: the Hawkeye Valley Member, the Garland Member (members of the Black Island Formation), the Icebox Formation, and the Roughlock Formation. The Winnipeg Group reaches a maximum thickness of 448 feet (137 m) in the center of the basin, in Williams County (Fig. 11).

Black Island Formation

The Black Island Formation reaches a maximum thickness of 265 feet in the center of the basin (Fig. 12). The Black Island Formation is divided in this study into two members: the Hawkeye Valley Member and the Garland Member. The name "Hawkeye Valley" is taken from the prominent drainage in which the stratotype well occurs and the name "Garland" is taken from the name of the type section well (Ellingson and LeFever, in press, 1995). These members are described separately below.

Hawkeye Valley Member

The Hawkeye Valley Member disconformably overlies the limestone, shale, and sandstone of the Deadwood Formation and underlies the sandstone of the Garland Member. The Hawkeye Valley Member reaches a maximum thickness of 128 ft (39 m)

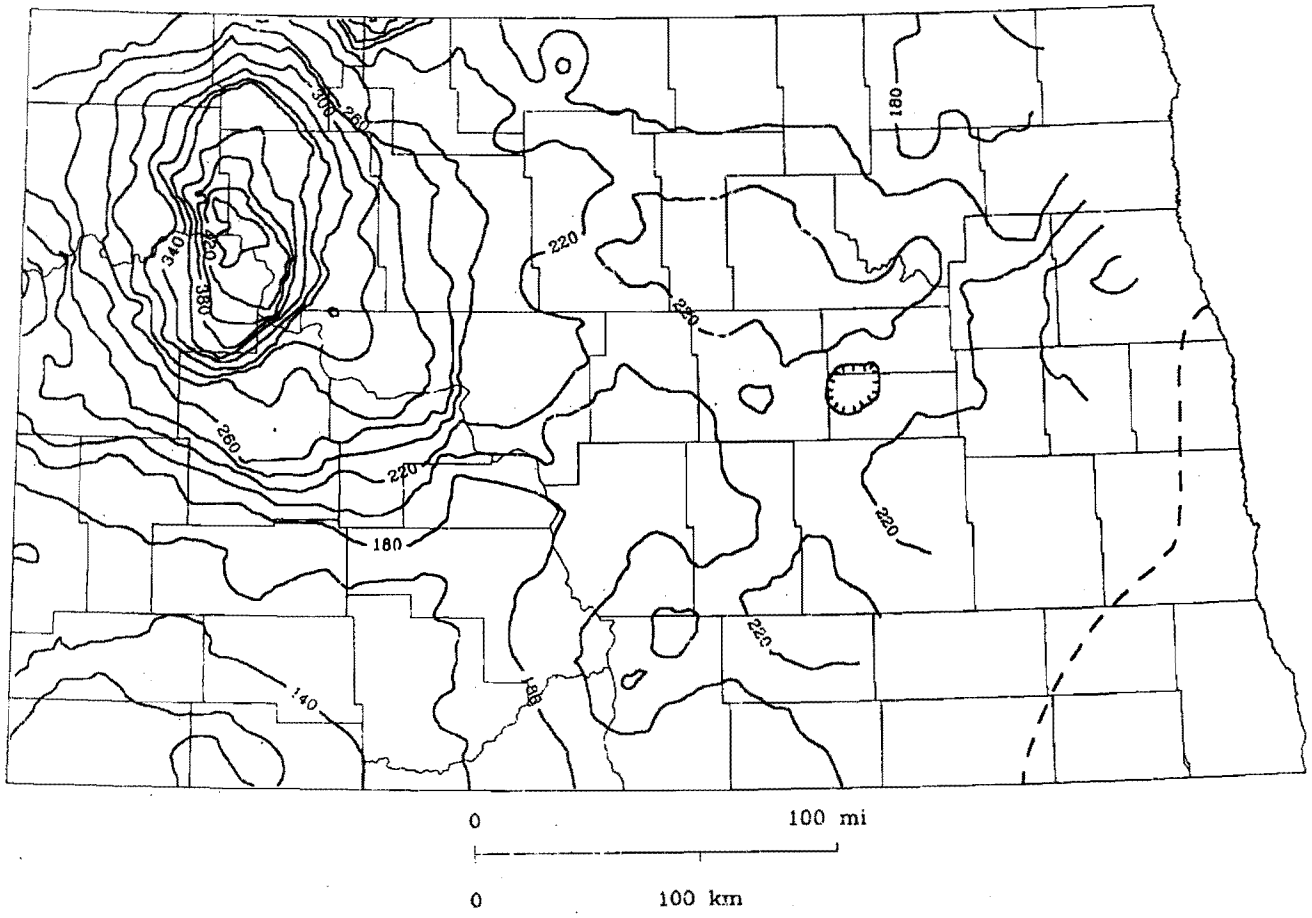

Figure 11. Isopach map of the Winnipeg Group. The dashed lines represent the approximate erosional edge of the Winnipeg Group.

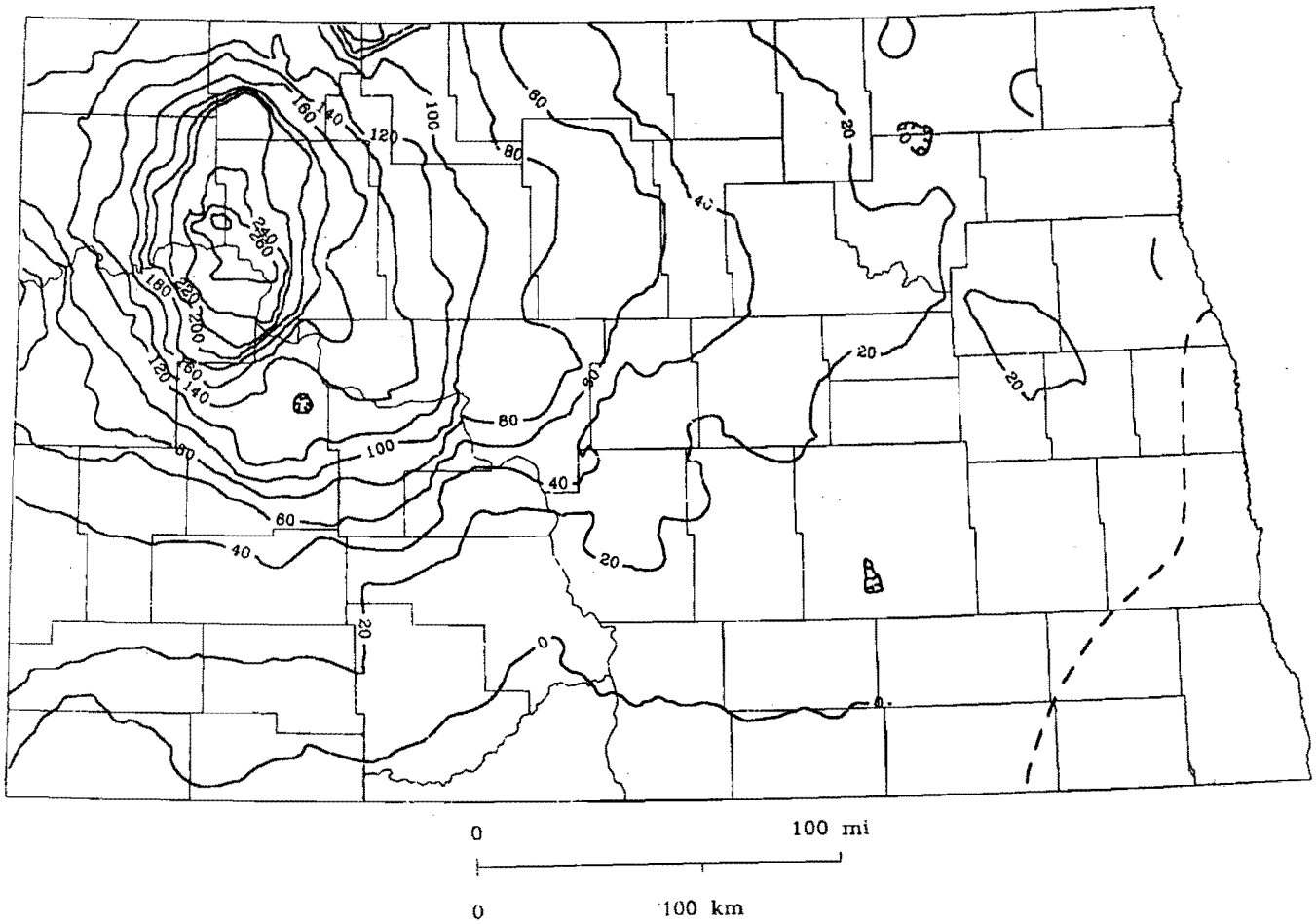

Figure 12. Isopach map of the Black Island Formation. The dashed lines represent the approximate erosional edge of the Winnipeg Group.

in Williams County (Fig. 13). As shown on the isopach map (Fig. 13), the Hawkeye Valley Member is restricted to the western half of North Dakota and the immediately surrounding areas. The isopach map shows a circular pattern, although a thickening trend exists in central North Dakota from Dunn County to Sheridan County.

There are two lithofacies identified in this study within the Hawkeye Valley Member: a red-bed lithofacies and a green quartz wacke lithofacies. The red-bed lithofacies consists of two lithotypes: a red quartz arenite and a red clayshale. The red quartz arenite is a dark reddish brown to dusky red quartz arenite (Fig. 14). It is generally fine- to medium-grained, moderately to well sorted, and well rounded. Hematite cement is the most common, although some quartz cement and clay matrix are also present. Although the lithotype is generally structureless to massive, prominent fine laminations are present locally. No fossils were observed within this lithotype, although the sandstone is slightly bioturbated in some cores and occasional burrows are present (Fig. 15). Thin beds (1-10 cm) of white quartz arenite are occasionally interbedded with the red quartz arenite (Fig. 16), as are lenses and layers of greenish-gray shale (Fig. 17). This lithotype is variable in thickness and ranges from 1-30 ft (0.3-9.1 m). The red quartz arenite usually overlies the red clayshale lithotype, but also underlies it in some areas. The red quartz arenite underlies the green quartz wacke, but is often interbedded with the red clayshale.

The red clayshale lithotype is characterized by a sequence of dusky red shales and interbedded dusky red and dark greenish gray shales (Fig. 18). These shales are finely laminated (1-4 mm) and are commonly interbedded with very dark finely laminated

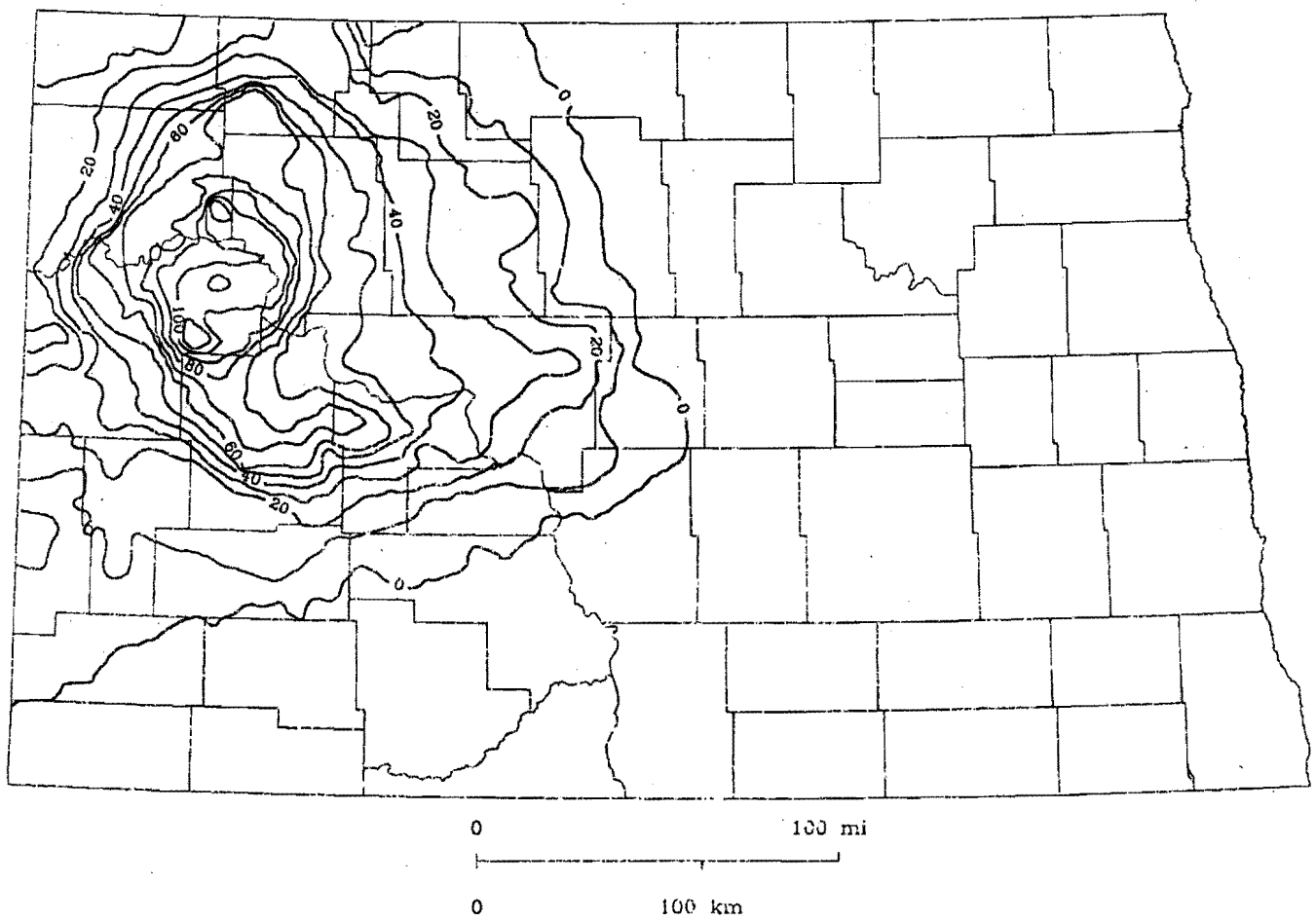

Figure 13. Isopach map of the Hawkeye Valley Member.

Figure 14. Core slab of dark reddish brown quartz arenite from the red quartz arenite lithotype, Hawkeye Valley Member.

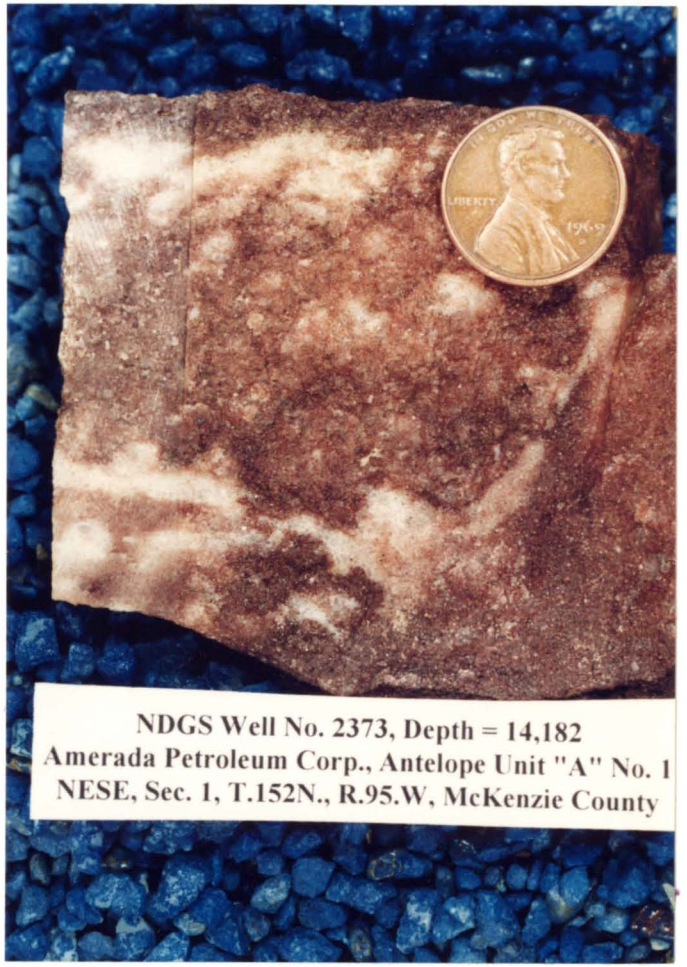

Figure 15. Bioturbation and burrows in the red quartz arenite lithotype, Hawkeye Valley Member.

Figure 16. Thin beds of white quartz arenite interbedded within the red quartz arenite lithotype, Hawkeye Valley Member.

Figure 17. Layers of greenish-gray shale interbedded within the red quartz arenite lithotype, Hawkeye Valley Member.

siltstones (1-2 cm), mudstones, and occasional red cross-bedded sandstones (Fig. 19). Mudcracks (desiccation cracks) occur in both the shales and interbedded mudstones (Fig. 20). Neither fossils nor evidence of bioturbation were observed in this lithotype. The red clayshale lithotype is variable in thickness and can range from 1-15 ft (0.3-4.6 m). The red clayshale is interbedded with the red quartz arenite lithotype throughout the basal portion of the Hawkeye Valley, but usually lies below the green quartz wacke lithotype.

The green quartz wacke lithofacies is predominantly a greenish-gray quartz wacke, which is a fine- to coarse-grained, poorly to moderately sorted, bioturbated argillaceous sandstone (Fig. 21). The green color results from the clay matrix. Lenses (< 2 cm) and thin layers (<3 cm) of clayshale occur within the quartz wacke. Occasional pyrite and phosphate nodules (<1.5 cm) occur throughout this wacke. The green quartz wacke lithofacies is usually at or toward the top of the Hawkeye Valley Member.

Garland Member

The Garland Member conformably overlies the Hawkeye Valley Member, except where the Hawkeye Valley is not present; there it rests unconformably on the Precambrian basement rocks. The Garland Member is conformably overlain by the shales of the Icebox Formation. This member is present over most of North Dakota, and reaches a maximum thickness of 169 ft (52 m) in McKenzie County (Fig. 22). The Garland Member is absent in the extreme southern portion of the state, and is generally less than 20 feet (6 m) thick in the eastern third of North Dakota.

There are two lithofacies recognized within the Garland Member: a quartz arenite lithofacies and a green quartz wacke lithofacies. The green quartz wacke lithofacies is a

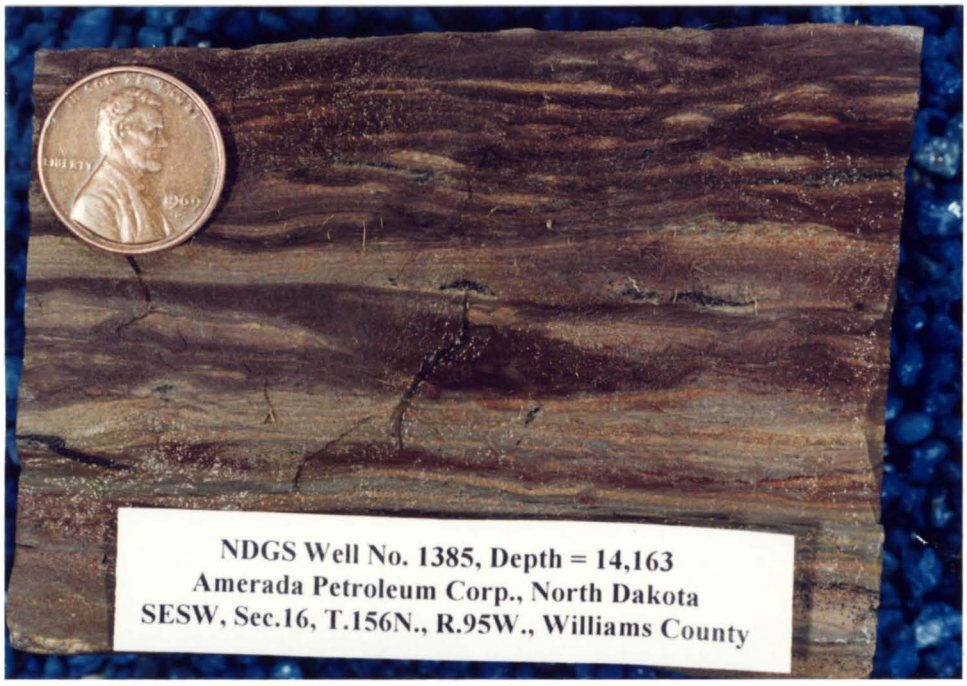

Figure 18. Dusky red shales and interbedded dusky red and dark greenish-gray shales within the red clayshale lithotype, Hawkeye Valley Member.

Figure 19. Interlaminated siltstones, mudstones, and sandstones within the red clayshale lithotype, Hawkeye Valley Member.

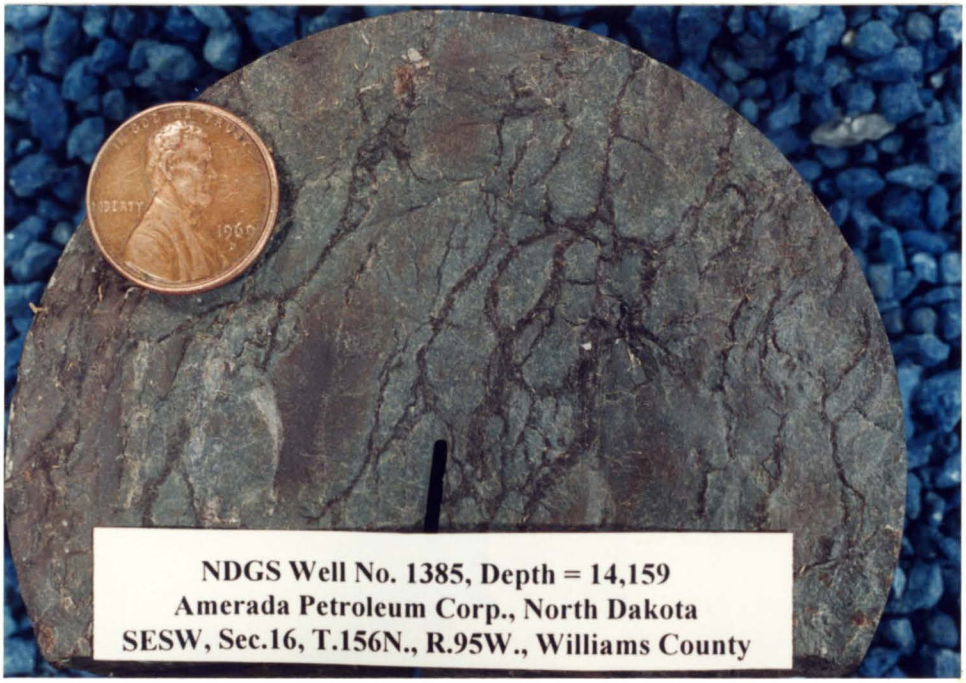

Figure 20. Desiccation cracks within the mudstones and shales of the red clayshale lithotype, Hawkeye Valley Member.

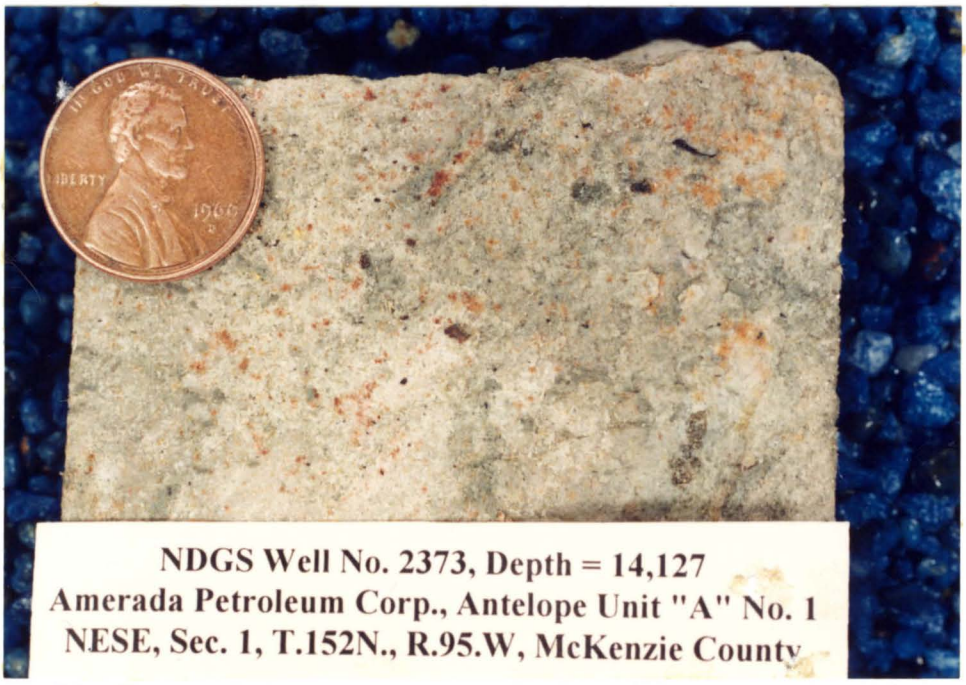

Figure 21. Characteristic green quartz wacke from the green quartz wacke lithotype, Hawkeye Valley Member.

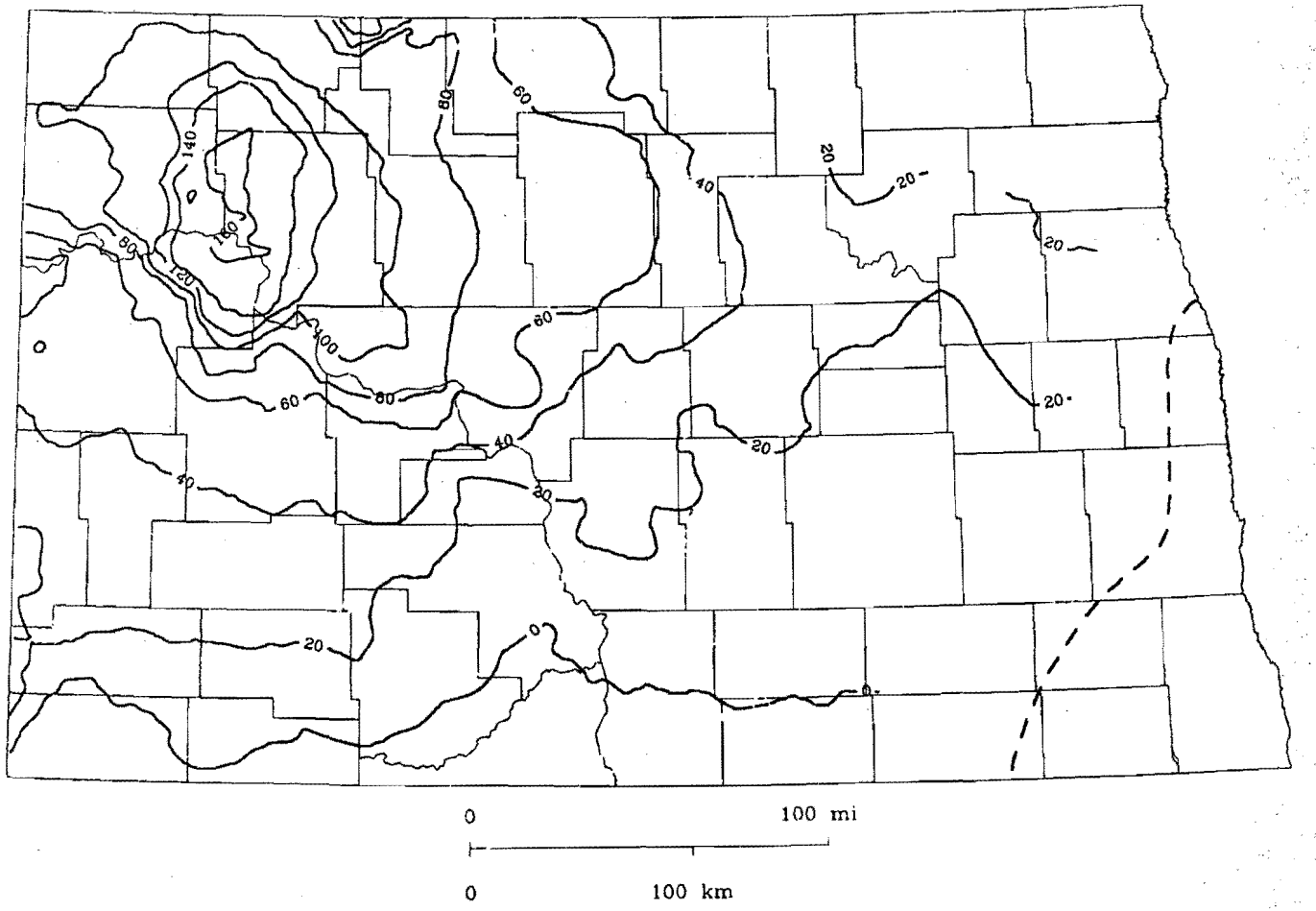

Figure 22. Isopach map of the Garland Member. The dashed lines represent the approximate erosional edge of the Winnipeg Group.

light greenish-gray to greenish gray sandstone. The sandstone is a fine- to medium-grained, moderately sorted, argillaceous quartz wacke that is very similar to the green quartz wacke lithofacies of the Hawkeye Valley Member. Clayshale layers and lenses occur throughout this lithofacies (Fig. 23). The sandstone ranges from slightly to extensively bioturbated, and typically exhibits moderate bioturbation, although no body fossils were observed. Pyrite and phosphate nodules occur sporadically, usually as layers or lenses (<3 cm) (Fig. 23). These green quartz wackes occur both above and below the quartz arenite lithofacies, and usually have gradational bases and sharp upper contacts.

The quartz arenite lithofacies consists of three lithotypes: a bioturbated quartz arenite, a structured quartz arenite, and a structureless quartz arenite. The bioturbated quartz arenite lithotype is a fine- to medium-grained, moderately to well sorted, medium gray to dark gray sandstone. Bioturbation is very prominent, and is the distinguishing feature of this lithotype (Fig. 24). The sandstone is generally heavily bioturbated, but grades both upward and downward to moderately bioturbated. In zones where the sandstone is extensively bioturbated, it may grade into a black clayshale with occasional sandstone lenses, and further grade into a pure clayshale (Fig. 25). Extensively bioturbated sandstones grade into clayshales, and slightly bioturbated areas grade into massive sandstones characteristic of the other two lithotypes, with only occasional areas of bioturbation and burrows. Where the sandstone is moderately bioturbated, recognizable burrows are very prominent (Fig. 26). Thus, a whole spectrum of characteristics can be observed from pure, clean quartz arenite, to slightly bioturbated sandstone, to heavily bioturbated sandstone, and finally to pure clayshale. Sulfur staining

Figure 23. Phosphate nodules occurring within the green quartz wacke lithofacies of the Garland Member.

Figure 24. Characteristic bioturbation within the bioturbated quartz arenite lithotype, Garland Member.

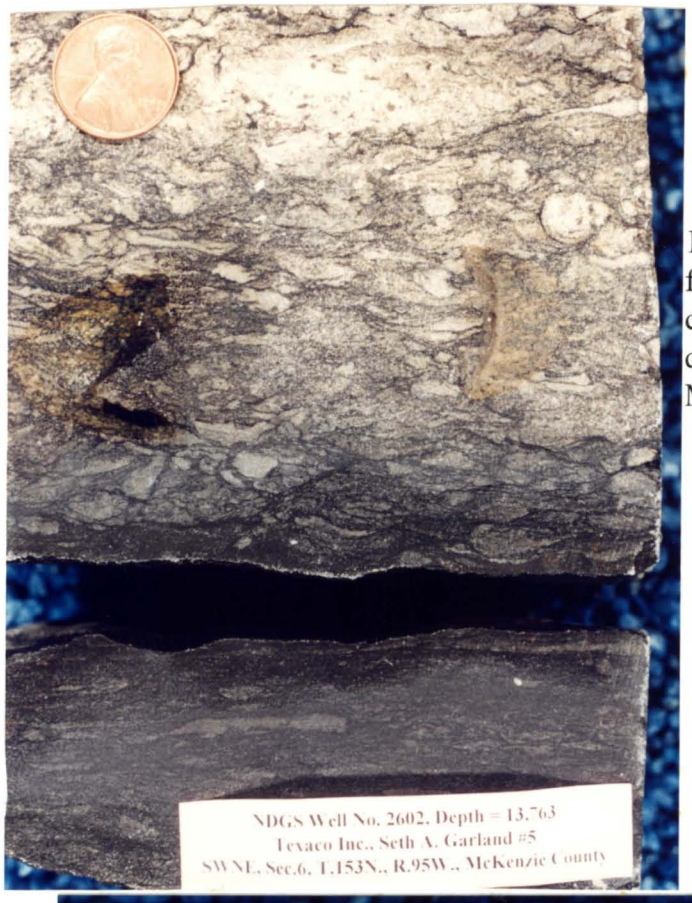

Figure 25. Gradation downward from bioturbated quartz arenite to clayshale within the bioturbated quartz arenite lithotype, Garland Member.

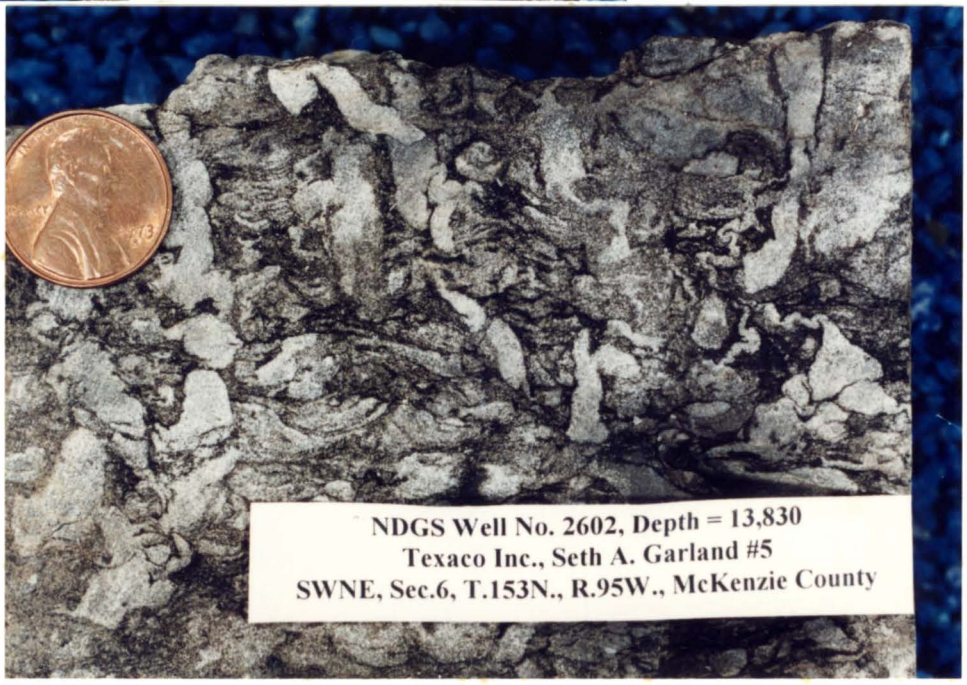

Figure 26. Burrows within the bioturbated quartz arenite lithotype, Garland member.

is very common, and gives the sandstone an orange-yellow appearance. Pyrite and phosphate nodules also occur throughout the lithotype, as do stylolites. The thickness of this lithotype is variable, ranging from < 1 ft (0.3 m) to 55 ft (16.8 m); it typically occurs near the top of the Garland Member, but is present locally in thinner deposits toward the base.

The structureless quartz arenite lithotype is a fine- to medium-grained, well-sorted, quartz-cemented, massive, quartz arenite, with occasional stylolites (Fig. 27). The thickness of this lithotype is variable, and ranges from < 1 ft (0.3 m) to about 20 ft (6.1 m). The lithotype is generally located below the thickest deposits of the bioturbated lithotype, but is also interbedded with the bioturbated quartz arenites lower in the Garland Member.

The structured quartz arenite lithotype is a light olive gray to light gray, fine- to medium-grained, well-sorted, quartz-cemented, quartz arenite. It is similar to the structureless quartz arenite except that it is generally lighter in color and contains very prominent laminations and cross-bedding (Fig. 28). The laminations are 1-4 mm thick and occur in beds which range from 1-15 cm. The laminations are generally horizontal but also occur at angles up to 20° (Fig. 29). Both tabular and trough cross-bedding are present throughout this lithotype; the bed sets range in thickness from 3-10 cm. Occasional 2-4 cm thick herringbone cross-stratification sets occur, in beds which range in thickness up to about 20 cm (Fig. 30). Stylolites also occur within this lithology. The thickness of the structured quartz arenite lithotype ranges from 1-8 ft (0.3-2.4 m). The

Figure 27. Characteristic massive sandstone of the structureless quartz arenite lithotype, Garland Member.

Figure 28. Characteristic cross-bedding within the structured quartz arenite lithotype, Garland Member.

Figure 29. Low angle laminations within the structured quartz arenite lithotype, Garland Member.

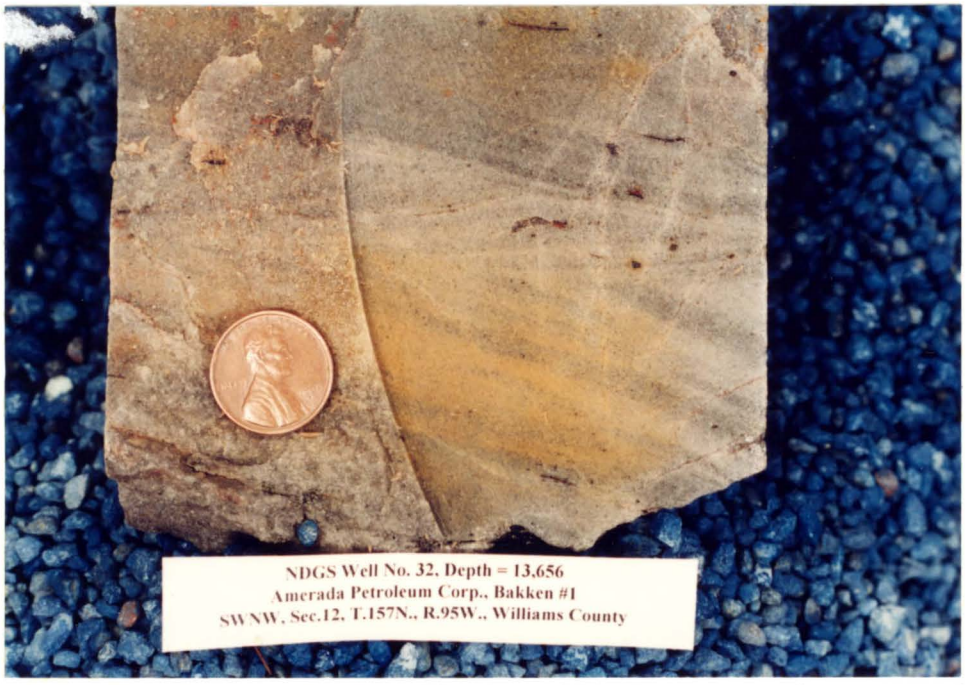

Figure 30. Herringbone cross-stratification within the structured quartz arenite lithotype, Garland Member.

lithotype is usually located in the middle or lower half of the Garland Member. It is sometimes interbedded with the structureless quartz arenite lithofacies, but usually grades into it. This lithotype is not interbedded with the bioturbated quartz arenite, but is in gradational contact with it both above and below. No fossils were observed within this lithotype, although Holland and Waldren (1955) reported conodonts in this and other lithotypes within the quartz arenite lithofacies.

Icebox Formation

The Icebox Formation has conformable, gradational contacts with both the underlying Black Island Formation and the overlying Roughlock Formation. The Icebox reaches a maximum thickness of 167 ft (51 m) in Grand Forks County; the maximum thickness in the center of the basin is 156 ft (48 m) in McKenzie County (Fig. 31). The area of increased thickness in Grand Forks County is coincident with a large east-west trending sandstone body, which is discussed below. In the extreme eastern part of North Dakota, post-Red River erosion has removed much of the Winnipeg Group, and is the cause of the abrupt limit depicted in Figure 31.

The Icebox Formation consists predominantly of noncalcareous greenish gray to dark greenish gray clayshale. Cores of the Icebox Formation generally exhibit shaley partings (Fig. 32) and prominent fissility (Fig. 33), although the shale is locally very well indurated. Occasional siltstone and sandstone lenses and nodules (<2 cm) occur toward the base of the unit (Fig. 34). Bioturbation is common throughout the Icebox Formation, and in some places it contains very prominent burrows (Fig. 35). Soft-sediment deformation also occurs within the clayshale. Occasional phosphate and pyrite nodules

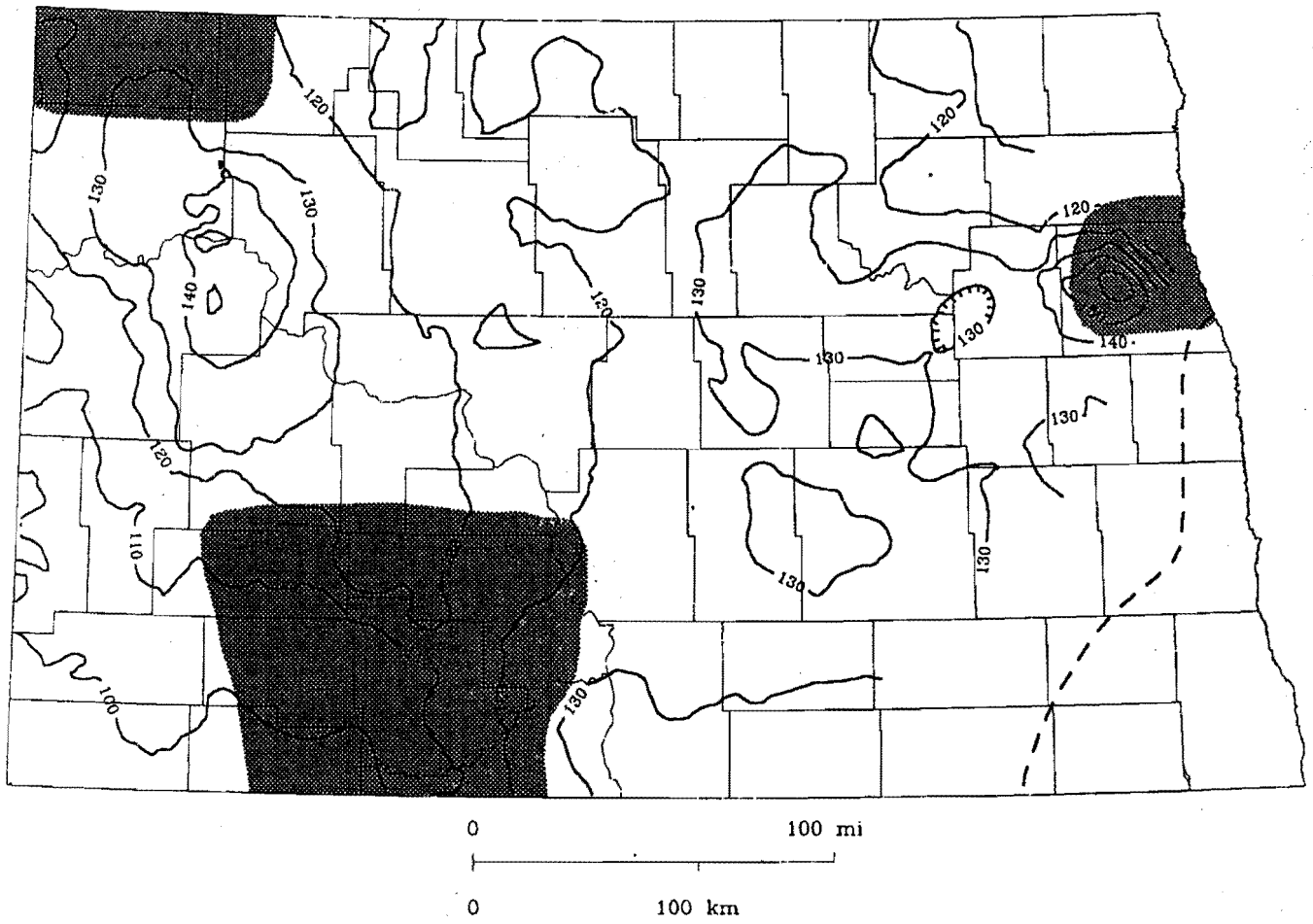

Figure 31. Isopach map of the Icebox Formation. The dashed lines represent the approximate erosional edge of the Winnipeg Group.

Figure 32. Shaley partings within the Icebox Formation.

Figure 33. Very prominent fissility of the shales within the Icebox Formation.

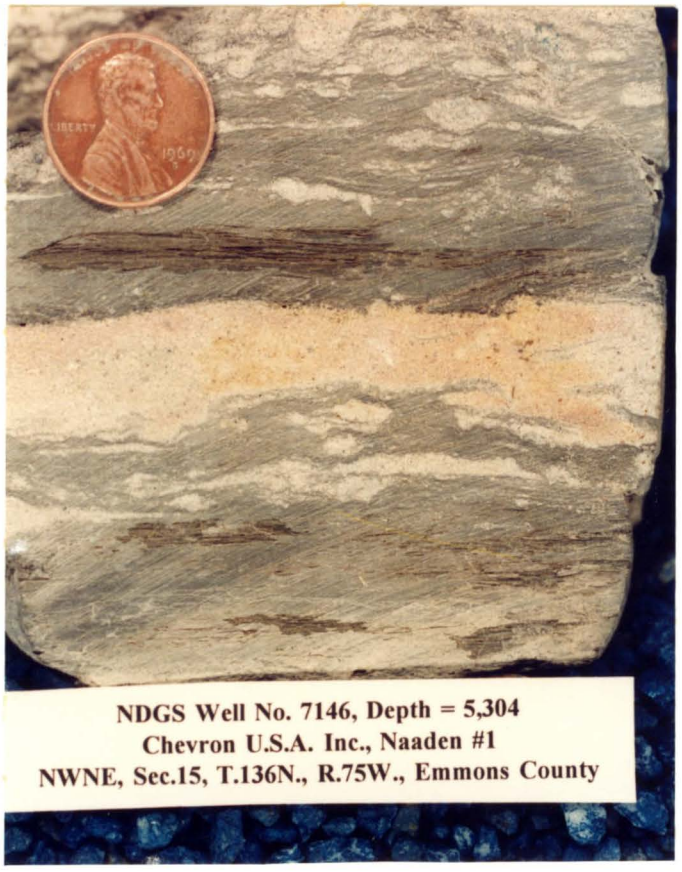

Figure 34. Sandstone lenses and layers within the shales of the Icebox Formation.

Figure 35. Bioturbation and horizontal worm burrows within the shales of the Icebox Formation.

(<5 mm) are scattered throughout the Icebox. Local zones within the Icebox clayshale are fossiliferous, and contain brachiopods, trilobite fragments, and many other, unidentified fossil fragments (Fig. 36 & 37).

The Icebox intertongues with the underlying Black Island Formation in parts of North Dakota. The intertonguing usually occurs between clayshale, with sandstone lenses, of the Icebox Formation, and the bioturbated quartz arenite lithotype of the Garland Member. Three sandstone lithosomes are present within the Icebox Formation (Fig. 31). The sandstones in extreme northwestern North Dakota, in Divide County, are at the base of the Icebox and represent intertonguing with the underlying Black Island Formation. The other two sandstone lithosomes, in Grand Forks County and in south central North Dakota, are located in the middle to upper portions of the Icebox Formation. These sandstone lithosomes are fine- to medium-grained, moderately to well sorted, quartz wacke. The sandstone bodies are generally moderately bioturbated, although laminations and occasional cross-bedding occur within the slightly bioturbated areas. These sandstone lithosomes are lithologically similar to the lithofacies of the Black Island Formation. The sandstones in Divide County reach a maximum thickness of approximately 45 ft (13.7 m), and are gradational both above and below with the bioturbated clayshale. The lithosome in Grand Forks County reaches a maximum thickness of about 60 ft (18.3 m) and is also gradationally enclosed by the bioturbated clayshale of the Icebox Formation. The sand body in south-central North Dakota is variable in thickness, and discontinuous; it reaches a maximum thickness of 35 ft (10.7 m). Most of this sand body consists of several layers of sandstone interbedded with

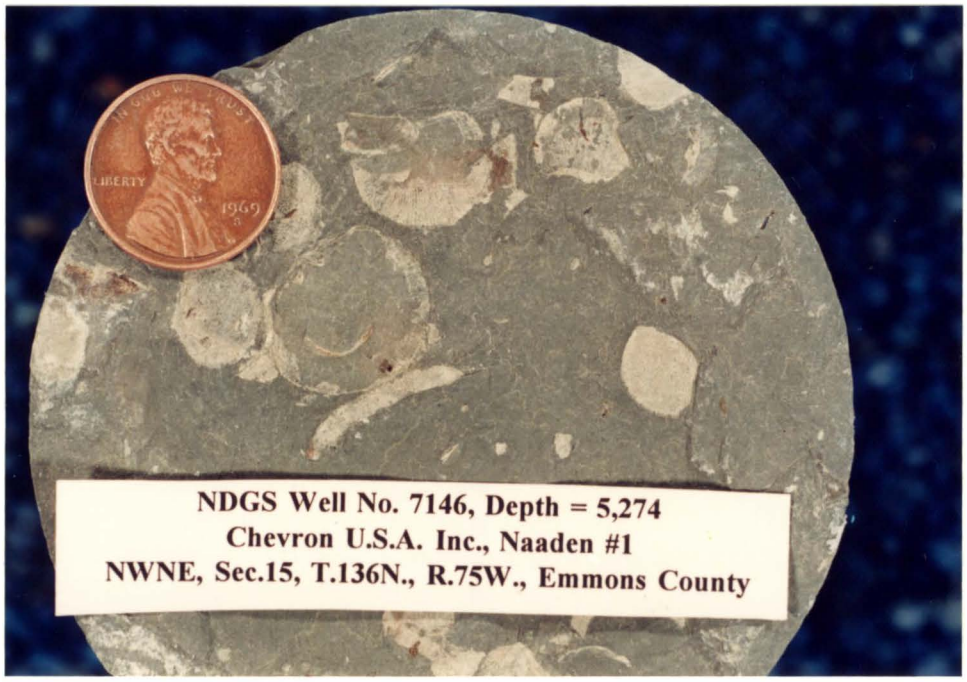

Figure 36. Brachiopod fossils within the Icebox Formation.

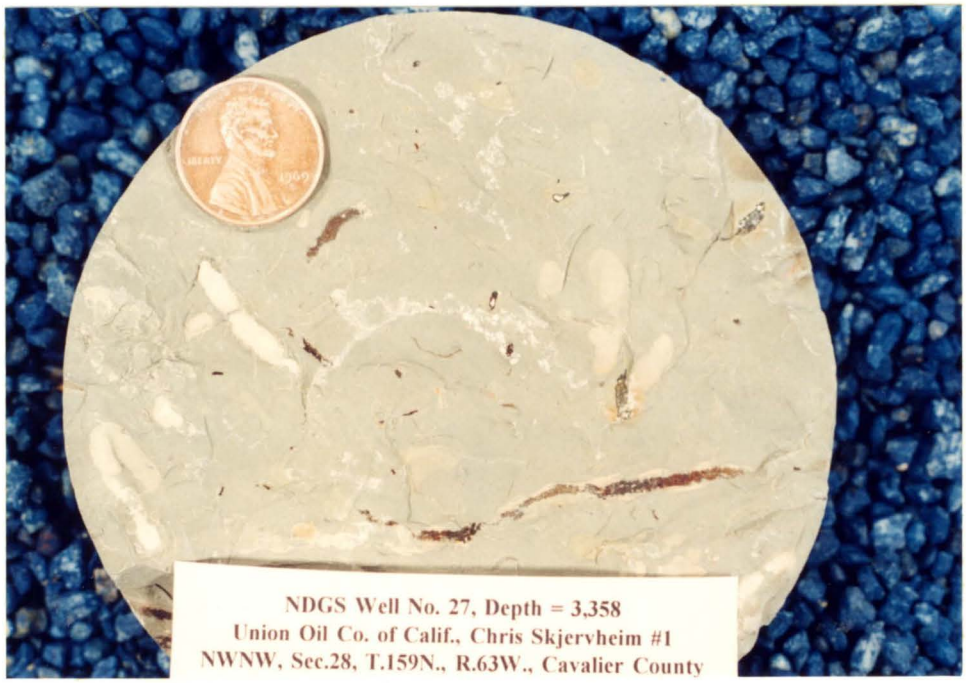

Figure 37. Fossil fragments within the Icebox Formation.

clayshale. These sand bodies are discussed in detail by Kessler (1991). Limestone lenses are also present in southeastern North Dakota in the lower Icebox (Carlson, 1964).

Roughlock Formation

The Roughlock Formation is a transitional unit between the underlying Icebox Formation and the overlying Red River Formation. The Roughlock Formation reaches a maximum thickness of 95 ft (29 m) in the extreme eastern part of North Dakota, just west of the erosional limit of the Winnipeg Group (Fig. 38). The Roughlock gradually thins to the west, and is consistently 20-30 ft (6.1-9.1 m) thick in the western third of the state. A thickening trend extends from Lamoure County westward to Grant County. The Roughlock Formation is very thin (< 10 ft; 3 m) in the northwestern and southwestern corners of North Dakota.

The Roughlock Formation is a light greenish gray to olive gray calcareous clayshale with limestone nodules, which grades upward into interbedded calcareous shales and limestones, to predominantly nodular limestone, and finally into the overlying Red River Formation. The Roughlock is progressively less argillaceous upward, and is transitional between the Icebox shales below and the clean carbonates of the Red River Formation. The nodules within the shaley matrix range in size from 0.5 to 10 cm (Fig. 39). Well log responses indicate that the Roughlock is a relatively homogeneous, gradual transition between the clastic and carbonate lithologies throughout most of the state, except in the south-central portion, where a sandstone lithosome is present. This sandstone lithosome (Fig. 38) reaches a maximum thickness of approximately 40 ft (12.2 m). The sandstone lithosome is interbedded with thin layers of shale. Another sandstone

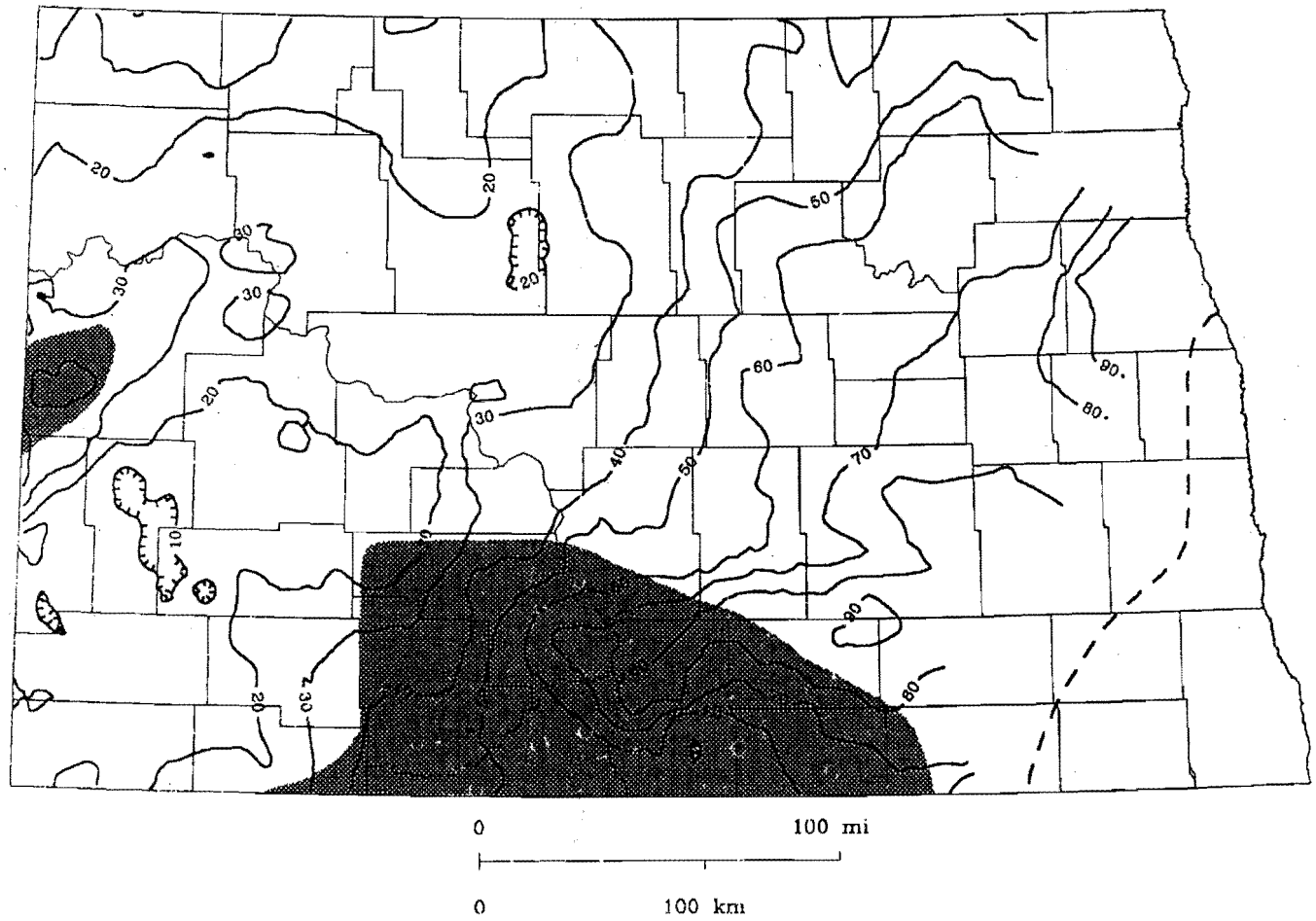

Figure 38. Isopach map of the Roughlock Formation. The dashed lines represent the approximate erosional edge of the Winnipeg Group.

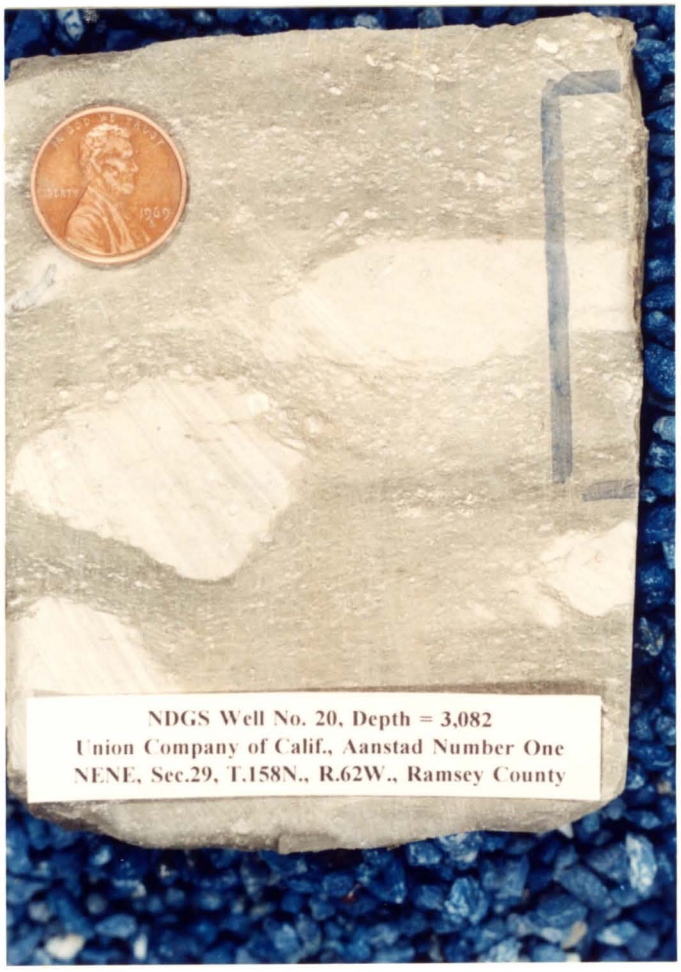

Figure 39. Limestone nodules and fossil fragments scattered throughout the shaley matrix of the Roughlock Formation.

occurs within the Roughlock in extreme western North Dakota. This lithosome ranges in thickness from 5-15 ft (1.5-4.6 m), and extends westward into Montana. Fossils occur throughout the Roughlock Formation, and include brachiopods and fragments of trilobites and other unidentified fossils (Fig. 39). Occasional pyrite nodules (<5 mm in diameter) and layers (1 mm) also occur in the lower portion of the Roughlock.

ENVIRONMENTAL INTERPRETATIONS

Introduction

Environmental interpretations of the units of the Winnipeg Group were based on comparing the lithologic and stratigraphic information obtained in this study to process-response models of modern and ancient environments. It is possible, however, that no modern environmental models accurately depict the environments in which these units were deposited. Stanley (1989) described the landscape at Ordovician time as "large areas of barren rock and soil with little or no humus." Vascular plants did not invade the land until Late Silurian time (Stanley, 1989, p. 356). As described by Stanley (1989), during Winnipeg time, sedimentation and erosion rates must have been much greater; thus caution should be taken when comparing ancient and modern environments.

Lithologic Trends

The Winnipeg Group unconformably overlies the Deadwood Formation (Cambrian - Lower Ordovician) over most of North Dakota, except in the extreme eastern part, where it lies directly on Precambrian basement rocks. The Winnipeg is conformably overlain by the dolomitic limestones of the Red River Formation. Figure 4 represents two cross-sections (a north-south and an east-west) running through the deepest part of the Williston Basin. These cross-sections illustrate the relationships between the units of the Winnipeg Group and the relations to the overlying and underlying formations. The

Deadwood Formation pinches out to the east and northeast so that the Winnipeg Group rests nonconformably on Precambrian rocks to the east of this Deadwood limit. The Deadwood increases in thickness to the west. The Black Island is thickest in the center of the basin and thins southward until it pinches out just north of the South Dakota border. The Hawkeye Valley Member is present only in the center of the basin and pinches out in all directions. The Garland Member is more widespread throughout the state. The Icebox Formation's thickness remains fairly consistent throughout the state and conformably overlies the Black Island except where the Icebox lies directly on the Deadwood Formation in southern North Dakota (where the Black Island is absent). The Roughlock is conformable with both the underlying Icebox and the overlying Red River Formation and gradually thickens towards the east.

Hawkeye Valley Member

The Hawkeye Valley Member consists of two lithofacies: a red-bed lithofacies and a green quartz wacke lithofacies. The reddish brown color of the Hawkeye Valley Member is the most obvious and distinctive characteristic that defines this member. The red-bed lithofacies consists of two lithotypes: a red quartz arenite and a red clayshale. Red beds are usually thought to be good indicators of continental environments, although Reineck and Singh (1980) suggested that most ocean basins have large areas covered by red to reddish brown clay. However, Heckel (1972) stated that red beds occur in all grain sizes, not just clay, and are mainly nonmarine in origin. Potter et al. (1980) suggested that the color in shales is controlled by the amount of organic matter present when deposited, because the ferric/ferrous ratio is controlled by the oxidation rate, which is in

turn controlled by the amount of organic matter in the sediment (Thompson, 1984). Using Potter et al.'s (1980) model, the reddish brown color of the red bed lithotype contains a low percentage of organic carbon and a high ferric/ferrous ratio. This low percent of organic carbon suggests a non-marine environment for the red bed lithotype. This conclusion is consistent with Thompson's (1984) determination of organic carbon and ferric/ferrous ratios.

Continental red beds can represent a wide range of non-marine depositional environments including alluvial fans, river floodplains, deserts, lakes, and deltas. Red beds are not exclusively red and often contain variable proportions of other strata that show a variety of other colors resulting from minor variations in depositional environments (Turner, 1980). The occurrence of ferric oxides in red beds indicates that they were formed under oxidizing conditions but this is of no paleoclimatic significance because red beds form in both arid and moist tropical climates. Turner (1980) stated that, although red beds may form in many climatic settings, they are best known from and characteristic of delta plain deposits of moist tropical climates. At the time of deposition of the Hawkeye Valley Member, what is now North Dakota appears to have been located in low latitudes, near the equator (Stanley, 1989), which might indicate that the red beds were deposited in a moist tropical climate.

Turner (1980) suggested several criteria for recognizing a delta plain paleoenvironment, some of which include: sandstone channel deposits, bank deposits, red and drab color, fining- and coarsening-upward trends, cross-bedded sands and cross-laminated silts, fine-grained suspension load sediments due to overbank flooding, fine

laminations, alternating sands and muds, sands containing either parallel or cross laminations, slight bioturbation of sandstones, and mudcracks. The Hawkeye Valley Member exhibits many of the above characteristics (as described in the lithologic descriptions).

The structureless dusky red shales and interbedded dusky red and dark greenish gray shales of the red clayshale lithotype suggest deposition from suspension. Horizontally laminated siltstones represent episodic sedimentation in still water. Fine-grained, thin cross-bedded sandstones indicate times of relatively high energy flow conditions. These thin cross-bedded sandstones are often interbedded with laminated shales, which indicates variable current conditions and rapid changes in the depositional system, which would be expected within a deltaic plain environment. The interbedding of shales with finely laminated siltstones, mudstones, and occasional dusky red cross-bedded sandstones indicate intermediate slack water periods when clay settled out between periods of transportation of silts and fine-grained sands. Mudcracks, which are caused by the drying and shrinking of mud and clay, are present near the base of the red clayshale lithotype. These mudcracks, along with the distinctive red color and pervasive hematite cement, strongly suggest that the red clayshale lithotype was deposited in a subaerial environment. The red quartz arenite lithotype within the red bed lithofacies is characterized by a fine- to medium-grained, moderately to well sorted, well rounded, dark reddish brown to dusky red quartz arenite. The thick deposits of this reddish brown quartz arenite represent channel deposits or bank deposits of distributary channels. Occasional bioturbation and the presence of burrows toward the top of the red bed

lithofacies, which lies directly below the green quartz wacke lithofacies, suggests the beginning of a transgressive sequence.

The features described above, and the very prominent reddish color of the red bed lithofacies, suggest that this lithofacies was deposited in a deltaic plain environment. The major criterion for interpretation of this unit was the reddish-brown color, although depositional environments can not be accurately interpreted only by color. However, the color, along with the previously described sedimentary structures, strongly suggests that the red bed lithofacies of the Hawkeye Valley Member was deposited within a deltaic plain.

The green quartz wacke lithofacies consists of a fine- to coarse-grained, poorly to moderately sorted, bioturbated argillaceous sandstone. The very obvious difference in lithology and sharp contact with the underlying red bed lithofacies suggests a very different origin for this lithotype. The common bioturbation and lack of subaerial exposure (criteria discussed above) suggest a subaqueous origin, perhaps in a nearshore marine or lagoonal environment. The abundance of green clay stringers and lenses within the heavily bioturbated sandstone again suggests a nearshore or lagoonal environment. Thompson (1984), LeFever et al. (1987), and Carlson and Thompson (1987) suggested two possible origins for the green quartz wacke lithofacies. They suggested that these rocks may have formed as the result of the weathering of preexisting strata of the lower member of the Black Island Formation (Hawkeye Valley Member in this study) (Thompson, 1984) or by a different and more likely explanation, which suggested that the lithofacies represents the initial deposits of the transgression that later deposited the

quartz arenite of the upper member of the Black Island (Garland Member of this study). This study supports both of these hypotheses; small amounts of "red" sandstone occur within the lower portions of the green quartz wacke lithofacies, which suggests that some of the red bed lithofacies may have been reworked. However, these red sandstones are restricted to the lower portion of the green quartz wacke lithofacies, which suggests that this lithofacies is the initial deposit of the transgression that later deposited the Garland Member. The interbedding of this lithofacies with the red bed lithofacies at the top of the section and the occurrence of the green quartz wacke lithofacies in the lower portions of the Garland Member suggest that a facies relationship exists between the Hawkeye Valley and Garland Members.

Garland Member

The Garland Member consists of two lithofacies: a quartz arenite lithofacies and a green quartz wacke lithofacies. The quartz arenite lithofacies consists of three lithotypes: a structured quartz arenite, a bioturbated quartz arenite, and a structureless quartz arenite. Thompson (1984) suggested that the environment under which the upper Black Island Formation (Garland Member of this study) was deposited may have been somewhat similar to that of the modern environment of the Oregon coast, where a sand facies is controlled by sediment supply, shelf hydraulic regime, and burrowing benthic organisms (Clifton et al., 1971). Clifton et al. (1971) noted that, in general, the Oregon coast sand occurs in the nearshore environment, with water depths ranging from 160-320 feet (50-100 m). He also suggested that primary sedimentary structures are commonly obliterated due to extensive bioturbation, but stratification is occasionally preserved

(Thompson, 1984). Thompson (1984), LeFever et al. (1987), and Carlson and Thompson (1987) all suggested that the upper Black Island Formation (Garland Member) was deposited in a nearshore environment, which is consistent with the results of this study.

The structured quartz arenite lithotype is the dominant lithotype found towards the base of the Garland Member. The structured quartz arenite lithotype is characterized by well-rounded and well-sorted quartz arenite, which supports the interpretation that deposition occurred in an active foreshore or nearshore environment. Thompson (1984) suggested that the horizontal laminations and low angle laminations found within this lithotype represent upper flow regime conditions with deposition from suspension, which is consistent with this study. Thompson (1984) also suggested that hummocky cross-stratification may also be present in the upper Black Island (Garland Member). The large scale of hummocky cross-stratification, along with the roughly horizontal orientation of the laminae, makes it difficult to recognize in cores. This hummocky cross-stratification usually occurs in the lower part of shore-line sequences, especially under high wave energy. Herringbone cross-stratification suggests tidal influences and these lithofacies may indicate intertidal or subtidal deposition, perhaps in minor tidal channels. The scarcity of fossils within the structured quartz arenite lithotype suggest an active environment, in which it would be difficult for benthic organisms to survive. Interpretation of a nearshore environment for the quartz arenite lithofacies is also supported by the position of the adjacent rock units. The Garland Member is conformably underlain by the Hawkeye Valley Member, which is interpreted to represent a deltaic/fluvial environment, and is conformably overlain by the Icebox Formation,

which is interpreted in this study to represent an offshore deposit. The relative position of the Garland Member is thus between the underlying continental deposits and the overlying marine shales, and a nearshore environment interpretation is reasonable. The texture, structures, and relative position of the structured quartz arenite lithotype suggest that this lithotype was deposited in a nearshore environment with minor tidal influences.

The bioturbated quartz arenite is characterized by an abundance of bioturbated sandstones. The high degree of bioturbation and the general lack of sedimentary structures suggest deposition in a relatively low-energy environment, with little significant transport of sediment, which is interpreted as a marine setting below normal wave base, in the lower shoreface or offshore. Toward the base of this lithotype, the bioturbation is less extensive and more burrows are present; this probably represents the intermediate position between the underlying structured quartz arenite and the overlying heavily bioturbated sandstones. This lithotype generally occurs toward the top of the Garland Member between the underlying structured and structureless quartz arenite lithofacies and the overlying Icebox shales. This position is consistent with the lower shore to offshore interpretation. Occasionally, the bioturbated quartz arenite grades downward into structureless quartz arenite, then to structured quartz arenite, back to structureless quartz arenite, and finally back into bioturbated quartz arenite, which probably indicates offshore sand bars that were covered by offshore deposits due to the continued transgression. The prominent bioturbation, lack of structures, the gradational contacts with the surrounding units, and the relative position of the bioturbated quartz

arenite lithotype suggest that it was deposited in a low-energy nearshore or offshore environment.

The interpretation of the structureless quartz arenite lithotype is more difficult, due to the lack of sedimentary structures. This lithotype is generally a well-cemented, well-sorted, massive quartzitic sandstone. It is possible that the laminations may have been lost due to compaction and diagenesis, although the relative position of this lithotype remains constant throughout the Garland Member. Its typical occurrence between the structured quartz arenite and the bioturbated quartz arenite suggests deposition in an environment intermediate between the two, perhaps the upper shoreface. Towards the contacts with the overlying and underlying lithotypes, the structureless quartz arenite lithotype begins to show characteristics of the surrounding lithotypes. The structureless quartz arenite seems to be a gradational unit between the other two lithotypes; this probably represents the outer limits of the normal wave base.

The green quartz wacke lithofacies of the Garland Member is very similar to the green quartz arenite lithofacies of the Hawkeye Valley Member. Due to the presence of this lithofacies in both the upper most portion of the Hawkeye Valley Member and the lower most portion of the Garland Member, the green quartz wacke lithofacies may be interpreted as the transitional unit between these members and probably represents the initial deposits of the Late Ordovician transgression. The interbedding of the green quartz wacke lithofacies with the other lithofacies within both the Hawkeye Valley and Garland Members suggests that facies relationships existed between these two members.

Icebox Formation

The Icebox Formation consists predominantly of noncalcareous, greenish gray, fissile to well indurated, slightly bioturbated clayshales. The Icebox Formation was deposited in an offshore marine environment, seaward of the nearshore environments of the Black Island Formation and beyond the range of coarser clastic influx, except for some local areas. Occasional siltstone and sandstone lenses and nodules occur toward the base of the Icebox, and represent a gradational contact with the underlying Garland sandstones. In certain areas, the Icebox Formation shows an interbedding relationship with the underlying Black Island Formation, which suggests that facies relationships exist between the two formations. Marine invertebrates, such as the orthid and strophomenid brachiopods (Boardman et al., 1987), clearly identify the Icebox as marine in origin and probably indicate conditions with approximately normal salinities (Johnson, 1978). The abundant bioturbation, horizontal burrows, and epifaunal suspension feeders (brachiopods) suggest that the upper portion of the substrate experienced mildly oxidizing conditions (Thompson, 1984). Water depths are uncertain, but the sandy lithosomes suggest that depths may not have been great; the lack of coarse material may simply indicate distance from shore rather than water depth.

The three sandstone lithosomes within the Icebox Formation probably represent three different depositional environments. The sandstone lithosome in northwestern North Dakota (Divide County) represents an intertonguing relationship between the base of the Icebox Formation and the upper extremes of the underlying Garland Member, which probably was due to small-scale fluctuations in sea level or variations in clastic

input. Thompson (1984) described the upper portion of this lithosome as more continuous and probably representing a nearshore deposit similar to the structured quartz arenite of the Garland Member. Thompson (1984) suggested that the cross-laminated sandstones present in the middle of this lithosome were deposited under lower flow regime conditions; they are overlain by horizontally laminated and bioturbated sandstones grading into the normal clayshale of the Icebox Formation. This lithotype is interpreted to represent a tongue of the Garland Member within the Icebox Formation. The lithosome in Divide County is interpreted to represent a transgressive event (marked by the transition from sandstone of the Garland Member to the clayshale of the Icebox) , followed by a regression (depositing the nearshore sandstone lithosome), and then another transgressive sequence (represented by the normal clayshales of the Icebox). The large-scale transgressive-regressive event was accompanied by several small-scale transgression-regression events depositing clayshale and sandstone layers less than 3 feet (1 m) thick. The interbedding of the sandstone and clayshale suggests that a facies relationship exists between the upper portions of the Garland Member and the lower portions of the Icebox Formation.

A second sandstone lithosome in the Icebox Formation is located in Grand Forks County, North Dakota. Results of this study suggests that this lithosome was deposited as an offshore bar within the Icebox. In 1959, Andrichuk described an elongated sandstone body within the Winnipeg shale in southern Manitoba, and named it the "Carman sandstone." Vigrass (1971) interpreted the Carman sandstone as an offshore deposit that was deposited up to 100 miles (160 km) from the shore. The lithosome in

Grand Forks County and the Carman sandstone have similar lithology and textural characteristics (well-sorted, commonly argillaceous, and friable sandstone) (Thompson, 1984). Both sandstone bodies are elongate in shape and oriented with their long axis running approximately east-west. Thompson (1984) suggested that the similarities between these two sandstone lithosomes indicate they may have been deposited under similar conditions. Kessler (1991) described three large elongated east-west trending sand bodies within the Icebox Formation: the Carman sand and two smaller sand bodies in eastern North Dakota. Kessler (1991) suggested that the Carman sand, as well as the other two sand bodies in eastern North Dakota, were probably formed by storm and tidal-currents. The two sand bodies in eastern North Dakota, which were previously thought to be one large sandstone body (Thompson, 1984), were split into these two smaller sand bodies by Kessler . Kessler (1991) described these two sand bodies as the outer shelf equivalents of the Carman sand. He also suggested that the shelf ridge development in the Icebox Formation was related to a lower than usual basin subsidence rate for the middle Caradoc eastern Williston Basin margin during transgression (Kessler, 1991). This slow subsidence resulted in the development of shoaling sand ridges to a critical depth for the deposition of tidal sediments (Kessler, 1991). There is generally agreement that these sandstone lithosomes in the northeastern part of the basin are the product of offshore deposition on topographic highs, such as the shoal areas Kessler (1991) described; that interpretation is consistent with the results of this study.

The third Icebox sandstone lithosome, which is located in south-central North Dakota, is much less understood than the other two lithosomes. The unit is uncored and

the log responses indicate that the unit is discontinuous and consists of interbedded sandstones and shales. This lithosome was also probably deposited in shoal areas, although the discontinuous distribution suggests that such areas were localized rather than forming a single, shallow platform. Thompson (1984) and LeFever et al. (1987) suggested that these sandstones might be the distal deposits of a delta building into the basin from South Dakota. No core exists for the Winnipeg in that part of North Dakota, and there is no well log control in South Dakota, so their explanation remains speculative.

Roughlock Formation

The Roughlock Formation is a transitional unit between the underlying shales of the Icebox Formation and the overlying limestones of the Red River Formation. The Roughlock Formation consists of a light greenish gray to olive gray calcareous clayshale with limestone nodules, which grades upward into interbedded calcareous shales and limestones, to predominantly nodular limestone, and finally into the overlying Red River limestones. LeFever et al. (1987) suggested that the environmental conditions in which the Roughlock was deposited appear to be similar to those of the Icebox Formation (offshore) except for a decrease in the amount of detrital input, which allowed the production of carbonates (this is consistent with the results of this study). The Roughlock becomes less argillaceous upward due to the decrease in detrital sediment until it grades into the clean limestones of the Red River Formation. The Roughlock Formation contains a rich and diverse faunal assemblage, which includes brachiopods, echinoderms, and trilobite fragments, and suggests that it was deposited in an open marine environment with normal salinities (Thompson, 1984).

Wilson (1975) described the several conditions necessary for the production of carbonate sedimentation, a few of which include clear, warm, and shallow water, light, and the absence of siliciclastics. These conditions can be satisfied at or near the equator, which is consistent with the location of North Dakota during the Late Ordovician (Stanley, 1989). Wilson (1975) listed several characteristics of a shelf facies which are similar to characteristics observed in Roughlock strata. The shelf facies consists of water depths of tens to even a few hundred meters, and of generally oxygenated, normal marine salinities, with good current circulation, at depths below normal wave base but still affected by storms. The shelf facies is characterized by carbonates and shales, fossiliferous limestones interbedded with marls, gray to greenish color, abundant burrows, wavy nodular beds, occasional silt and shale beds, and a very diverse shelly fauna preserved both in and on the substrate (Wilson, 1975). The Roughlock, which consists of nodular limestone and shales, is very fossiliferous and burrowed, and is greenish-gray in color, which fits the carbonate shelf environment that Wilson (1975) described. Evidence suggests that the Roughlock Formation was deposited in an offshore carbonate shelf environment.

The Roughlock Formation has two sandstone lithosomes: a large sand body in south-central North Dakota, and a smaller elongated body in east-central North Dakota. The lack of core makes the interpretation of this unit difficult. However, the well logs suggest that there are several thin sand bodies interbedded with layers of shale. The sandstone lithosome in south-central North Dakota is probably similar in origin to the sand body located in that area within the Icebox Formation. The lithosomes apparently

represent deposition in shoal areas, although Thompson (1984) and Carlson and Thompson (1987) suggested that the lithosome in south-central North Dakota might be of deltaic origin, and possibly genetically related to the underlying sandy unit in the Icebox Formation.

DEPOSITIONAL HISTORY

Pre-Winnipeg Deposition

Until the latter part of Cambrian time, the area which is now North Dakota was exposed to erosion and developed a surface of considerable relief (LeFever et al., 1987). The area was first covered by the Cambrian transgression during Dresbachian time, when deposition occurred around islands of Precambrian basement (LeFever et al., 1987). Members A through(E of the Deadwood Formation were deposited from Dresbachian to Arenigian time and are composed of limestones, shales, and sandstones. During the deposition of the Deadwood, a number of transgressive-regressive events occurred (Anderson, 1988). LeFever et al. (1987) suggested that the initial subsidence of the Williston Basin began no later than during deposition of member D of the Deadwood Formation (late Tremadocian), and possibly even earlier; the isopach pattern and backstripping techniques they used in the study suggest an initiation during member C time (LeFever et al., 1987). During the Middle Ordovician (latest Llanvirnian), there was a major eustatic sea level drop, and marine deposition of the Deadwood Formation in North Dakota ceased (LeFever et al., 1987). Prior to the onset of Winnipeg deposition, the Williston Basin was exposed to erosion for some 25-30 million years, since the latest Llanvirnian (Middle Ordovician). During this interval, the Deadwood Formation was extensively eroded over the entire state, and removed from the eastern part of North

Dakota (LeFever et al., 1987). By Late Ordovician time, sea level had risen far enough to resume deposition in the basin, giving rise to the initial deposits of the Winnipeg Group.

Winnipeg Deposition

The Winnipeg Group (Upper Ordovician) represents the initial deposits in the Williston Basin of the Late Ordovician transgression that covered most of the North American craton. In determining the depositional history of the Winnipeg Group, several major concepts must be kept in mind. The first concept that will be examined is the time-transgressive nature of the Winnipeg Group. In 1964, Clarence G. Carlson was able, for the first time, to trace the Roughlock from outcrops in Manitoba, beneath the Williston Basin, and into the Black Hills of South Dakota, demonstrating that this unit was physically continuous throughout the Williston Basin. Walter C. Sweet (written communication to Thompson, 1984) later conducted a conodont study, which determined that the Roughlock Formation is considerably younger in eastern North Dakota than in the Black Hills. The Roughlock thus exhibits different ages in different localities, which indicates that the Roughlock Formation is time-transgressive in nature. Fuller (1961) indicated that the Black Island Formation is older in the Williston Basin than in outcrops on islands of Lake Winnipeg, Manitoba, suggesting it is also time-transgressive.

The second major concept that is important in understanding the depositional history of the Winnipeg Group is the facies relationships that exist between the lithostratigraphic units. As described earlier in the text, the contacts between all of the units within the Winnipeg Group are gradational. An interbedding relationship exists between the Hawkeye Valley Member and the Garland Member as well as between the

Garland Member and the overlying Icebox Formation. This interbedding relationship suggests that a facies relationship exists between the units involved. Thompson (1984) has suggested that the contact between the Icebox and the Roughlock Formations is transitional, and that they exhibit facies relationships. The Roughlock Formation is simply a transitional unit between the underlying Icebox Formation and the overlying Red River Formation, and thus represents a facies relationship. Thus, it appears that a facies relationship exists between all of the units of the Winnipeg Group, as well as with the overlying Red River Formation.

Another concept related to the depositional history of the Winnipeg Group is the presence of a marine connection. Two ideas exist concerning where this marine connection originated, either from the southeast or the southwest. Gerhard et al. (1982) stated that isopach studies suggest a southwesterly connection to the western geosyncline through the central Rockies. However, Carlson (1964) stated that well data provided evidence to support a physical continuity between the Winnipeg Group and the Upper Ordovician section in southeastern Minnesota (Thompson, 1984). Thompson (1984) suggested that the primary connection of the Late Ordovician sea to North Dakota was to the southeast, through Minnesota. Thompson (1984) believed this was possible due to a break or sag in the Transcontinental Arch along its northeastern portion during the Late Ordovician. Thompson (1984) examined Foster's (1972) sandstone-shale ratio map and isopach map and suggested that the truncated isopach contour lines and a high percentage of shale at the east and southeast erosional limit provided evidence that the Winnipeg originally extended considerably farther to the southeast, thus supporting a marine

connection to the southeast. This study does not either support or refute that a sag or break existed in the Transcontinental Arch during the Late Ordovician. A regional investigation of the Williston Basin and southwestern Minnesota would be necessary to reach a conclusion. Whether the Black Island and the St. Peter, and the Icebox and the Glenwood Formations, were once physically continuous units, extending across the Transcontinental Arch, remains unknown at this time.

After the major eustatic sea level drop and erosion of much of the Deadwood Formation in Early Ordovician, sea levels began to rise again in the Late Ordovician. The isolated and circular pattern of isopach contours of the Hawkeye Valley Member suggest that this unit may have been deposited at or during the initial stages of this transgression. LeFever et al. (1987) suggested that the subsidence of the Williston Basin began during the deposition of the C or D Member of the Deadwood Formation; thus a depression may have been present during the initial deposition of the Winnipeg. The isopach contours of the Hawkeye Valley Member suggest that a depression existed during the deposition of the deltaic sediment. The circular pattern and the large areal extent of the deltaic deposits of the Hawkeye Valley Member suggest that the fluvial systems were providing sediment to the basin from every direction, but especially from the highlands to the north and east. The Deadwood Formation and the Precambrian basement rocks were the likely source of sediment for the Hawkeye Valley Member. The Hawkeye Valley Member reaches a maximum thickness of 128 feet in the center of the basin; these thick accumulations of continental and deltaic deposits suggest that the rate of sedimentation kept pace with subsidence so that there was not a large enough volume of open water to

create a beach environment in the early Williston Basin (Thompson, 1984). The above information suggests that the deposition of the Hawkeye Valley Member began about the same time the transgressing Late Ordovician sea reached North Dakota.

As sea level continued to rise, the deltaic deposits of the Hawkeye Valley Member were covered by widespread shallow marine and marginal marine deposits, in lagoonal and barrier island environments represented by the green quartz wacke lithofacies in both the Hawkeye Valley and the Garland Members. These green quartz wacke lithofacies are inferred to be the initial deposits of the Late Ordovician transgression. The presence of this lithotype in both the upper portions of the Hawkeye Valley Member and the lower portions of the Garland Member suggests intertonguing between the two members. This intertonguing relationship indicates that the Hawkeye Valley and Garland Members probably exhibit a facies relationship, as well as representing an intermittent transgression rather than a gradual, continuous transgression.

By the end of Hawkeye Valley Member deposition, the Williston Basin had subsided enough to accumulate a substantial amount of standing water, as represented by the nearshore deposits of the Garland Member. The most rapid rate of subsidence occurred in the center of the Williston Basin, as it did for the Hawkeye Valley Member. The subsidence rate of the Williston Basin was rapid enough and the transgressive rates fast enough, so that deeper marine deposits began to accumulate. As the basin continued to subside, the structured quartz arenite lithotype was covered with a structureless quartz arenite, which accumulated at or near wave base, and was finally covered by the offshore bioturbated quartz arenites. With continued transgression and basin subsidence, the

depositional environments gradually shifted eastward. Thompson (1984) suggested that the thin deposits in eastern North Dakota, of the upper member of the Black Island Formation (Garland Member in this study), were due to either the relatively rapid transgression over the eastern part of the state or due to minimal subsidence in this part of the state. Tidal influences may have been a minor contributor to the sedimentation pattern of the Black Island Formation, as depicted in the herringbone cross-stratification in the structured quartz arenite lithotype of the Garland Member and later in the Icebox Formation. By the end of Black Island time, the sea covered all of North Dakota, and Icebox shales were deposited in the western part of the state.

By this time, the Late Ordovician transgression had advanced far enough so that all of North Dakota had been inundated, all of the Deadwood Formation had been covered, deposition of the Black Island sands had ceased in North Dakota, and shale of the Icebox Formation was being deposited in western North Dakota. Intertonguing Garland and Icebox strata are evident throughout the state, indicating a discontinuous transgression instead of a gradual, continuous transgression. The water was deep enough and the influx of sand was far enough away so that the shales of the Icebox Formation could be deposited over most of North Dakota. Over much of Manitoba and Saskatchewan, the Winnipeg is composed mostly of sandstones interbedded with smaller amounts of shale and has been interpreted to have been deposited on a large, shallow, low sloped shelf (Vigrass, 1971). Thus, minor fluctuations in sea level could have resulted in a large variation in the position of the shoreline, and the sandstone lithosome within the Icebox Formation in northwestern North Dakota may have been the result of one of these

sea level fluctuations, where nearshore deposits temporarily advanced basinward (Thompson, 1984). The three different sand bodies within the Winnipeg Group are of different origins. The sandstone lithosome in Divide County is located at the base of the Icebox, whereas the other two lithosomes are located towards the middle of the Icebox Formation. Thompson (1984) and LeFever et al. (1987) suggested that the large sand body in south-central North Dakota may be due to deltaic deposition from the south. The sandstone lithosome in Grand Forks County has been interpreted by Kessler (1991) as storm or tidal-current in origin and is the product of offshore deposition on topographic highs, such as shoal areas.

Continued rise in sea level and migration of the shoreline to the east and north gradually inundated the sources of fine-grained clastic sediments of the Icebox Formation. With this reduction of clastic sedimentation, conditions became more favorable for the deposition of carbonates. Western North Dakota was the first area to receive carbonate deposition, due to its distance from the sources of the clastic sediment. These resulting argillaceous carbonates make up the Roughlock Formation. The Roughlock represents a gradual transition between the underlying shales of the Icebox Formation and the clean carbonates of the Red River Formation. In extreme northwestern North Dakota, the transition between the Icebox shales and the Red River limestones must have occurred very rapidly, as there is virtually no Roughlock present and the Red River Formation was deposited directly on the clayshales of the Icebox Formation (Thompson, 1984). Thompson (1984) suggested that the Icebox, Roughlock, and the Red River Formations are facies of each other. The large sandstone lithosome in south-central

North Dakota within the Roughlock Formation was probably deposited similarly to the sandstone body within the Icebox. The Roughlock Formation is more of a siltstone in South Dakota, probably due to its closer proximity to a source area (Thompson, 1984).

Eventually, the Late Ordovician transgression continued until all the sources of terrigenous clastics had been covered, and the clean carbonates of the Red River Formation were deposited over the Winnipeg Group throughout North Dakota.

CONCLUSIONS

1) The strata of the Winnipeg Group are divided into three formations, in ascending order, the Black Island, the Icebox, and the Roughlock Formations. This study has proposed names for the previously unnamed members of the Black Island Formation, the Hawkeye Valley Member and the Garland Member. Each of these units is lithologically distinct and mappable.

2) The Winnipeg Group (Upper Ordovician) unconformably overlies the Deadwood Formation (Cambrian - Lower Ordovician) over most of North Dakota, except in the extreme eastern part, where it lies directly on Precambrian basement rocks. The Winnipeg is conformably overlain by the Red River Formation (Upper Ordovician).

3) The Hawkeye Valley Member consists of two lithofacies: a red-bed lithofacies and a green quartz wacke lithofacies. The red-bed lithofacies consists of two lithotypes: a red quartz arenite and a red clayshale. The Hawkeye Valley Member reaches a maximum thickness of 128 feet (39 m) in Williams County and is restricted to the western half of North Dakota and the immediately surrounding areas. Abundant desiccation cracks and the distinctive red color strongly suggest that the red-bed lithofacies was deposited in a subareal environment. The red-bed lithofacies represents a fluvial/deltaic environment and the green quartz wacke lithofacies represents a nearshore marine or lagoonal environment.

4) The Garland Member consists of two lithofacies: a quartz arenite lithofacies and a green quartz wacke lithofacies. The green quartz wacke lithofacies is similar in character to the green quartz wacke lithofacies found within the Hawkeye Valley, which represents the initial deposits of the Late Ordovician transgression. The quartz arenite lithofacies consists of three lithotypes: a bioturbated quartz arenite, a structured quartz arenite, and a structureless quartz arenite. The Garland Member reaches a maximum thickness of 169 feet (52 m) in McKenzie County. Prominent sedimentary structures and good sorting in the structured quartz arenite indicate that deposition occurred in an active foreshore or nearshore environment. The high degree of bioturbation and lack of sedimentary structures in the bioturbated quartz arenite lithotype indicate deposition in a relatively low-energy environment below normal wave base. The lithofacies within the Garland Member thus represent a shallow marine environment.

5) The Icebox Formation is a fossiliferous, bioturbated shale with minor sandstones, and represents an offshore deposit. The Icebox Formation reaches a maximum thickness of 167 feet (51 m) in Grand Forks County; the maximum thickness in the center of the basin is 156 feet (48 m) in McKenzie County.

6) The Roughlock Formation is a fossiliferous, calcareous shale deposited in a deeper marine environment. The Roughlock reaches a maximum thickness of 95 feet (29 m) in the extreme eastern part of North Dakota and gradually thins to the west. The contacts between all of the units within the Winnipeg are intertonguing and gradational.

7) During the Middle Ordovician (Llanvirnian) there was a major sea level drop, causing erosion of much of the Deadwood Formation. Sea level rose again during the

Late Ordovician, and the Hawkeye Valley was deposited unconformably on the Deadwood. As sea level continued to rise, the Garland was deposited, followed by offshore marine Icebox shales. Local topographic highs probably had sufficient relief to cause the formation of sand bodies during Icebox deposition. Still farther offshore, where the influx of clays was minor, the calcareous shales of the Roughlock were deposited, and finally deposition of the Red River limestones occurred.

APPENDICES

APPENDIX A

Name and location of wells from which well logs were studied. Wells are listed within each county according to their North Dakota Geological Survey well number. The locations of these wells are described as follows: Townships and ranges are north and west respectively. (T = township, R = range, S = section, and Q = quarter of the quarter-section description). The operator and well name are from records of the North Dakota Geological Survey.

WELL	T	R	S	Q	OPERATOR	NAME
Adams County						
6322	130	91	7	NESW	ENERGETICS INC.	SOELBERG #23-7
7642	130	95	28	NWSE	AMOCO PROD. CO.	JACOB CHRISTMAN #1
Barnes County						
4640	140	59	9	SESW	J. M. JOHNSTON ET AL	ALLAN E. VIG #1
Benson County						
632	154	70	31	NWSE	CALVERT DRILLING CO.	ARTHUR J. & IDA J. & GINA STADUM #1
Billings County						
291	139	100	9	NWNE	AMERADA PETROLEUM CORP.	HERMAN MAY U. #1
555	143	100	17	SESE	STANOLIND OIL AND GAS COMPANY	N.W.I. (NP) # 1
3268	139	101	10	NESW	AMERADA PETROLEUM CORPORATION	SCORIA UNIT #8
6228	144	98	3	NWSW	GULF OIL CORP.	ZABOLOTNEY #1-3-4-A
6303	143	100	29	NESW	TENNECO OIL CO.	BN #1-29
6913	143	99	9	SENW	AMOCO PROD. CO.	THOMPSON #1
7307	143	99	22	SENE	AMOCO PROD. CO.	KNUDTSON STATE #1
7520	143	99	21	NENE	AMOCO PROD. CO.	H. T. KNUDTSON #1
7934	142	100	23	SWNW	W. H. HUNT TRUST ESTATE	ANNA OSADCHUK B-1
8226	143	100	27	NWSW	COASTAL OIL & GAS CORP & HUNT ENERGY	27-143-100 HLEBECHUK ET AL #1
8487	143	102	13	SESE	CONOCO, INC.	BLACKTAIL #13-1
8603	142	98	31	SWSE	ADOBE OIL AND GAS CORPORATION	STATE KORDONOWY #34-31
11335	139	102	11	SWNE	AMERADA HESS CORPORATION	BNRR #11-32
Bottineau County						
38	160	81	31	SWSE	CALIFORNIA OIL CO.	BLANCHE THOMPSON #1
64	163	77	18	SWNW	HUNT OIL	OLIVER OLSON #1
110	163	75	23	NWNW	LION OIL	HUSS #1
2219	161	79	6	SESW	CALIFORNIA OIL CO.	BERT HENRY #4
4655	162	78	31	SESW	AMERADA PETROLEUM CORP.	H. D. LILLESTRAND #1

WELL	T	R	S	Q	OPERATOR	NAME
Bottineau County						
4790	159	81	20	SESE	UNION OIL CO. OF CALIF.	ABRA STEEN #1
4846	163	81	8	NENW	LAMAR HUNT	W. CRANSTON #1
5184	162	77	14	SENE	CHAMPLIN PET. CO.	DUNBAR #1 42-14
9522	161	77	21	SWNW	COASTAL OIL & GAS CORP.	COGC 21-161-77 BJORNSETH #1
Bowman County						
485	129	104	16	NWNW	WILLIAM HERBERT HUNT	ZACH BROOKS-STATE #1
1575	129	106	9	NWSW	CARTER OIL CO.	LEWIS L. & ELLEN JOHNSON #1
9656	131	100	6	NWNE	PLACID OIL CO.	CORNELL #6-2
9805	130	104	32	NESW	CLAYTON W. WILLIAMS, JR.	WALLMAN #1
Burke County						
8893	162	89	8	SWSW	MONSANTO COMPANY	MELBY #1
Burleigh County						
19	140	77	6	SWSW	CONTINENTAL-PURE, DAVIDSON	STRATIGRAPHIC TEST # 1
145	137	76	32	NWNW	CONTINENTAL	PAULH MCCAY#1
151	140	80	18	SWSW	HUNT OIL	EMMA KLEVEN
155	140	75	9	NENE	CONTINENTAL	DRONEN #1
174	140	77	3	NWNW	CONTINENTAL	DUENELAND #1
701	144	75	36	NENE	CAROLINE HUNT TRUST ESTATE	BOARD OF UNIV. & SCHOOL LANDS #1
723	139	76	36	NENE	CAROLINE HUNT TRUST ESTATE	R. P. SCHLABACH #1
756	137	77	32	SESE	CAROLINE HUNT TRUST ESTATE	R. A. NICHOLSON #1
765	142	76	31	SWSW	CAROLINE HUNT TRUST ESTATE	SODER INVESTMENT CO. #1
772	140	79	23	NWNW	CAROLINE HUNT TRUST ESTATE	PAUL RYBERG #1
1409	140	77	11	NWSE	LEACH OIL & CALVERT	PATTERSON LAND CO. #1
6264	139	76	9	NENE	TOM F. MARSH	FUNSTON #1
7010	138	78	31	NENE	ASAMERA OIL (U.S.) INC.	WELCH #1
8674	141	76	17	SWSW	SUN OIL COMPANY	T. D. THORSON #1
12057	144	79	21	SESE	MCOR OIL & GAS CORP.	L. WALL # 1-21

WELL	T	R	S	Q	OPERATOR	NAME
Cavalier County						
27	159	63	28	NWNW	UNION OIL CO. OF CALIF.	CHRIS SKJERVHEIM #1
1694	162	63	10	NWNW	JOHNSON OIL	EARL MOORE #1
2342	160	57	3	NWSW	POWERS LAKE PETROLEUM CO.	GRIMSI GOODMAN ESTATE #1
Dickey County						
515	129	63	11	SENW	H. HANSON OIL SYNDICATE	HAROLD BILLEY #1
682	130	63	34	SESE	SNOWDEN	CHESTER L. GIBSON #1
1394	129	66	22	NWNW	CALVERT DRILLING CO.	MARVIN KAMM
Divide County						
1443	162	96	6	SWNE	DAKAMONT EXPLORATION CORP.	HAROLD E. JACOBSON #1
1546	162	101	34	NENW	KERR MCGEE CORP.	ARLET JOHNSON
2010	163	102	7	NWNE	CARTER OIL CO.	DALLAS D. MOORE #1
6798	162	96	16	NESE	SHELL OIL CO.	RINDEL #43-16
7087	163	95	18	SESW	SHELL OIL CO.	SVANGSTU #24-18
7660	163	97	24	SWSW	PATRICK PETR. CORP.	VAALER #1-24
7942	160	97	19	NWSE	W. H. HUNT TRUST ESTATE	LEONARD ROSTEN #1
8707	161	95	25	SENW	HOME PETROLEUM CORPORATION	KJELSHUS #2
9398	163	101	16	SESE	CONOCO, INC.	STATE 16 #1
9413	163	98	16	SESE	TEXACO, INC.	HAUGLAND #1
9446	162	102	1	SESE	TENNECO OIL CO.	REISTAD #1-1
9528	163	102	20	NWNW	CONOCO, INC.	CONOCO MOORE 20 #1
9622	163	98	10	NWNW	TEXACO INC.	ARNOLD HAGEN STATE #1
9677	164	98	33	SESW	TEXACO INC.	R. L. HANSON #1
Dunn County						
6086	145	94	7	NENE	AMOCO PROD. CO.	BERENT SELLE #1
6148	141	96	2	SWSW	AMOCO PROD. CO.	ANDREW M. HEISER #1
6530	141	95	18	SENE	AMOCO PROD. CO.	WOLBERG #1
7402	144	91	9	SWNE	MOSBACHER PRUET OIL CO.	NEUROHR #9-1

WELL	T	R	S	Q	OPERATOR	NAME
Dunn County						
7412	145	93	18	SWNW	CITIES SERVICE CO.	STATE OF ND #A-1
7584	145	95	8	NENW	AMOCO PROD. CO.	ROSHAU #1
8077	147	96	10	NESW	MESA PETROLEUM COMPANY	PELTON #1-10
8313	145	93	22	NWSW	MESA PETROLEUM COMPANY	HAUSAUER #1-22
8491	142	96	30	NESW	VANDERBILT RESOURCES CORPORATION	BULLINGER #1-30
8536	144	93	7	SWSE	TERRA RESOURCES, INC.	KLING #1-7
8613	144	93	20	SWSW	EXXON CORPORATION	ADOLF GEIST #1
8709	147	93	8	NESW	SHELL OIL COMPANY	BURBANK BIA #23-8
8768	145	92	30	NWNW	TERRA RESOURCES, INC.	WERNER #1-30
9027	144	92	31	SESW	LUFF EXPLORATION CO.	GELLER N-31
9044	146	93	11	SENW	ANR PRODUCTION CO.	HANSEN #1-11A
9080	144	92	16	SENW	GETTY OIL CO.	HALLIDAY #16-6
9397	146	93	25	SWSE	TXO PRODUCTION CORP.	COOK
9527	146	97	7	NWNW	GULF OIL CORP.	ROQUETTE 1-7-1A
10072	147	93	14	NENE	GULF OIL CORP.	MOCCASIN INDIAN UNIT 1-14-2B
10606	142	93	15	NWNW	CONOCO, INC.	CONOCO-FRIDLEY 15 #1
10627	141	93	21	NESW	NANCE PETROLEUM CORPORATION	DAUENHAUER #11-21
11363	144	91	18	SWSW	CONOCO INC.	CONOCO NEUROHR 18 1
12400	142	97	9	NWSE	MERIDIAN OIL INC.	GRIGGS #33-9
Eddy County						
437	150	67	16	NWNW	CALVERT DRILLING CO.	N.DAK. STATE #1
768	150	65	8	NENE	CALVERT DRILLING CO.	#1 STATE #1
1274	148	62	9	SESE	WETCH ZACHMEIER & DISNEY	C. E. BLASKY #1
Emmons County						
16	133	75	35	NWSW	NORTHERN ORDINANCE, INC.	FRANKLIN INVESTMENT CO. #1
23	133	76	35	NESE	ROESSER & PENDELTON	J. J. WEBER #1
43	132	78	8	NESE	PEAK DRILLING	OLHAUSER #1
7101	132	76	10	SWSW	KELDON OIL CO.	HORNER #1

WELL	T	R	S	Q	OPERATOR	NAME
Emmons County						
7146	136	75	15	NWNE	CHEVRON U.S.A., INC.	NAADEN #1
7936	136	75	13	NWNW	CHEVRON U.S.A. INC.	RASSEN RAMBOUGH #1
10173	135	76	14	SWSW	SOUTHWESTERN ENERGY PRODUCTION CO.	BEASTROM #1-14
Foster County						
287	146	63	13	NWNW	FRAZIER-CONRAY	SARAH DUNBAR #1
295	145	62	26	SWNE	T. M. EVANS	BAILEY #1
334	145	64	24	NENE	T. M. EVANS	CHRISTIAN ERICKSON #1
403	146	66	15	NENE	PURE OIL	J. M. CARR #1
1105	146	65	8	SESW	CARDINAL, KAUFMAN, GREAT PLAINS ET AL	J. S. SMITH #1
1112	146	66	23	NENE	CARDINAL, KAUFMAN, GREAT PLAINS ET AL	N. A. GRAVES & FEDERAL LAND BANK #1
1126	146	67	10	NWNW	CARDINAL DRLG. CO. ET AL	J. M. ANDERSON #1
1227	147	64	25	NENE	MIKE WETCH	H. F. SPICKLER #1-A
Golden Valley County						
410	143	103	24	NESW	GULF OIL CORP.	DOROUGH FEDERAL #1
470	140	105	15	NESE	BLACKWOOD & NICHOLS	GILMAN & LANG #1
6272	137	106	22	NENW	SHELL OIL CO.	KREMERS #21-22
6513	141	104	31	NENE	SHELL OIL CO.	DAVIDSON #41-31
6563	139	105	4	NWNE	SHELL OIL CO.	SMITH #31-4
7753	141	104	7	SENE	MORAN EXPLORATION, INC.	KUNICK #1
7969	142	105	32	NWSE	MORAN EXPLOR., INC.	STECKER #1
8590	144	103	28	SENW	IKE LOVELADY, INC.	MOORE-FEDERAL #1-28
9148	139	105	16	NENE	HUNT OIL COMPANY	KIPPLEY-STATE #1-16
9540	140	104	32	NESE	MOBIL OIL CORP.	PEARL OLSTAD #1
Grand Forks County						
580	151	53	15	NENE	A. J. SCOTT	A. J. SCOTT #1
1356	152	54	24	SWSE	NORTH PLAINS PET. INC.	F. F. DANNER #1
3191	153	52	5	NWSW	CANADIAN-DAKOTA SASTEX	DENNIS WOSICK #1-A

WELL	T	R	S	Q	OPERATOR	NAME
Grand Forks County						
3204	152	51	17	NWNW	CANADIAN-DAKOTA SASTEX	JULIAN NERESEN ESTATE #1
12110	149	54	33	NESE	LYLE O. GERMUNDSON	MIDBOE #1
Grant County						
5572	132	86	27	NENW	GAS PROD. ENT. INC.	BURLINGTON NORTHERN #1
6420	132	86	7	SWSW	MARSHALL R. YOUNG OIL CO.	7-132-86-BN #1
6586	134	90	17	NWNE	THE ANSCHUTZ CORP.	FRED ALT #1
7020	137	88	5	SENE	TEXAS PACIFIC OIL CO.	WILLIAM STECKLER #1
8549	134	87	16	SESE	SHELL OIL COMPANY	HIRNING-STATE #44-16
8680	131	88	35	NENW	SHELL OIL COMPANY	BN #21-35
Griggs County						
4719	146	61	5	NWSE	JACK M. JOHNSTON DRILLING CO.	WILLIAM M. RAHLIF
9659	148	61	1	NWSW	PETROTEX MANAGEMENT CO.	TEXERGY #1 DONOHUE
Hettinger County						
7075	133	93	26	SWSE	AMOCO PROD. CO.	ROKUSEK #1
7453	133	97	24	SESW	AMOCO PROD. CO.	URLACHER #1
8312	135	96	35	NWSW	SKYLINE OIL COMPANY	FEDERAL HERBERHOLZ 35 #1
10522	136	95	31	SESW	AMOCO PRODUCTION COMPANY	KREB-AMOCO #1-31
Kidder County						
24	141	73	36	SENE	MAGNOLIA PET.	DAK.
230	143	71	16	NESE	CARTER OIL CO.	NORTH DAKOTA STATE #1
748	142	74	32	NWNE	CAROLINE HUNT TRUST ESTATE	E. B. SAUTER #1
La Moure County						
3999	133	64	18	NWNW	VAUGHN PETROLEUM INC.	H. SMITH #1
5117	133	66	9	SWSW	DON BILLS	JUVELUS BJUR #1

WELL	T	R	S	Q	OPERATOR	NAME
Logan County						
590	136	73	6	NWNE	CAROLINE HUNT TRUST ESTATE	F. M. FULLER #1
1347	136	71	25	NWNW	CALVERT, LEACH, INTERNATION, WESTERN	RAY CRAIG #1
5523	135	73	29	NWNW	WISER OIL CO.	NO. 2 ET AL BALTZER A. WEIGEL #1
McHenry County						
39	157	78	3	NESW	HUNT OIL	W. B. SHOEMAKER #1
61	153	77	17	NWSE	HUNT OIL	PETER LENNERTZ #1
8307	155	77	31	NENW	ASAMERA OIL (U.S.) INC.	LARSON #1
8803	151	80	22	NENE	ATLANTIC RICHFIELD COMPANY	WUNDERLICH #1
11922	159	79	15	SENW	CITATION OIL & GAS CORP.	METTLER 1-15
McIntosh County						
89	131	73	15	NENE	GENERAL ATLAS CARBON	A. KETTERLING #1
620	130	69	13	NESE	CALVERT DRILLING CO.	C. C. NITSCHKE #1
621	130	69	19	NWNW	CALVERT DRILLING CO.	JOHN BENDER #1
622	131	69	17	SWNW	CALVERT DRILLING CO.	KARL SCHOCK #1
McKenzie County						
956	148	104	28	NWSW	GULF OIL CORP.	BENNIE-PIERRE FED. U #1
2373	152	95	1	NESE	AMERADA PETROLEUM CORP.	ANTELOPE UNIT
2602	153	95	6	SWNE	TEXACO INC.	SETH A. GARLAND #5
5836	148	102	16	SWNE	KERR MCGEE CORP.	N.D. STATE #1-X
6112	153	95	23	SENW	TIGER OIL CO.	W. J. DINWOODIE #22-23
6387	148	104	6	SWSE	SHELL OIL CO.	USA #34X-6
6414	148	104	8	NENW	SHELL OIL CO.	U.S. GOVT #21-8
6501	152	101	6	NESE	GULF OIL CORP.	ECKERT FOUNDATION #1
6790	152	102	35	SWNW	SUPERIOR OIL CO.	DONALD LINK ET AL #1
7001	154	95	34	NWSW	TEXACO INC. & AMERADA	RED RIVER UNIT 1 #1
7203	149	99	14	NWSE	AMOCO PROD. CO	WILBUR CAMPBELL #1
7479	146	99	16	SESW	PENNZOIL CO.	GRASSY BUTTE #16-24

WELL	T	R	S	Q	OPERATOR	NAME
McKenzie County						
7571	151	95	31	SWNE	TEXACO INC.	REITSCH NCT-2 #4
7572	151	95	32	SWSW	TEXACO INC.	LOOMER #1
7607	154	95	33	SESE	AMERADA HESS CORP.	FEDERAL #33-3D
7631	151	99	33	NENE	TEXACO INC.	HENRY TORSTENSON #1
7873	150	99	15	SESW	TEXACO, INC.	FELLAND
7988	153	95	5	NWSW	TEXACO, INC.	RED RIVER UNIT 2 #1
8083	150	95	7	SWNE	TEXACO INC.	MOSHOLDER #4
8090	152	95	6	NESE	AMERADA HESS CORPORATION	GRIMESTAD #4-6
8092	151	99	27	SWNE	TEXACO INC.	R. T. LATTIN #1
8131	151	99	10	SWSW	TEXACO INC.	C. L. STENBERG
8165	151	101	23	SENE	SUNBEHM GAS, INC.	SKEDSVOLD #1
8187	148	101	10	NWNE	W. H. HUNT TRUST ESTATE	LARSON #1
8193	146	102	3	SENW	PENNZOIL COMPANY & DEPCO	COVERED BRIDGE #3-22
8268	151	102	13	NENE	AL-AQUITAINE EXPLORATION, LTD.	THURLOW #1-13
8302	149	101	24	NWSE	TRAVERSE OIL COMPANY	NYGAARD #1-24
8314	147	103	8	SENE	SHELL OIL COMPANY	USA #42-8
8372	150	100	26	NWNE	MOBIL OIL CORPORATION	ROGNESS ET AL #1
8468	146	101	27	SENE	PENNZOIL COMPANY & DEPCO	BEICEGEL CREEK #27-42 BN
8626	152	98	17	SWNE	PATRICK PETROLEUM COMPANY	ENDERUD #1-17
8663	147	98	25	SENE	GULF OIL CORPORATION	MORMON BUTTE FED. #2-25-2C
8737	147	102	4	NWSE	ABRAXAS PETROLEUM CORPORATION	BURNING MINE BUTTE #4-33
8882	153	101	35	SESE	TEXAS GAS EXPLORATION CORP.	LINDVIG 1-35
9004	150	100	10	NESE	EXXON CORPORATION	FLECK #1
9005	145	100	21	SWSE	GULF OIL CORP.	FEDERAL #1-21-3D
9006	152	102	23	SESE	SUPERIOR OIL CO.	BARROWS #1
9217	149	96	3	SENW	AMAREX, INC.	ANDERSON #1
9901	148	103	25	NWNE	SHELL OIL CO.	USA #31-25-155
9957	152	97	5	NENE	TEXACO INC.	L. J. GRANTIER
11110	152	95	20	SENW	AMERADA HESS CORP.	SWENSON 20-22
12345	150	96	25	NENW	SUN EXPLORATION & PRODUCTION	DELMER RINK #1

WELL	T	R	S	Q	OPERATOR	NAME
McKenzie County						
12589	153	94	30	NESW	AMERADA HESS CORP.	MCKEEN 30-3
12596	150	97	3	NENE	SUN EXPLORATION & PRODUCTION CO.	ISABEL-BRYANT # 1-3
12699	148	100	8	SWNW	CONOCO, INC.	SCHULTZ 8 # 3
12726	151	95	8	NESW	TEXACO INC.	GOV'T. T. G. DOROUGH # 9
McLean County						
22	146	81	10	SWNE	SAMEDAN OIL CORP.	VAUGHN HANSON #1
49	150	80	28	SWSW	STANOLIND	MCLEAN COUNTY #1
7783	150	90	1	SENW	HOME PETR. CORP.	TRIBAL #1-1
8060	148	89	7	SWNE	APACHE CORP.	SOLCUM #1
8711	146	80	31	SESE	SUN OIL COMPANY	FLEMMER #1
8720	144	81	34	NENE	SUN OIL COMPANY	FAHLGREN #1
8993	149	80	26	SESW	ATLANTIC RICHFIELD CO.	KLAIN #1
Mercer County						
21	142	89	28	NWNE	KELLY-PLYMOUTH	FRITZ LEUTZ #1
8675	142	90	6	NENW	MGF OIL CORPORATION	ENTZE #21-6
8712	145	90	29	SWSW	GULF OIL CORPORATION	ISAAK #1-29-4D
Morton County						
26	136	81	29	NENW	PHILLIPS-CARTER	DAKOTA #1
1620	139	90	27	NESW	PAN AMERICAN PET. CORP.	RAYMOND YETTER #1
3859	135	83	34	SENE	AMERADA PETROLEUM CORP.	JAMES MEYER #1
7340	140	88	26	NWSE	AMOCO PROD. CO.	RICHTER #1
7691	138	85	19	SENW	AMOCO PROD. CO.	OLIN #1
7797	137	87	14	SESE	TEXAS PACIFIC OIL CO.	BACHLER #1
7937	138	86	19	NENE	AMOCO PROD. CO.	OLSEN #1
8158	138	82	6	SWSE	PENZOIL COMPANY	SWEET BRIAR #6-34
8553	140	82	17	SENW	SHELL OIL COMPANY	VOGEL #22-27

WELL	T	R	S	Q	OPERATOR	NAME
Mountrail County						
6780	151	89	24	SENE	BASS ENTERPR. PROD. CO.	ROBERT ANDES #24-1
6872	153	88	16	NESE	MARATHON OIL CO.	MAE OLSON #1
9326	156	92	1	SWNW	GULF OIL CORPORATION	JUMA 1-1-1D
12597	157	94	6	SENW	AMERADA HESS CORP.	KNOSHAUG 6-22
Nelson County						
1934	152	60	5	SESE	REELFOOT DEV. CO., INC.	L. & A. BRYL #1
4664	151	61	32	NWSW	JACK M. JOHNSTON DRILLING CO.	SYDNEY L. HAAS #1
4785	151	60	6	NENE	JACK M. JOHNSTON DRILLING CO.	GRITZ #1
9143	149	59	25	SWSE	PETROTEX MANAGEMENT CO.	GLADE #1A
Oliver County						
15	141	81	18	SESE	CARTER OIL CO.	E. L. SEMLING #1
8144	141	82	15	SESE	PENNZOIL CO.	LITTLE BOOT #15-44
Pembina County						
700	164	56	28	NESE	TURNER OIL	THEODORE BEIANUS #1
Pierce County						
30	158	72	28	NENE	AJAX	BELL #1
435	158	69	12	SENW	MIDWEST OIL CORP.	HECKMAN #1
706	157	70	23	SESE	SHELL OIL CO.	GIFFORD MARCHUS #1
3920	152	74	23	SESE	A. J. HODGES IND., INC.	ALEX MARTIN #1
5576	152	73	34	SWSW	GETTY OIL	LUDWIG VETTER #1
12125	158	72	1	SENE	CHAPMAN EXPLORATION, INC.	L. SELVIG #1
Ramsey County						
20	158	62	29	NENE	UNION OIL COMPANY OF CALIFORNIA	AANSTAD NUMBER ONE
196	154	65	16	NENE	CARTER OIL COMPANY	ALLAN MACDIARMID # 1
246	154	63	36	NENE	NORTHERN NATURAL GAS PRODUCING CO.	RAYMOND P. & BLANCHE T. LEE

WELL	T	R	S	Q	OPERATOR	NAME
Ramsey County						
383	158	62	17	NWNW	S. D. JOHNSON	M. D. WOLF # 1
407	153	63	13	NESW	CALVERT EXPLORATION COMPANY	CARL JACK # 1
408	153	63	1	SWSW	CALVERT EXPLORATION COMPANY	W. HALEY # 1
411	158	63	11	SWSE	S. D. JOHNSON	EDWIN WERNER # 1
422	158	62	33	NESW	MCLAUGHLIN INC.	WOLFE # 1
4745	156	62	14	NWSW	JOHN R. BLACK ESTATE	CECIL J. MILLER #1
4914	156	61	32	NENE	MILLER & FOX DRILLING CORP.	ERWIN LORENZ #1
Renville County						
6296	163	87	9	NESW	SHELL OIL CO.	LARSON #23X-9
6349	164	87	34	SWSW	SHELL OIL CO.	MOTT #14-34
6401	163	87	10	NESW	SHELL OIL CO.	WISDAHL #23-10
6436	163	87	5	NESE	SHELL OIL CO.	DUERRE #43-5
6466	163	87	3	SWNE	SHELL OIL CO.	MOTT #32X-3
6504	162	87	1	SWNE	GREAT YELLOWSTONE	ONES #1
6624	161	85	1	SENW	SHELL OIL CO.	OSTERBERG #22X-1
6684	161	85	2	NENW	SHELL OIL CO.	OSTERBERG #21-2
6749	163	87	3	NWSE	SHELL OIL CO.	GILBERTSON #33-3
7577	160	86	15	SWNW	SHELL OIL CO.	DEWING #12-15
Rolette County						
83	161	73	23	SENW	LION OIL COMPANY	SEBELIUS #1
316	160	70	23	NWSW	EVANS PRODUCTION CORPORATION	ANDY LEROY JOHNSON #1
13586	159	72	11	NENE	EAGLE OPERATIONS INC.	ZINN LAW #41-11
Sheridan County						
665	148	76	15	NENE	CAROLINE HUNT TRUST ESTATE	JOHN WALTZ JR. # 1
684	147	75	1	NENE	CAROLINE HUNT TRUST ESTATE	J. R. MATZ # 1
693	146	76	19	SWSW	CAROLINE HUNT TRUST ESTATE	WALTER E. BAUER # 1
735	146	74	16	SWSW	CAROLINE HUNT TRUST ESTATE	C. A. PFEIFFER # 1

WELL	T	R	S	Q	OPERATOR	NAME
Sheridan County						
9343	146	76	29	NWNW	MOSBACHER-PRUETT OIL CO.	STATE-DICK #29-1
Sioux County						
631	131	80	29	NESW	OHIO OIL COMPANY	STANDING ROCK SIOUX TRIBE # 1
6654	129	85	27	SESE	UNICHEM INT'L. INC.	JACOBS #1
Slope County						
8629	136	98	34	SENE	COBRA OIL AND GAS CORP.	STATE SMITH #34-1
9244	136	98	2	NWSE	WILLIAM C. KIRKWOOD	EHLIS #32-2
11484	135	98	24	NENW	MILESTONE PETROLEUM, INC.	KIRSCHMAN 21-24
Stark County						
6447	139	97	8	SWNW	ANADARKO PROD. CO.	KOSTELECKY #1
8088	141	93	28	NWNE	MOBIL OIL CORPORATION	WILLIAM BERNHARDT #1
8169	138	92	21	NENW	GULF OIL CORP.	LEVIATHAN #1-21-1B
8342	140	95	36	NWNW	SUPRON ENERGY CORPORATION	LAWRENCE #1
8665	137	92	4	NESW	GULF OIL CORPORATION	KILZER #1-4-4B
8837	137	95	17	SWSE	TERRA RESOURCES, INC.	PRANGE #1-17A
9056	139	93	24	SENW	GULF OIL CORP.	OGRE #1-24-1C
9135	138	91	28	SENE	PIONEER PRODUCTION CORP.	DIEDE #1-28
9256	139	93	14	NWSE	GULF OIL CORPORATION	HUTCHINSON 1-14-3A
9257	139	92	19	NESW	GULF OIL CORPORATION	HAMANN #1-19-4B
9322	139	96	29	SESE	WILLIAM C. KIRKWOOD	KOSTELECKY #44-29
9341	139	93	10	NESW	GULF OIL CORP.	MOORE #1-10-4B
9348	139	92	30	NWSE	EXXON CORP.	HAMMON #1
9407	139	92	32	NESW	GULF OIL CORP.	HOFF 1-32-4B
9475	140	94	24	NWNE	FLARE ENERGY CORP.	HAUGEN #2X-24
9684	138	97	34	NENW	MOBIL OIL CORP.	J. F. FISHER #1
9796	139	92	20	SWNE	GULF OIL CORP.	RUMMEL #1-20-2D
10430	137	92	36	NENW	GULF OIL CORPORATION	MESSER STATE #1-36-1B

WELL	T	R	S	Q	OPERATOR	NAME
Stark County						
10570	138	96	1	NWSE	THE LOUISIANA LAND & EXPLORATION CO.	MILLER 33-1 #1
Steele County						
9922	144	56	28	SWNW	NYVATEX OIL CORP.	FOSDICK 12-28-R
Stutsman County						
40	141	67	11	NWNW	BARNETT DRILLING INC.	JOHN GAIER #1
120	142	63	21	SENW	GENERAL ATLAS CARBON CO.	A PEPLINSKI #1
134	142	65	15	SWNE	GENERAL ATLAS CARBON CO.	F BORTHEL #1
370	140	65	21	NWNW	HERMAN HANSON OIL SYNDICATE	REG OGILVIE
406	140	65	20	NENE	HERMON HANSON OIL SYNDICATE	M. M. MUELLER #2
644	139	68	5	SESE	GORDON B. BUTTERFIELD	RUDOLPH TRAUTMAN #1
668	137	67	25	SESW	CALVERT EXPL. CO.	MARGARET MEYERS #1
669	139	68	35	SESW	CALVERT EXPL. CO.	CHRIST RAV #1
670	139	67	24	SESW	CALVERT EXPL. CO.	D. C. WOOD #1
671	140	67	12	NWSW	CALVERT EXPL. CO.	GEORGE GANSER #1
672	139	67	12	NWNW	CALVERT EXPL. CO.	VINCENT WANZEK #1
673	138	67	26	NENE	CALVERT EXPL. CO.	F. L. ROBERTSON #1
7415	137	67	28	NENE	KISSINGER PETR. CORP.	STERN #1-28
9776	143	63	8	SWSE	DABBLER PETROLEUM, INC.	WANZEK #34-8
Towner County						
100	161	68	35	SWSE	UNION OIL COMPANY OF CALIFORNIA	ARNE SAARI NUMBER ONE
171	163	65	18	NWNE	F H RHODES	HAROLD MURPHY # 1
194	157	65	17	SWSE	F H RHODES	R R GIBBENS # 1
227	158	66	31	SESW	EARL F. WAKEFIELD	EDNA LOUISE HILL # 1
390	160	67	24	SWSE	MIDWEST EXPLORATION CORP.	H. ANANN # 1
434	163	68	27	NWNW	MIDWEST EXPLORATION COMPANY INC.	HENRY P. JUTENEN # 1
3980	162	68	7	SWSE	LA HABANA CORP. & NAT'L. ASSOC. PETR.	KEITH R. DUNLOP #1

WELL	T	R	S	Q	OPERATOR	NAME
Walsh County						
2623	156	58	9	NENW	TRAUGOTT DRILLING	HATTIE BAKKE #1
2973	156	56	8	SWSE	I. J. WILHITE-CANADIAN DAKOTA DVMT., INC.	A. O. GAARDER #1
Ward County						
47	155	81	23	SESW	WILLIAM HERBERT HUNT TRUST ESTATE	JOE H. & ANNA WALD #1
52	156	85	24	NENE	WANETE	M. O. LEE ET AL #1
105	153	85	2	SWNE	STANOLIND	WALTER & INGEBERG WASWICK #1
588	152	82	33	SWSE	WILLIAM HERBERT HUNT	F. C. NEUMANN #1
7612	155	87	15	SESW	MARATHON OIL CO.	BERG #15-24
11055	156	81	19	NENW	INEXCO OIL COMPANY	HUNTZINGER 1-19
Wells County						
207	146	73	27	SESE	CONTINENTAL OIL COMPANY	JOHN LUETH NUMBER ONE
609	148	71	14	SWSE	CAROLINE HUNT TRUST ESTATE	GEORGE LEITNER #1
642	150	70	32	NWNE	CAROLINE HUNT TRUST ESTATE	OBED LARSON #1
689	147	71	31	NENE	CAROLINE HUNT TRUST ESTATE	N. THORMODSGARD #1
1211	146	68	8	NENE	CALVERT DRILLING CO.	FRANCIS ZWINGLER #1
9899	146	69	25	NENW	DOVER OIL CO.	POLRIES #2
11599	145	70	28	SENE	TRUE OIL COMPANY	KRUEGER 42-28
11653	148	70	35	NWNE	TRUE OIL COMPANY	JULIAR 31-35
11654	149	70	24	NWNW	TRUE OIL COMPANY	MASON 11-24
Williams County						
32	157	95	12	SWNW	AMERADA PETROLEUM CORP.	BAKKEN #1
1231	155	96	2	SENE	AMERADA PETROLEUM CORP.	IVERSON + NELSON U. #1
1385	156	95	16	SESW	AMERADA PETROLEUM CORP.	N.D.
1403	155	96	15	SWNE	AMERADA PETROLEUM CORP.	BOE-OLSON #1
1514	156	96	34	SENE	AMERADA PETROLEUM CORP.	ULVEN UNIT #1
1636	156	95	17	SESW	AMERADA PETROLEUM CORP.	PETERSON DAVIDSON U. #1
3844	155	96	1	SESE	AMERADA PETROLEUM CORP.	BLOU #3

WELL	T	R	S	Q	OPERATOR	NAME
Williams County						
4321	158	95	36	NWSW	AMERADA PETROLEUM CORP.	N.D. C "B" #9
4323	158	95	26	NESW	AMERADA PETROLEUM CORP.	HJALMER IVES #B-1
4618	156	103	17	NENW	AMERADA PETROLEUM CORP.	NILS TROGSTAD #1
4716	155	96	11	CNW	AMERADA PETROLEUM CORPORATION	B.L.O.U. #4
5577	157	95	29	NENW	TIGER OIL CO.	NELSON #21-29
5725	157	95	20	SESE	TIGER OIL CO.	BIWER #44-20
5912	156	96	35	NESW	AMERADA PETROLEUM CORP.	B.L.O. UNIT #6
5937	157	95	30	SENE	TIGER OIL CO.	SCHMIDT #42-30
6098	154	95	3	SENE	TIGER OIL CO.	HOVE #42-3
7005	155	96	24	NENE	AMERADA HESS CORP.	UDLAND #41-24 #1
7848	158	100	2	NWSE	DEPCO, INC.	SMITH #33-2
7931	155	97	33	SESW	MAPCO INC.	NCGA #14-33
8316	159	102	18	SWSE	DEPCO, INC.	FISCHER #34-18
8646	154	100	23	NENE	SAMEDAN OIL CORPORATION	DONAHUE #1
8692	159	99	30	SWNE	TEXAS GAS EXPLORATION CORP.	SOGARD #1-30
9100	159	100	11	NWSW	TEXAS GAS EXPLORATION CORP.	ESTERBY #1-11
9800	158	97	27	NWSE	ATLANTIC RICHFIELD CO.	SIMPSON #1
10329	158	100	36	SESE	ATLANTIC RICHFIELD COMPANY	STATE GAFKJEN #1
10908	156	102	30	NWSE	THE SUPERIOR OIL CO.	HARSTAD 30-33
12024	157	95	3	SWNW	TEXAKOTA, INC.	H. BORSTAD 3-3
12270	158	95	12	NENW	AMERADA HESS CORPORATION	DROVDAHL #12-21
12305	156	96	13	NENE	SUN EXPLORATION AND PRODUCTION CO.	NELS ANDERSON #1
12363	157	95	14	SENW	AMERADA HESS CORP.	ASTRID ONGSTAD # 14-22
12432	155	96	2	SESE	AMERADA HESS CORP.	BEAVER LODGE-SILURIAN UNIT # D-407
12592	156	95	18	NESW	AMERADA HESS CORP.	BEAVER LODGE ORDOVICIAN UNIT # 7
12831	156	96	22	SESE	AMERADA HESS CORP.	NELSON # 22-44
12971	156	95	20	NWSW	AMERADA HESS CORP.	BEAVER LODGE-DEVONIAN UNIT # I-313A
13395	155	96	2	SENE	AMERADA HESS CORP.	BLOU #8

APPENDIX B

Formation and Member Tops. Wells are listed within each county according to their North Dakota Geological Survey well number. Depths in feet from Kelly Bushing; Winnipeg Group, Roughlock Formation, Icebox Formation, Black Island Formation, Garland Member, Hawkeye Valley Member. (- = missing data).

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Adams County							
6322	8855	8855	8893	-	-	8990	9400
7642	9663	9663	9682	-	-	9777	-
Barnes County							
4640	1691	1691	1778	1913	-	1928	1945
Benson County							
632	4857	4857	4917	5051	-	5090	5142
Billings County							
291	12801	12801	12809	12925	12952	12959	-
555	13748	13748	13758	13872	-	-	-
3268	12483	12483	12496	12598	12619	12631	13509
6228	14135	14135	14150	14282	14332	14359	15265
6303	13396	13396	13403	13516	13550	13569	14224
6913	14082	14082	14099	14213	14257	14272	-
7307	14099	14099	14110	14228	14269	14278	-
7520	14053	14053	14068	14186	14220	14234	-
7934	13432	13432	13442	13552	13591	13603	14389
8226	13563	13563	13572	13688	13724	13739	-
8487	13049	13049	13060	13171	13205	13227	-
8603	13436	13436	13445	13556	13589	13606	-
11335	12255	12255	12272	12377	12402	12412	-
Bottineau County							
38	7820	7820	7842	7970	8040	8050	8246
64	6142	6142	6171	6295	-	6337	6407
110	6190	6190	6227	6351	-	6382	6424
2219	6948	6948	6968	7086	-	7138	7258

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Bottineau County							
4655	6458	6458	6481	6591	-	6640	6690
4790	7908	7908	7930	8042	8110	8118	-
4846	7216	7216	7230	7354	-	-	7553
5184	6111	6111	6138	6258	-	6305	6360
9522.1	6322	6322	6347	6468	-	6510	6604
Bowman County							
485	9700	9700	9703	-	-	9800	-
1575	8732	8732	8745	-	-	8839	-
9656	10680	10681	10694	-	-	10797	-
9805	9675	9675	9690	-	-	9783	-
Burke County							
8893	10419	10419	10432	10548	10642	10670	10878
Burleigh County							
19	6488	6488	6538	6665	-	6685	6947
145	5607	5607	5682	5811	-	5828	6166
151	7548	7548	7601	7718	-	7735	8088
155	5685	5685	5745	5870	-	5882	6144
174	6400	6400	6452	6575	-	6596	6858
701	6022	6022	6072	6198	-	6218	-
723	5631	5631	5689	5818	-	5833	-
756	5905	5905	5980	6103	-	6121	-
765	6517	6517	6563	6686	-	6710	-
772	7008	7008	7058	7181	-	7204	-
1409	6328	6328	6380	6505	-	6528	-
6264	5884	5884	5942	6069	-	6091	6300
7010	6280	6280	6341	6467	-	6478	6758

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Burleigh County							
8674	6250	6250	6299	6425	-	6445	6700
12057	7526	7526	7542	7694	7720	7733	-
Cavalier County							
27	3221	3221	3272	-	-	-	3400
1694	3186	3186	3228	3343	-	-	3365
2342	2137	2137	2185	2287	-	-	2312
Dickey County							
515	1585	1585	1638	-	-	-	-
682	1670	1670	1740	-	-	-	-
1394	2880	2880	2950	-	-	3085	3147
Divide County							
1443	11348	11348	11353	11480	-	-	-
1546	11604	11604	11615	11740	-	-	-
2010	10818	10818	10821	10944	-	-	-
6798	11650	11650	11660	11787	11894	11908	12350
7087	11055	11055	11062	11188	11287	11300	11783
7660	11096	11096	11100	11223	-	-	-
7942	12755	12755	12771	12905	13023	13062	13616
8707	12581	12581	12589	12717	-	-	-
9398	11209	11209	11222	11342	11427	11430	-
9413	11179	11179	11182	11305	-	-	-
9446	11208	11208	11222	11340	-	-	-
9528	10939	10939	10943	11060	-	-	-
9622	11041	11041	11047	11164	-	11264	-
9677	10919	10919	10919	11050	11142	11148	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Dunn County							
6086	13920	13920	13930	14060	14110	14185	-
6148	13262	13262	13275	13393	-	-	-
6530	13104	13104	13118	13230	13268	13280	-
7402	12560	12560	12578	12706	12760	12805	-
7412	13673	13673	13687	13818	13878	-	-
7584	14161	14161	14178	14310	14358	14426	-
8077	14578	14578	14598	14736	14818	14896	-
8313	13529	13529	13552	13684	13740	13812	-
8491	13450	13450	13466	13585	-	-	-
8536	13451	13451	13470	13598	-	-	-
8613	13531	13531	13550	13676	13730	13796	-
8709	14083	14083	14104	14238	14318	14380	-
8768	13448	13448	13470	13597	13650	-	-
9027	13020	13020	13039	13170	13213	13275	-
9044	13805	13805	13826	13957	14020	14082	-
9080	13144	13144	13164	13291	13348	13418	-
9397	13848	13848	13867	14000	14058	14120	-
9527	14438	14438	14460	14591	14640	14701	-
10072	14105	14105	14126	14261	14328	14383	-
10606	12785	12785	12804	12928	12974	13003	-
10627	12314	12314	12330	12444	12488	12498	-
11363	12978	12978	12990	13118	13174	13221	-
12400	13372	13372	13390	13508	13549	13561	-
Eddy County							
437	3900	3900	3968	4101	-	4128	4223
768	3560	3560	3622	3755	-	3783	3858
1274	2830	2830	2900	3031	-	3040	3084

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Emmons County							
16	4870	4870	4932	-	-	5062	5350
23	5040	5040	5121	-	-	5245	5543
43	5321	5321	5403	-	-	5540	5865
7101	4900	4900	4950	-	-	5080	5394
7146	5092	5092	5173	5300	-	5315	5592
7936	5063	5063	5145	5270	-	5282	-
10173	5318	5318	5400	5527	-	5540	-
Foster County							
287	2838	2838	2912	3042	-	3054	3106
295	2579	2579	2655	2787	-	2803	2862
334	2989	2989	3064	3193	-	3212	3289
403	3373	3373	3436	-	-	-	3560
1105	3323	3323	3392	3518	-	3524	-
1112	3498	3498	3567	3700	-	3710	3791
1126	3850	3850	3913	-	-	-	-
1227	2981	2981	3056	3185	-	3202	3271
Golden Valley County							
410	12988	12988	13008	13115	13153	13160	-
470	12268	12268	12277	12380	12400	12414	-
6272	10962	10962	10973	11080	11100	11105	11502
6513	12371	12371	12380	12482	12506	12520	-
6563	11978	11978	11987	12085	12102	12118	-
7753	12408	12408	12424	12524	12548	12554	-
7969	12116	12116	12150	12248	-	-	-
8590	12790	12790	12828	12930	12970	12988	-
9148	11900	11900	11909	12007	12026	12038	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Golden Valley County							
9540	12282	12282	12297	12400	12422	12430	-
Grand Forks County							
580	637	637	731	888	-	-	895
1356	791	791	882	1049	-	-	1060
3191	561	561	656	775	-	-	792
3204	320	320	410	530	-	-	558
12110	882	882	977	1113	-	-	1130
Grant County							
5572	7740	7740	7790	-	-	7902	-
6420	8026	8026	8072	-	-	8190	-
6586	9690	9690	9730	9830	-	9850	10424
7020	10177	10177	10201	10317	-	10328	10960
8549	8753	8753	8788	8895	-	8906	9438
8680	8122	8122	8172	-	-	8277	8817
Griggs County							
4719	2504	2504	2578	2712	-	2722	2773
9659	2486	2486	2564	-	-	-	-
Hettinger County							
7075	10028	10028	10059	10165	-	10168	10725
7453	10585	10585	10600	10699	-	10707	11193
8312	11008	11008	11027	11130	-	11149	-
10522	11278	11278	11305	11412	-	11435	-
Kidder County							
24	5175	5175	5232	5361	-	5370	5604

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Kidder County							
230	4822	4822	4883	5015	-	5026	5139
748	5624	5624	5680	5799	-	5824	-
La Moure County							
3999	2413	2413	2490	-	-	-	-
5117	3021	3021	3106	-	-	-	-
Logan County							
590	4878	4878	4963	5088	-	5095	-
1347	4123	4123	4210	4332	-	4351	4550
5523	4802	4802	4878	5005	-	5010	-
McHenry County							
39	6872	6872	6905	7020	-	7096	7203
61	6946	6946	6972	7097	-	7167	-
8307	6900	6900	6934	7053	-	7117	-
8803	8335	8335	8358	8470	8532	8542	-
11922	6953	6953	6977	7094	-	-	-
McIntosh County							
89	4370	4370	4427	-	-	4560	4772
620	3255	3255	3320	-	-	3460	3590
621	3450	3450	3512	-	-	3644	3828
622	3560	3560	3630	-	-	3768	3924
McKenzie County							
956	13310	13310	13350	13462	-	-	-
2373	13788	13788	13818	13963	14120	14224	15120
2602	13550	13550	13570	13726	-	-	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
McKenzie County							
5836	13810	13810	13847	13960	-	-	-
6112	14176	14176	14208	14353	14515	14610	-
6387	13306	13306	13345	13454	13497	13505	14360
6414	13330	13330	13367	13472	13540	13550	-
6501	13943	13943	13970	-	-	-	-
6790	14020	14020	14050	-	-	-	-
7001	13477	13477	13507	13658	-	-	-
7203	14524	14524	14557	14680	14730	-	-
7479	14387	14387	14409	14531	-	-	-
7571	14438	14438	14458	14611	14741	14848	-
7572	14358	14358	14395	14540	14680	14780	-
7607	13590	13590	13621	13772	13930	14034	-
7631	14387	14387	14417	14534	14591	14650	-
7873	14570	14570	14603	14734	14800	14860	-
7988	13586	13586	13616	13760	13920	14008	-
8083	14390	14390	14420	14565	14703	14801	-
8090	14180	14180	14208	14358	14513	14622	-
8092	14736	14736	14771	14902	14966	-	-
8131	14910	14910	14948	15075	15143	15225	-
8165	14003	14003	14030	14149	14198	14250	-
8187	14210	14210	14247	14356	14406	14443	14947
8193	13410	13410	13451	13559	13610	13628	-
8268	13874	13874	13901	14017	-	-	-
8302	14223	14223	14258	14372	-	-	-
8314	13337	13337	13377	13488	13530	13560	14420
8372	14546	14546	14579	-	-	-	-
8468	13620	13620	13645	13762	13810	13848	-
8626	15026	15026	15059	15190	-	-	-
8663	14334	14334	14355	14489	14543	14596	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
McKenzie County							
8737	13711	13711	13752	13867	13915	13948	-
8882	14042	14042	14068	-	-	-	-
9004	14535	14535	14570	14688	14740	14801	-
9005	13702	13702	13727	13842	13882	13910	-
9006	14020	14020	14048	-	-	-	-
9217	14673	14673	14695	14838	14925	15042	-
9901	13733	13733	13774	13888	13938	13950	-
9957	14430	14430	14468	14603	-	-	-
11110	14342	14342	14368	14518	14660	14772	-
12345	14710	14710	14738	14888	15018	15099	-
12589	14090	14090	14123	14273	14442	14538	-
12596	14630	14630	14660	14800	14870	14979	-
12699	14210	14210	14247	14363	14418	14458	-
12726	14506	14506	14531	14680	14830	-	-
McLean County							
22	8750	8750	8780	8896	8966	8988	-
49	8629	8629	8660	8780	8840	8865	-
7783	13258	13258	13280	13410	13525	13580	-
8060	12890	12890	12912	13040	13143	13190	-
8711	8384	8384	8416	8530	8560	8575	8843
8720	8158	8158	8191	8309	8345	8361	8659
8993	8383	8383	8408	8527	8577	8610	8784
Mercer County							
21	11867	11867	11883	12010	12062	12079	-
8675	12188	12188	12205	12327	12369	12393	-
8712	12800	12800	12821	12948	13000	13069	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Morton County							
26	7122	7122	7195	-	-	7318	7758
1620	11018	11018	11032	11162	-	11183	-
3859	7562	7562	7621	-	-	7743	8194
7340	10531	10531	10548	10675	10709	10713	11340
7691	9158	9158	9198	9312	-	9323	-
7797	9581	9581	9615	9733	-	9740	10172
7937	9200	9200	9232	9334	-	9354	9691
8158	7794	7794	7840	7958	-	7972	-
8553	8390	8390	8425	8542	-	8555	8859
Mountrail County							
6780	12605	12605	12630	12753	12854	12901	13421
6872	12280	12280	12305	12428	12533	12584	13177
9326	13511	13511	13540	13670	13810	13878	-
12597	13440	13440	13470	13601	13765	13840	-
Nelson County							
1934	2530	2530	2598	2731	-	-	2740
4664	2665	2665	2735	2863	-	2882	2905
4785	2522	2522	2596	2724	-	-	2745
9143	2079	2079	2157	2291	-	2316	-
Oliver County							
15	8310	8310	8345	8465	-	8478	8835
8144	8405	8405	8440	8556	8564	8568	-
Pembina County							
700	1398	1398	1434	1540	-	-	1543

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Pierce County							
30	5230	5230	5250	-	-	-	-
435	4381	4381	4423	4553	-	-	4585
706	4754	4754	4800	4932	-	4970	4994
3920	5717	5717	5758	5885	-	5940	-
5576	5550	5550	5594	5727	-	5782	5850
12125	5192	5192	5225	5346		-	-
Ramsey County							
20	3035	3035	3094	3213	-	-	-
196	3500	3500	3561	3686	-	3708	3740
246	3010	3010	3086	3188	-	-	3248
383	3065	3065	3136	3255	-	-	-
407	3006	3006	3071	3207	-	3231	3275
408	3020	3020	3086	-	-	-	-
411	3140	3140	3208	3328	-	-	-
422	3020	3020	3085	-	-	-	3194
4745	2880	2880	2947	3058	-	-	3080
4914	2770	2770	2840	2958	-	-	2978
Renville County							
6296	9292	9292	9302	9415	-	9455	9533
6349	8946	8946	8957	9042	-	9050	9066
6401	9148	9148	9158	9270	-	9290	9515
6436	9247	9247	9259	9377	-	9410	9556
6466	9026	9026	9032	9140	-	-	9200
6504	9350	9350	9364	9472	9570	9574	9829
6624	8912	8912	8926	9038	9123	9131	9310
6684	8928	8928	8940	9049	9138	9144	9261

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Renville County							
6749	8944	8944	8952	9052	9059	9061	9064
7577	9743	9743	9760	9869	9957	9982	10122
Rolette County							
83	5303	5303	5340	5468	-	-	5502
316	4728	4728	4770	4898	-	4920	4940
13586	5093	5093	5129	5258	-	5288	-
Sheridan County							
665	6569	6569	6608	6730	-	6772	-
684	6153	6153	6198	6325	-	6360	-
693	6921	6921	6960	7086	7108	7113	-
735	6116	6116	6158	6287	-	6308	-
9343	6860	6860	6900	7020	7041	7050	7233
Sioux County							
631	5650	5650	5702	-	-	5835	-
6654	7060	7060	7110	-	-	-	-
Slope County							
8629	11616	11616	11628	11733	-	11753	-
9244	11991	11991	12003	12108	-	12132	-
11484	11452	11452	11468	11572	-	11592	-
Stark County							
6447	12487	12487	12500	12610	12632	12642	-
8088	12212	12212	12228	12340	12372	12390	-
8169	11229	11229	11248	11359	11381	11384	12151
8342	12550	12550	12562	12673	12692	12712	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Stark County							
8665	11000	11000	11022	11127	-	11153	-
8837	11805	11805	11830	11933	-	11960	-
9056	11644	11644	11656	11770	11797	11807	-
9135	11092	11092	11118	11230	-	-	-
9256	11781	11781	11800	11911	11934	11944	-
9257	11641	11641	11658	11773	11798	11808	-
9322	12471	12471	12487	12599	12620	12630	-
9341	11953	11953	11967	12084	-	-	-
9348	11544	11544	11567	11674	11695	11706	-
9407	11469	11469	11488	11599	-	11630	-
9475	12357	12357	12371	12480	12509	12530	-
9684	12365	12365	12373	12481	12502	12508	-
9796	11684	11684	11703	11817	-	-	-
10430	10782	10782	10804	10910	-	10940	-
10570	12235	12235	12258	12372	12403	12410	-
Steele County							
9922	1108	1108	1180	1306	-	-	-
Stutsman County							
40	3782	3782	3856	3986	-	3993	4136
120	2642	2642	2728	2850	-	2865	2917
134	3103	3103	3186	3313	-	3333	3425
370	3000	3000	3080	3205	-	3222	3268
406	3014	3014	3090	3221	-	3233	3308
644	3955	3955	4021	4160	-	4177	4305
668	3370	3370	3463	3587	-	3592	3695
669	3741	3741	3820	3948	-	3960	4100
670	3498	3498	3572	-	-	-	3700

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Stutsman County							
671	3624	3624	3695	3829	-	3834	3988
672	3563	3563	3632	-	-	3764	3892
673	3460	3460	3550	-	-	-	3678
7415	3548	3548	3640	3767	-	3775	3858
9776	2799	2799	2876	3008	-	3025	-
Towner County							
100	4313	4313	4356	4480	-	-	4500
171	3582	3582	3642	3766	-	-	3782
194	3569	3569	3622	3744	-	-	3760
227	3822	3822	3866	3997	-	-	4031
390	3871	3871	3918	4041	-	-	4062
434	4246	4246	4283	4409	-	-	4427
3980	4400	4400	4441	4563	-	-	4584
Walsh County							
2623	2310	2310	2374	-	-	-	2488
2973	1608	1608	1673	1787	-	-	1803
Ward County							
47	8190	8190	8207	8328	8398	8420	8620
52	9938	9938	9952	10070	-	-	-
105	10737	10737	10764	10874	10967	10990	-
588	9466	9466	9486	9606	-	-	-
7612	11558	11558	11581	11701	11803	11842	12317
11055	8398	8398	8422	8542	8612	8633	-
Wells County							
207	5625	5625	5680	5805	-	5823	6020

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Wells County							
609	4812	4812	4872	5000	-	5022	5180
642	4787	4787	4843	4974	-	5007	-
689	4996	4996	5058	5195	-	5220	-
1211	4098	4098	4158	4283	-	4302	4380
9899	4287	4287	4350	-	-	-	-
11599	4760	4760	4820	4948	-	4977	-
11653	4542	4542	4604	4732	-	4763	-
11654	4631	4631	4689	4820	-	4851	-
Williams County							
32	13386	13386	13410	13560	-	-	-
1231	13231	13231	13252	13383	13520	-	13587
1385	13753	13753	13775	13918	14087	14170	14795
1403	13262	13262	13283	13427	13595	13669	-
1514	13513	13513	13538	13683	13852	13928	-
1636	13597	13597	13617	13760	13919	14002	-
3844	13542	13542	13574	13720	13854	13982	14537
4321	13315	13315	13336	13472	13640	13706	14284
4323	13165	13165	13185	13317	13470	13538	-
4618	13279	13279	13300	13423	13521	13532	14279
4716	13319	13319	13342	13489	13636	13710	-
5577	13150	13150	13174	13304	-	-	-
5725	13302	13302	13326	13463	-	-	-
5912	13397	13397	13428	13573	-	-	-
5937	13292	13292	13319	13451	-	-	-
6098	13957	13957	13986	14134	14293	14400	-
7005	13610	13610	13632	13761	13913	14025	-
7848	13085	13085	13100	13232	13332	13355	-
7931	14598	14598	14625	14760	-	-	-

NDGS Well #	Winnipeg Group	Roughlock Formation	Icebox Formation	Garland Member	Hawkeye Valley Mbr.	Deadwood Formation	Precambrian Basement
Williams County							
8316	12322	12322	12341	12459	12560	12573	-
8646	14518	14518	14541	14677	-	-	-
8692	12818	12818	12831	12972	-	-	-
9100	12586	12586	12598	12727	-	-	-
9800	13862	13862	13882	14018	14121	14185	-
10329	13526	13526	13547	-	-	-	-
10908	13655	13655	13679	13803	-	-	-
12024	13334	13334	13368	13499	-	-	-
12270	13111	13111	13132	13252	13408	13480	-
12305	13590	13590	13613	13741	-	13977	-
12363	13290	13290	13308	13448	-	13688	-
12432	13278	13278	13300	13432	-	13578	-
12592	13485	13485	13511	13643	13798	13880	-
12831	13542	13542	13563	13698	-	13932	-
12971	13750	13750	13770	13922	-	-	-
13395	13288	13288	13300	13452	-	13603	-

APPENDIX C

Formation and Member Thicknesses. Wells are listed within each county according to their North Dakota Geological Survey well number. Thicknesses in feet; Winnipeg Group, Roughlock Formation, Icebox Formation, Black Island Formation, Garland Member, Hawkeye Valley Member. (- = missing data).

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Adams County						
6322	135	38	97	0	0	0
7642	114	19	95	0	0	0
Barnes County						
4640	237	87	135	15	15	0
Benson County						
632	233	60	134	39	39	0
Billings County						
291	158	8	116	34	27	7
555	-	10	114	-	-	-
3268	148	13	102	33	21	12
6228	224	15	132	77	50	27
6303	173	7	113	53	34	19
6913	190	17	114	59	44	15
7307	179	11	118	50	41	9
7520	181	15	118	48	34	14
7934	171	10	110	51	39	12
8226	176	9	116	51	36	15
8487	178	11	111	56	34	22
8603	170	9	111	50	33	17
11335	157	17	105	35	25	10
Bottineau County						
38	230	22	128	80	70	10
64	195	29	124	42	42	0
110	192	37	124	31	31	0
2219	190	20	118	52	52	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Bottineau County						
4655	232	23	110	49	49	0
4790	210	22	112	76	68	8
4846	-	14	124	-	-	-
5184	194	27	120	47	47	0
9522.1	188	25	121	42	42	0
Bowman County						
485	100	3	97	0	0	0
1575	107	13	94	0	0	0
9656	117	13	103	0	0	0
9805	108	15	93	0	0	0
Burke County						
8893	251	13	116	122	94	28
Burleigh County						
19	197	50	127	20	20	0
145	221	75	129	17	17	0
151	187	53	117	17	17	0
155	197	60	125	12	12	0
174	196	52	123	21	21	0
701	196	50	126	20	20	0
723	202	58	129	15	15	0
756	216	75	123	18	18	0
765	193	46	123	24	24	0
772	196	50	123	23	23	0
1409	200	52	125	23	23	0
6264	207	58	127	22	22	0
7010	198	61	126	11	11	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Burleigh County						
8674	195	49	126	20	20	0
12057	207	16	152	39	26	13
Cavalier County						
27	179	51	128	0	-	0
1694	179	42	115	22	-	0
2342	175	48	102	25	-	0
Dickey County						
515	-	53	-	-	-	0
682	-	70	-	-	-	0
1394	205	70	135	0	0	0
Divide County						
1443	-	5	127	-	-	-
1546	-	11	125	-	-	-
2010	-	3	123	-	-	-
6798	258	10	127	121	107	14
7087	245	7	126	112	99	13
7660	-	4	123	-	-	-
7942	307	16	134	157	118	39
8707	-	8	128	-	-	-
9398	221	13	120	88	85	3
9413	-	3	123	-	-	-
9446	-	14	118	-	-	-
9528	-	4	117	-	-	-
9622	223	6	117	100	100	0
9677	229	0	131	98	92	6

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Dunn County						
6086	265	10	130	125	50	75
6148	-	13	118	-	-	-
6530	176	14	112	50	38	12
7402	245	18	128	99	54	45
7412	-	14	131	-	60	-
7584	265	17	132	116	48	68
8077	-	20	138	160	82	78
8313	283	23	132	128	56	72
8491	-	16	119	-	-	-
8536	-	19	128	-	-	-
8613	265	19	126	120	54	66
8709	297	21	134	142	80	62
8768	-	22	127	-	53	-
9027	255	19	131	105	43	62
9044	277	21	131	125	63	62
9080	274	20	127	127	57	70
9397	272	19	133	120	58	62
9527	263	22	131	110	49	61
10072	278	21	135	122	67	55
10606	218	19	124	75	46	29
10627	184	16	114	54	44	10
11363	243	12	128	103	56	47
12400	189	18	118	53	41	12
Eddy County						
437	228	68	133	27	27	0
768	223	62	133	28	28	0
1274	210	70	131	9	9	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Emmons County						
16	192	62	130	0	0	0
23	205	81	124	0	0	0
43	219	82	137	0	0	0
7101	180	50	130	0	0	0
7146	223	81	127	15	15	0
7936	219	82	125	12	12	0
10173	222	82	127	13	13	0
Foster County						
287	216	74	130	12	12	0
295	224	76	132	16	16	0
334	223	75	129	19	19	0
403	187	63	124	0	-	0
1105	201	69	126	6	6	0
1112	212	69	133	10	10	0
1126	-	63	-	-	-	0
1227	221	75	129	17	17	0
Golden Valley County						
410	172	20	107	45	38	7
470	146	9	103	34	20	14
6272	143	11	107	25	20	5
6513	149	9	102	38	24	14
6563	140	9	98	33	17	16
7753	146	16	100	30	24	6
7969	-	34	98	-	-	-
8590	198	38	102	58	40	18
9148	138	9	98	31	19	12
9540	148	15	103	30	22	8

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Grand Forks County						
580	258	94	157	7	7	0
1356	269	91	167	11	11	0
3191	248	95	119	17	17	0
3204	266	90	120	28	28	0
12110	248	95	136	17	17	0
Grant County						
5572	162	50	-	-	-	-
6420	164	46	118	0	0	0
6586	160	40	100	20	20	0
7020	151	24	116	11	11	0
8549	153	35	107	11	11	0
8680	155	50	105	0	0	0
Griggs County						
4719	218	74	134	10	10	0
9659	-	78	-	-	-	0
Hettinger County						
7075	140	31	106	3	3	0
7453	122	15	99	8	8	0
8312	141	19	103	19	19	0
10522	157	27	107	23	23	0
Kidder County						
24	195	57	129	9	9	0
230	204	61	132	11	11	0
748	200	56	119	25	25	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
La Moure County						
3999	-	77	-	-	-	0
5117	-	85	-	-	-	0
Logan County						
590	217	85	125	7	7	0
1347	228	87	122	19	19	0
5523	208	76	127	5	5	0
McHenry County						
39	224	33	115	76	76	0
61	221	26	125	70	70	0
8307	217	34	119	64	64	0
8803	207	23	112	72	62	10
11922	-	-	117	-	-	-
McIntosh County						
89	190	57	133	0	0	0
620	205	65	140	0	0	0
621	194	62	132	0	0	0
622	208	70	138	0	0	0
McKenzie County						
956	-	40	112	-	-	-
2373	436	30	145	261	157	104
2602	-	20	156	-	-	-
5836	-	37	113	-	-	-
6112	434	32	145	257	162	95
6387	199	39	109	51	43	8
6414	220	37	105	78	68	10

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
McKenzie County						
6501	-	27	-	-	-	-
6790	-	30	-	-	-	-
7001	-	30	151	-	-	-
7203	-	33	123	-	50	-
7479	-	22	122	-	-	-
7571	410	20	153	237	130	107
7572	-	37	145	240	140	100
7607	444	31	151	262	158	104
7631	263	30	117	116	57	59
7873	290	33	131	126	66	60
7988	422	30	144	248	160	88
8083	411	30	145	236	138	98
8090	442	28	150	264	155	109
8092	-	35	131	-	64	-
8131	315	38	127	150	68	82
8165	247	27	119	101	49	52
8187	233	37	109	87	50	37
8193	218	41	108	69	51	18
8268	-	27	116	-	-	-
8302	-	35	114	-	-	-
8314	223	40	111	72	42	30
8372	-	33	-	-	-	-
8468	228	25	117	86	48	38
8626	-	33	131	-	-	-
8663	262	21	134	107	54	53
8737	237	41	115	81	48	33
8882	-	26	-	-	-	-
9004	266	35	118	113	52	61
9005	-	25	115	68	40	28

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
McKenzie County						
9006	-	28	-	-	-	-
9217	369	22	143	204	87	117
9901	217	41	114	62	50	12
9957	-	38	135	-	-	-
11110	430	26	150	254	142	112
12345	389	28	150	211	130	81
12589	448	33	150	265	169	96
12596	349	30	140	179	70	109
12699	248	37	116	95	55	40
12726	-	25	149	-	150	-
McLean County						
22	238	30	116	92	70	22
49	236	31	120	85	60	25
7783	322	22	130	170	115	55
8060	300	22	128	150	103	47
8711	191	32	114	45	30	15
8720	203	33	118	52	36	16
8993	227	25	119	83	50	33
Mercer County						
21	212	16	127	69	52	17
8675	205	17	122	66	42	24
8712	269	21	127	121	52	69
Morton County						
26	196	73	123	0	0	0
1620	165	14	130	21	21	0
3859	181	59	122	0	0	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Morton County						
7340	182	17	127	38	34	4
7691	165	40	114	11	11	0
7797	159	34	125	7	7	0
7937	154	32	122	0	20	0
8158	178	46	118	14	14	0
8553	165	35	117	13	13	0
Mountrail County						
6780	296	25	123	148	101	47
6872	304	25	123	156	105	51
9326	367	29	130	208	140	68
12597	400	30	131	239	164	75
Nelson County						
1934	210	68	133	9	9	0
4664	217	70	128	19	19	0
4785	223	74	128	21	21	0
9143	237	78	134	25	25	0
Oliver County						
15	168	35	120	13	13	0
8144	163	35	116	12	8	4
Pembina County						
700	145	36	106	3	3	0
Pierce County						
30	-	20	-	-	-	0
435	204	42	130	32	32	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Pierce County						
706	216	46	132	38	38	0
3920	223	41	127	55	55	0
5576	232	44	133	55	55	0
12125	-	33	121	-	-	0
Ramsey County						
20	-	59	119	-	-	0
196	208	61	125	22	22	0
246	-	-	-	60	60	0
383	-	71	119	-	-	0
407	225	65	136	24	24	0
408	-	66	-	-	-	0
411	-	68	120	-	-	0
422	174	65	109	0	0	0
4745	200	67	111	22	22	0
4914	208	70	118	20	20	0
Renville County						
6296	163	10	113	40	40	0
6349	104	11	85	8	8	0
6401	142	10	112	20	20	0
6436	163	12	118	33	33	0
6466	174	6	108	60	60	0
6504	224	14	108	102	98	4
6624	219	14	112	93	85	8
6684	216	12	109	95	89	6
6749	117	8	100	9	7	2
7577	239	17	109	113	88	25

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Rolette County						
83	199	37	128	34	34	0
316	192	42	128	22	22	0
13586	195	36	129	30	30	0
Sheridan County						
665	203	39	122	42	42	0
684	207	45	127	35	35	0
693	192	39	126	27	22	5
735	192	42	129	21	21	0
9343	190	40	120	30	21	9
Sioux County						
631	185	52	133	0	0	0
6654	-	50	-	-	-	-
Slope County						
8629	137	12	105	20	20	0
9244	141	12	105	24	24	0
11484	140	16	104	20	20	0
Stark County						
6447	155	13	110	32	22	10
8088	178	16	112	50	32	18
8169	155	19	111	25	22	3
8342	162	12	111	39	19	20
8665	153	22	105	26	26	0
8837	155	25	103	27	27	0
9056	163	12	114	37	27	10
9135	-	26	112	-	-	-

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Stark County						
9256	163	19	111	33	23	10
9257	167	17	115	35	25	10
9322	159	16	112	31	21	10
9341	-	14	117	-	-	-
9348	162	23	107	32	21	11
9407	161	19	111	31	31	0
9475	173	14	109	50	29	21
9684	143	8	108	27	21	6
9796	-	19	114	-	-	-
10430	-	22	106	30	30	-
10570	175	23	114	38	31	7
Steele County						
9922	-	72	126	-	-	0
Stutsman County						
40	211	74	130	7	7	0
120	223	86	122	15	15	0
134	230	83	127	20	20	0
370	222	80	125	17	17	0
406	219	76	131	12	12	0
644	222	66	139	17	17	0
668	222	93	124	5	5	0
669	219	79	128	12	12	0
670	202	74	128	0	0	0
671	210	71	134	5	5	0
672	201	69	132	0	0	0
673	218	90	128	0	0	0
7415	227	92	127	8	8	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Stutsman County						
9776	226	77	132	17	17	0
Towner County						
100	187	43	124	20	20	0
171	200	60	124	16	16	0
194	191	53	122	16	16	0
227	209	44	131	34	34	0
390	191	47	123	21	21	0
434	181	37	126	18	18	0
3980	184	41	122	21	21	0
Walsh County						
2623	178	64	114	0	0	0
2973	195	65	114	16	16	0
Ward County						
47	230	17	121	92	70	22
52	-	14	118	-	-	-
105	253	27	110	116	93	23
588	-	20	120	-	-	-
7612	284	23	120	141	102	39
11055	235	24	120	91	70	21
Wells County						
207	198	55	125	18	18	0
609	210	60	128	22	22	0
642	220	56	131	33	33	0
689	224	62	137	25	25	0
1211	204	60	125	19	19	0

NDGS Well #	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
Wells County	-	-	-	-	-	-
9899	-	63	-	-	-	0
11599	217	60	128	29	29	0
11653	221	62	128	31	31	0
11654	220	58	131	31	31	0
Williams County						
32	-	24	150	-	-	-
1231	356	21	131	204	137	67
1385	417	22	143	252	169	83
1403	407	21	144	242	168	74
1514	415	25	145	245	169	76
1636	405	20	143	242	159	83
3844	440	32	146	262	134	128
4321	391	21	136	234	168	66
4323	373	20	132	221	153	68
4618	253	21	123	109	98	11
4716	391	23	147	221	147	74
5577	-	24	130	-	-	-
5725	-	24	137	-	-	-
5912	-	31	145	-	-	-
5937	-	27	132	-	-	-
6098	443	29	148	266	159	107
7005	415	22	129	264	152	112
7848	270	15	132	123	100	23
7931	-	27	135	-	-	-
8316	251	19	118	114	101	13
8646	-	23	136	-	-	-
8692	-	13	141	-	-	-
9100	-	12	129	-	-	-

NDGS Well # Williams County	Total Winnipeg	Roughlock Formation	Icebox Formation	Black Island Formation	Garland Member	Hawkeye Valley Member
9800	323	20	136	167	103	64
10329	-	-	-	-	-	-
10908	-	24	124	-	-	-
12024	-	34	131	-	-	-
12270	369	21	120	228	156	72
12305	387	23	128	236	-	-
12363	398	18	140	240	-	-
12432	300	22	132	146	-	-
12592	395	26	132	237	155	82
12831	390	21	135	234	-	-
12971	-	20	152	-	-	-
13395	315	12	152	151	-	-

APPENDIX D

Core descriptions of strata from the Winnipeg Group. Wells are arranged by North Dakota Geological Survey Well number; depths are from the Kelly Bushing as given on the core boxes; operator names and well names are original names. Core descriptions were made using a hand lens and a 10x binocular microscope and were classified according to Gilbert (1954; sandstones), Potter et al. (1980; shales), and Folk (1959; carbonates). Rock colors were based on the Goddard et al. (1963) Rock Color Chart. Angularity, sorting, and grain size classification were determined using Tucker (1980).

NDGS Well No. 20
Union Oil Company of California, Aanstad #1
NENE, Sec. 29, T. 158 N., R. 62 W.
Ramsey County

Depth (feet)	Description
3059-3104	Limestone, dusky yellow-green with light gray nodules, silt-size, well-sorted, calcite cement, biomicrite, nodules of variable sizes (<.5-10 cm), effervesces in HCl, argillaceous, soft sediment deformation, rare stylolites, occasional microstylolites in matrix, fissile in areas, increasing downward, occasional pyrite seam <1 mm) toward base, many miscellaneous fossil fragments: brachiopods, echinoderms, trilobites, unidentified fossil fragments.
3104-3112	Shale and clayshale, greenish-gray, silica cement, clay matrix, noncalcareous, disintegrates, very fissile, small pieces.
3112-3114	Limestone, olive gray, calcite cement, extensive amounts of unidentified fossil fragments (<2 mm), echinoderms, pyrite nodules (1.5 cm).
3114-3218	No Core.
3218-3219	Sandstone, light-dark gray, coarse to fine-grained, moderately to poorly-sorted, sub-rounded, calcite cement, occasional stylolites, massive, granite fragments.
3219-	Precambrian basement, pink granite, amphibole.

NDGS Well No. 27
Union Oil Co. of Calif., Chris Skjervheim #1
NWNW, Sec. 28, T. 159 N., R. 63 W.
Cavalier County

Depth (feet)	Description
3352-3353	Clayshale, grayish-olive, noncalcareous, clay matrix, echinoderms, occasional fossil fragments, very fissile, shaley partings.
3353-3355	Clayshale, dark greenish-gray, noncalcareous, clay matrix, echinoderm fragments, occasional fossil fragments, faint fine laminations, fissile, shaley partings.

Depth (feet)	Description
3355-3357	Clayshale, dark green-gray, noncalcareous, clay matrix, echinoderms, moderate fossil fragments, white specks - condonts, faint fine laminations, shaley partings, fissile.
3357-3358	Clayshale, grayish-olive, noncalcareous, clay matrix, echinoderms, fossil fragments, horizontal worm burrows (dark gray), faint fine laminations, shaley partings, fissile.
3358-3361	Clayshale, dark greenish-gray, noncalcareous, clay matrix, echinoderms, fossil fragments, extensively fissile, faint laminations, shaley partings, horizontal worm burrows (yellowish-gray).
3361-3365	Clayshale, light olive to greenish olive, noncalcareous, clay matrix, echinoderms, fossil fragments, extensively fissile, faint laminations, shaley partings.
3365-3372	Clayshale, grayish olive-green to greenish -gray, noncalcareous, clay matrix, echinoderms, fossil fragments (condonts?), extensively fissile, faint laminations, shaley partings, worm burrows- resistant, brownish-gray, more fissile downward.
3372-3378	Clayshale, light olive-gray to light olive-brown, noncalcareous, clay matrix, fissile, shale partings, laminated.

NDGS Well No. 32
Amerada Petroleum Corp., Bakken #1
SWNW, Sec. 12, T. 157 N., R. 95 W.
Williams County

Depth (feet)	Description
13572-13572.5	Quartzite, white, medium to fine-grained, well-sorted, rounded, silica cement, moderate bioturbation, stylolites, and burrows, slightly sulfur stained.
13572.5-13573	Quartzitic sandstone, white to greenish-gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation and stylolites, slight burrows, oxidized, sulfur stained.

Depth (feet)	Description
13573-13575	Quartzite, medium light-gray with medium dark-gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolites, moderately burrowed, massive.
13575-13575.4	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, sandstone lenses (<1 cm) in clay matrix, iron stains.
13575.4-13578	Quartzitic sandstone, medium gray to medium dark-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight to moderate bioturbation, moderate stylolites, faint burrows, sulfur stained, oxidized surface.
13578-13580.8	Sandstone, light gray to greenish-gray, medium to very fine-grained, moderately to poorly-sorted, well-rounded, silica cement, clay matrix in areas, moderately to heavily bioturbated, slight to moderate stylolites, moderate burrows, friable, sulfur stained, dirty.
13580.8-13583	Sandstone, light gray to white, medium to very fine-grained, moderately to poorly-sorted, rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderate burrows, sulfur and oxidized stains, sandstone lenses in clay matrix (<1.5 cm).
13583-13591	No Core.
13591-13592	Sandstone, light gray to light-dark gray, black matrix, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, sandstone to clayshale, sandstone lenses (<.5 cm) in clay matrix.
13592-13593.5	Sandstone, light gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, moderate bioturbation and burrows, occasional stylolites, friable, extensive sulfur rich-yellow.
13593.5-13593.8	Sandstone, light gray, dark yellow-orange staining, medium to fine-grained, moderately to well-sorted, rounded, silica cement, extensive bioturbation, friable, sulfur stained extensively.

Depth (feet)	Description
13593.8-13593.8	Sandstone, medium gray, orange stained, medium-grained, well-sorted, sub-rounded, silica cement, massive, moderately to extensively bioturbated, occasional stylolites, friable, sulfur stained.
13593.8-13596.5	Sandstone, medium gray, green-gray stained, medium to fine-grained, moderately-sorted, rounded, silica cement, clay matrix, moderate to extensive bioturbation, moderate stylolites and burrows.
13596.5-13602.5	Sandstone, light gray to light-dark gray gradational to yellow-gray, black matrix, medium to very fine-grained, moderately to poorly-sorted, sub-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, occasional pyrite nodules (<1 cm), friable, becoming more sulfur rich downward.
13602.5-13603.5	Quartzitic sandstone, medium gray to medium-light gray, medium to very fine-grained, moderately to poorly sorted, sub-rounded, well cemented (silica), slightly bioturbated, moderate stylolites, sight to moderate burrows, oxidized specks.
13603.5-13609.3	Sandstone, light gray to light olive gray, medium to fine-grained, moderately sorted, sub-rounded, silica cement, clay matrix, moderate to extensive bioturbation and stylolites, moderately burrowed, somewhat friable, occasional phosphate nodules (<1 cm).
13609.3-13610	Sandstone, light gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, moderately bioturbated, extensively burrowed, moderate to extensive stylolites, occasional phosphate nodules (<2 cm).
13610-13615.5	No Core.
13615.5-13616	Sandstone, light gray to green-gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, moderately bioturbated, moderate to extensive stylolites, slight burrows, sulfur stained.

Depth (feet)	Description
13616-13617	Sandstone, light gray, black matrix, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, extensive stylolites, moderate burrows, dark yellow-orange stained, sandstone lenses (<1.5 cm) in clay matrix.
13617-13620	Sandstone, light gray to greenish-gray, black matrix, medium to fine-grained, moderately to poorly-sorted, sub-rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, slightly burrowed, moderate stylolites, yellow sulfur stained.
13620-13628.5	Sandstone, light gray to light olive gray, black matrix, medium to fine-grained, moderately to poorly-sorted, sub-rounded, silica cement, clay matrix in areas, interbedded extensively burrowed quartzitic sandstone and extensively bioturbated sandstone with black-clay matrix, heavily sulfur stained (yellow-orange).
13628.5-13632	Quartzitic sandstone, medium to light gray, medium to fine-grained, moderately to well-sorted, sub-rounded, silica cement, slight bioturbation, extensive stylolites, moderately burrowed, faint laminations.
13632-13635	No Core.
13635-13636.5	Quartzitic sandstone, very light gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, slight to moderate bioturbation, extensive burrows, slightly stylolitic, extensively orange stained.
13636.5-13638.2	Quartzitic sandstone, light gray, medium to coarse-grained, moderately to well-sorted, sub-rounded, silica cement, slight bioturbation, burrows and stylolites, massive.
13638.2-13645.5	Sandstone, white to very light gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated and stylolitic, moderately burrowed, heavily yellow sulfur stained at top grading downward to less, gray-green clay matrix grading down to black clay matrix.

Depth (feet)	Description
13645.5-13650.3	Quartzitic sandstone, light gray to medium dark-gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, interbedded massive quartzite with faint cross laminations and slightly bioturbated sandstone, extensively burrowed, occasional stylolites.
13650.3-13656	Quartzitic sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, interbedded massive quartzite with very prominent cross-stratifications and laminations and extensively bioturbated sandstone, extensively stylolitic, moderately to extensively burrowed, alternating at 15 cm intervals.
13656-13658	Quartzitic sandstone, light gray to medium gray, medium to fine-grained, well-sorted, rounded, silica cement, occasional stylolites and burrows, very prominent herringbone cross-stratification and cross-stratification (3 cm sets), areas of slight bioturbation, orange oxidized specks.
13658-13664	Quartzitic sandstone, light gray to medium gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, interbedded massive quartzite (faint laminations, occasional burrows, slight stylolites) and moderate to extensive bioturbated sandstone (extensive stylolites, moderate burrows).
13664-13688.5	Sandstone, medium-gray to medium light gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, very prominent cross-stratification, herringbone cross-stratification, occasional stylolites and burrows.
13688.5-13676	Sandstone, medium light gray to medium gray, medium to coarse-grained, moderately to well-sorted, silica cement, faint laminations, occasional to moderate stylolites, slight to moderate burrows, slight bioturbation in areas, gradational with below.
13676-13692	Sandstone, medium light gray to medium gray, medium to coarse-grained, moderately to well-sorted, silica cement, faint laminations, occasional stylolites, massive, faint sulfur stained, gradational with below.

Depth (feet)	Description
13692-13699	Quartzitic sandstone, very light gray to light olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, very prominent laminations, cross-bedding, occasional stylolites and burrows, sulfur stained.
13699-13700	Quartzitic sandstone, light olive gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, moderate bioturbation and burrows, extensive stylolites.
13700-13706	Quartzitic sandstone, medium gray to white, medium to fine-grained, well-sorted, rounded, silica cement, moderate stylolites, prominent planar laminations, occasional 2 cm layer of extensive horizontal burrows, oxidized specks, occasional phosphate nodules (<.5 cm).

NDGS Well No. 105
Stanolind, Walter & Ingeberg Waswick #1
SWNE, Sec. 2, T. 153 N., R. 85 W.
Ward County

Depth (feet)	Description
10929-10930	Sandstone, very light gray with light gray burrows, medium to fine-grained, well-sorted, sub-rounded, silica cement, faint laminations, extensively burrowed (horizontal and vertical), moderate stylolites, slightly bioturbated.
10930-10931	Sandstone, medium gray, medium to fine-grained, well-sorted, rounded, silica cement, faint laminations, slightly burrowed, slight bioturbation, occasional stylolites.
10931-10931.5	Sandstone, very light gray with light gray burrows, medium to fine-grained, well-sorted, rounded, silica cement, extensively burrowed, moderately bioturbated, moderately stylolitic.
10931.5-10932	Sandstone, medium gray, medium to fine-grained, well-sorted, rounded, silica cement, faint laminations, slightly burrowed, slightly bioturbated, occasional stylolites.

Depth (feet)	Description
10932-10937	Interbedded bioturbated sandstone and clayshale-sandstone, light olive gray to light gray, medium to dark gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, sandstone layers (1-7 cm) interbedded with moderately bioturbated clayshale-sandstone, extensive stylolites, moderately burrowed, clay layers where extensively bioturbated (<1 cm), sulfur stained.
10937-10942	Sandstone, medium to light gray with medium to dark gray burrows, coarse to fine-grained, moderately-sorted, sub-rounded, silica cement, slightly laminated, moderate to extensive burrows, rubbled core, sulfur stained.
10942-10945	Sandstone, yellow-gray with medium to dark gray stylolites, medium to fine-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated, extensive stylolites, sandstone lenses (<.7 cm) in clay matrix, pyrite nodules (<1 cm).
10945-10946.5	Quartzite and sandstone, light gray, medium-grained, moderately to well-sorted, sub-rounded, silica cement, faint laminations, slight stylolites, none to slight bioturbation, occasional burrows, sulfur stained, coarsening downward.
10946.5-10948.5	Quartzite and sandstone, medium to light gray, coarse-grained, very well-sorted, well-rounded, silica cement, faint laminations, cross-bedding, occasional microstylolites.
10948.5-10951.5	Quartzite and sandstone, medium to light gray, coarse-grained, well-sorted, rounded, silica cement, interbedded massive sandstone and heavily stylolitic, medium to slightly bioturbated, moderately burrowed sandstone, sulfur stained, pyrite nodules (<.5 cm).
10951.5-10957	Sandstone, medium gray to greenish-gray, medium to coarse grained, well-sorted, rounded, silica cement, clay matrix, moderately bioturbated, extensive stylolites, slightly to moderately burrowed, heavily sulfur stained at the top.
10957-10960	Sandstone, light gray to medium gray, medium to coarse-grained, well-sorted, rounded, silica cement, slightly stylolitic, burrows rare, moderate laminations, pyrite nodules (<.4 cm).
10960-10961	Sandstone, light gray to light olive gray, coarse-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated, extensively stylolitic.

Depth (feet)	Description
10961-10968.5	Sandstone, medium gray, medium to coarse-grained, well-sorted, very well-rounded, silica cement, occasional stylolites, very prominent laminations (low angle) and cross-bedding, coarsening downward.
10968.5-10969	Sandstone, medium gray, coarse-grained, well-sorted, well-rounded, silica cement, moderately to extensively stylolitic, slightly bioturbated.
10969-10970	Sandstone, white to medium light gray, medium-grained, well-sorted, well-rounded, silica cement, moderate stylolites, very prominent low angle laminations, slightly bioturbated, few burrows, faint sulfur staining.
10970-10971	Sandstone, medium to dark gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, faint low angle laminations, few stylolites, cross-laminations, reactivation surfaces, glauconite specks, quartz nodules (<1 cm), few burrows, pyrite specks, soft glauconite layer (2 cm).
10971-10971.3	Sandstone, pinkish gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated, clay stringers with sandstone nodules and lenses in clay matrix, burrows.
10971.3-10972	Sandstone, very light gray to light gray, medium to fine-grained, well-sorted, rounded, silica cement, moderate cross-laminations, occasional stylolites, slight burrows and bioturbation, sulfur stained.
10972-10975.3	Sandstone, light gray, fine to coarse-grained, moderately-sorted, rounded, silica cement, clay in matrix, very prominent laminations and cross-bedding, greenish-gray clay stringers and layers (<.8cm) becoming more extensive downward, moderate stylolites, moderately bioturbated-increasing downward, large phosphate nodule (1 cm x 3 cm) and specks (<.3 cm), feldspar nodules (<1 cm).
10975.3-10976	Quartzitic sandstone, light gray, medium to coarse-grained, moderately-sorted, rounded, silica cement, sandstone nodules in sandstone matrix, moderately bioturbated grading downward to extensively bioturbated, phosphate nodules (<.3 cm).

Depth (feet)	Description
10976-10976.8	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, sandstone lenses and layers (<1 cm) in clay matrix, phosphate nodules (1 cm x 2 cm).
10976.8-10977.5	Clayshale, olive gray, silica cement, clay matrix, sandstone lenses (<.3 cm) in clay matrix.
10977.5-10980	Quartzitic sandstone, very light gray to medium light gray, medium-grained, well-sorted, well-rounded, silica cement, moderately laminationed, occasional stylolites, pyrite nodules (<.8 cm), moderate to extensive bioturbation, oxidized specks, 1 cm phosphate layer.
10980-10982.3	Sandstone, yellow-gray with greenish gray clay layers, medium to fine-grained, moderate to well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, quartzitic sandstone nodules (<2 cm), phosphate layers (<.2 cm), pyrite specks and nodules (<.5 cm), glauconite rich, sulfur stained.
10982.3-10983	Clayshale shale, dark greenish-gray, clay matrix, soft sediment deformation, fissile.
10983-11000	Sandstone and clayshale interbedded, white to yellowish-gray and greenish gray to dark-green gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, pyrite nodules in areas, clay stringers and layers (<2 cm), laminations, cross-bedding, feldspar nodules toward base, fissile and stylolitic clayshale.
11000-11003.8	Sandstone, yellowish-gray, medium-grained, very well-sorted, well-rounded, silica cement, faint low angle laminations, massive.
11003.8-11004	Sandstone, medium to light gray, medium-grained, well-sorted, well-rounded, silica cement, pyrite nodules, phosphate nodules (.4 cm x 2 cm), stylolitic, cross-bedding.
11004-11008	Sandstone, yellow-gray to medium gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, very prominent cross-bedding and laminations.

NDGS Well No. 207
Continental Oil Company, John Lueth #1
SESE, Sec. 27, T. 146 N., R. 73 W.
Wells County

Depth (feet)	Description

*This is a solid core, it has not been cut in half. The shale disintegrates when it comes in contact with water making it difficult to describe.

5750-5750.8	Shale, dark greenish-gray to dark-gray and green-gray, noncalcareous, clay matrix, slight bioturbation, soft sediment deformation, green-gray lenses in dark-green gray shale, shaley partings, fissile.
5750.8-5756	Shale, green-gray to dusky yellow-green, noncalcareous, clay matrix, fossil fragments-echinoderms, brachiopods, shaley partings, fissile, soft-sediment deformation.
5756-5764	Shale, medium olive-brown to grayish-olive, noncalcareous, clay matrix, fossil fragments-echinoderms, brachipods, shaley partings, fissile, soft-sediment deformation.
5764-5766	Shale, green-gray to dusky yellow-green, noncalcareous, clay matrix, fossil fragments-echinoderms, brachiopods, shaley partings, fissile, soft-sediment deformation.
5766-5768	Shale, medium olive-brown to grayish-olive, noncalcareous, clay matrix, fossil fragments-echinoderms, brachipods, shaley partings, fissile, soft-sediment deformation.
5768-5782	Shale, green-gray to dusky yellow-green, noncalcareous, clay matrix, fossil fragments-echinoderms, brachiopods, shaley partings, fissile, soft-sediment deformation.
5782-5785	Shale, green-gray to dusky yellow-green, noncalcareous, clay matrix, fossil fragments-echinoderms, brachiopods, shaley partings, fissile, soft-sediment deformation, white specks throughout (conodonts).
5785-5794	Shale, light olive to grayish-olive, noncalcareous, clay matrix, fossil fragments-echinoderms, brachipods, shaley partings, fissile, soft-sediment deformation, oxidized around some fossil fragments

Depth (feet)	Description
5794-5802	Shale, green-gray to dusky yellow-green, noncalcareous, clay matrix, fossil fragments-echinoderms, shaley partings, fissile, soft-sediment deformation, less fossiliferous (no brachiopods).
5802-5803	Shale, light olive to grayish-olive, noncalcareous, clay matrix, fossil fragments-echinoderms, shaley partings, fissile, soft-sediment deformation, oxidized around some fossil fragments, less fossiliferous (no brachiopods).
5803-5803.5	Shale, olive-gray to dark-green gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, sandstone lenses (<2 cm).
5803.5-5805	Shale, light olive to grayish-olive, noncalcareous, clay matrix, fossil fragments-echinoderms, shaley partings, fissile, soft-sediment deformation, oxidized around some fossil fragments, less fossiliferous (no brachiopods).
5805-5806	Shale, olive-gray to dark-green gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, sandstone lenses (<2 cm).
5806-5808	Clayshale with extensive sandstone lenses, dark-green gray and pink-gray to white, fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, sandstone lenses (<2 cm) in clay matrix, shaley partings, occasional vertical burrows filled with very light gray clay and white sandstone, shaley partings, fissile, soft-sediment deformation.
5808-5811	Clayshale, dusky-yellow olive and dark-green gray, noncalcareous, clay matrix, fossil echinoderms, occasional horizontal burrows, shaley partings, fissile soft-sediment deformation.
5811-5812	Sandstone, medium-dark gray to brownish-gray, medium to fine-grained, moderately-sorted, rounded, silica cement, clay matrix in areas, slight bioturbation, extensive stylolites, occasional burrows, occasional to moderate clay stringers and layers, dirty, occasional phosphate nodules (<.2 cm), extensive pyritized nodules and specks (<3 cm), oxidized.

Depth (feet)	Description
5812-5815	Sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderate bioturbation, occasional burrows, extensive green clay stringers and layers (<.2 cm), phosphate nodules, occasional quartz nodules (<1 cm), occasional stylolites.
5815-5817	Sandstone, light brownish-gray to dusky red, very dusky red filled burrows, fine grading downward to coarse-grained, moderately to well-sorted, well-rounded, silica cement, moderately bioturbated sandstone, moderately burrowed, occasional green clay stringers and layers (<.3 cm).

NDGS Well No. 291
Amerada Petroleum Corp., Herman May U. #1
NWNE, Sec. 9, T. 139 N., R. 100 W.
Billings County

Depth (feet)	Description
12929-12936	Sandstone, light green-gray, greenish-gray clay stringers, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, moderately bioturbated, moderately to extensively burrowed, occasional stylolites, extensive phosphate nodules (<1.5 cm), clay stringers throughout, occasional green clay layer (<2 cm).
12936-12940	Quartzitic sandstone, white, very fine-grained, very well-sorted, well-rounded, silica cement, massive, faint laminations, occasional areas of bioturbation and burrows, occasional clay layers toward base (<2 cm).
12940-12947.8	Clayshale, medium-dark gray to dark green-gray, noncalcareous, clay matrix, shaley partings, fissile, finely laminated, soft-sediment deformation.
12947.8-12948	Sandstone, yellow-gray to light-green gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately burrowed and stylolitic, clay stringers.

Depth (feet)	Description
12948-12951	Clayshale, medium-dark gray to dark green-gray, noncalcareous, clay matrix, shaley partings, fissile, finely laminated, soft-sediment deformation.

NDGS Well No. 470
Blackwood & Nichols, Gilman & Lang #1
NESE, Sec. 15, T. 140 N., R. 105 W.
Golden Valley County

Depth (feet)	Description
12405-12408.5	Clayshale, dark-green gray, noncalcareous, clay matrix, fossil fragments, burrows, friable laminations, soft-sediment deformation, fissile, shaley partings, nodular in areas, occasional calcite lens toward base, pyrite specks in areas, horizontal burrows towards base.
12408.5-12410	Limestone, light olive-gray to medium-light gray, coarse-grained, moderately-sorted, calcareous, fossil fragments, burrows, massive, calcite crystals replacing burrows, effervescent, occasional stylolites, extensively stylolitic 3 cm from base.
12410-12412	Clayshale, dark-green gray with dusky yellow-green lenses, slightly calcareous, clay matrix, dark-green sandstone lenses throughout (<.8 cm), slight bioturbation, soft-sediment deformation, fissile, shaley partings, occasional stylolites, phosphate rich layers and lenses (<2 cm).
12412-12414	Limestone, light olive-gray to medium-light gray, medium-grained, moderately-sorted, calcareous, extensive fossil fragments, burrows, massive, calcite crystals replacing burrows, effervescent, occasional stylolites, extensively stylolitic 3 cm from base, occasional pyrite nodules (<.5 cm).
12414-12414.3	Clayshale, dark-green gray with dusky yellow-green lenses, slightly calcareous, clay matrix, dark-green sandstone lenses throughout (<.8 cm), slight bioturbation, soft-sediment deformation, fissile, shaley partings, occasional stylolites, phosphate rich layers and lenses (<2 cm).

Depth (feet)	Description
12414.3-12415	Limestone, light olive-gray to medium-light gray, fine-grained, moderately-sorted, calcareous, extensive fossil fragments, burrows, massive, calcite crystals replacing burrows, effervescent, occasional stylolites, extensively stylolitic 3 cm from base, occasional pyrite nodules (<.5 cm), fining of limestone decreases downward.

NDGS Well No. 1231
Amerada Petroleum Corp., Iverson & Nelson U. #1
SENE, Sec. 2, T. 155 N., R. 96 W.
Williams County

Depth (feet)	Description
14473-14473.8	Sandstone, medium gray grading to grayish black downward, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (< .5 cm) in clay matrix.
14473.8-14474.5	Sandstone, medium gray to dark gray, medium- to coarse-grained, moderately to well-sorted, rounded to sub-rounded, silica cement, massive, well cemented, sulfur stained.
14474.5-14476	Sandstone, very light gray grading to grayish-black downward, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated, stylolites, black clay layers, sandstone lenses (< 1.5 cm) and layers, horizontally and vertically burrowed.
14476-14492	Quartzite sandstone, medium gray to medium dark-gray, medium- to coarse-grained, moderately to well-sorted, sub-rounded, silica cement, occasional stylolites, massive, sulfur stained.
14492-14497.3	Quartzite sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolites, faint cross-laminations, sulfur stained.
14497.3-14498.7	Quartzite sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, slightly bioturbated to extensive bioturbation, prominent horizontal burrows, vertical burrows, extensive stylolites.

Depth (feet)	Description
14498.7-14500	Quartzite sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, massive, occasional horizontal burrows, phosphate specks toward the base, pyrite inclusions (< .3 cm) toward the base, sulfur stained.
14500-14500.4	Quartzite sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, faint bioturbation, extensive horizontal burrows, vertical burrows, moderate stylolites.
14500.4-14540	Quartzitic sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, faint laminations, occasional stylolites, occasional burrows toward the base.

NDGS Well No. 1385
Amerada Petroleum Corp., North Dakota
SESW, Sec. 16, T.156 N., R. 95 W.
Williams County

Depth (feet)	Description
14129-14132	Sandstone, greenish-gray to dark greenish-gray, fine- to medium-grained, moderately- to poorly-sorted, rounded to well-rounded, silica cement, clay matrix in areas, friable, glauconite throughout, occasional shale layers (<5 cm), occasional quartzite layer (<1.5 cm), oxidized specks and nodules (<1 cm).
14132-14134.5	Interlaminated sandstone and siltstone, grayish-green and grayish-red, silt-sized to medium-grained, moderately- to poorly-sorted, rounded- to well-rounded, quartz and hematite cement, clay matrix in areas, glauconite throughout, slightly bioturbated, coarse-grained quartz nodule (very glauconite rich) 10 cm, thin clay stringers.
14134.5-14135.3	Sandstone, greenish-gray, medium-grained, moderately- to well-sorted, well-rounded, silica cement, glauconite matrix, moderately bioturbated, shale stringers and lenses (<2 cm), oxidized specks.
14135.3-14135.8	Clayshale, silty, medium-dark gray, very fine-grained to silt-sized, moderately-sorted, rounded to well-rounded, silica cement, clay matrix, grading downward from clayshale to extensively bioturbated siltstone.

Depth (feet)	Description
14135.8-14138.8	Sandstone, very dark red, medium- to coarse-grained, poorly-sorted, rounded, silica and hematite cement, friable, greenish-gray shale stringers grading downward into shale lenses (<5 mm), heavily bioturbated at base, glauconite rich, coarse-grained sandstone lenses (<4 cm) toward base.
14138.8-14146.5	Sandstone, greenish-gray grading downward into white and grayish-orange, fine- to coarse-grained, poorly-sorted, rounded, silica cement, clay matrix in areas, green shaley stringers and lenses of shale (3 mm-3 cm) throughout, phosphate nodules (1 mm-2 cm), oxidized specks, glauconite rich towards top, friable.
14146.5-14149.5	Sandstone, grayish-red grading downward to dusky red and pink-red layers and lenses, fine-grained grading downward to coarse-grained, poorly-sorted, sub-rounded to rounded, silica and hematite cement, friable, porous, moderately bioturbated.
14149.5-14151	Sandstone, grayish-red, fine- to medium-grained, poorly-sorted, rounded to well-rounded, silica and hematite cement, friable, well defined low-angle laminations, shale stringers, occasional layers and lenses (<5 mm) of white siltstone and sandstone.
14151-14152	Siltstone, grayish-red to dusky red, very fine-grained to silt-sized, moderately-sorted, well-rounded, silica cement, clay matrix, thinly laminated siltstone and clayshale.
14152-14153	Sandstone, grayish-red, fine- to medium-grained, moderately-sorted, well-rounded, silica cement, massive, phosphate nodules (5 mm-2 cm), large yellowish-gray, medium-grained sandstone inclusions.
14153-14155.3	Sandstone, grayish-red with yellowish-gray nodules (3-8 cm), medium-grained, moderately- to well-sorted, well-rounded, silica and hematite cement, massive.
14155.3-14163.5	Clayshale, alternating reddish-brown and dark grayish-green bands, non-calcareous, soft sediment deformation, grading from predominantly red at top to green toward the base, gradational with below, mud cracks.
14163.5-14165.5	Clayshale, greenish-black, non-calcareous, shaley partings, siltstone layers and lenses (1-1.5 cm), soft sediment deformation, sandstone inclusions from below (<2 cm).

Depth (feet)	Description
14165.5-14170	Sandstone, light gray grading downward to very light gray, medium-grained, well-sorted, rounded, silica cement, moderately stylolitic, massive with faint laminations, pyrite nodules (<2 cm), oxidized specks, phosphate specks (<5 mm), slightly sulfur stained.
14170-14171	Sandstone, light olive-gray, medium-grained, well-sorted, rounded, silica cement, clay matrix, slightly bioturbated grading to extensively bioturbated at base, soft sediment deformation.
14171-14172.3	Sandstone, light olive-green, medium- to coarse-grained, moderately-sorted, rounded, silica cement, massive, black phosphate specks, oxidized specks.
14172.3-14174.5	Quartzite-sandstone, very light gray, medium to fine grained, well-sorted, well-rounded, silica cement, massive, very well cemented, occasional stylolites, pyrite nodules (<1 cm), occasional fractures filled with pyrite.

NDGS Well No. 1403
Amerada Petroleum Corp., Boe-Olson #1
SWNE, Sec. 15, T. 155 N., R. 96 W.
Williams County

Depth (feet)	Description
13456-13461.8	Sandstone, medium gray, medium- fine-grained, well to moderately-sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (< 1 cm) in clay matrix, burrows, stylolites, sulfur stained.
13461.8-13463.5	Clayshale and siltstone, medium gray to medium dark-gray grading downward to grayish-black layers, silt-size, moderately sorted, silica cement, clay matrix, occasional stylolites, soft sediment deformation.
13463.5-13468	Sandstone, medium gray, medium to fine-grained, well to moderately sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<1 cm) in clay matrix, occasional horizontal and vertical burrows, sulfur stained.
13468-13480	No Core.

Depth (feet)	Description
13480-13484.5	Sandstone, medium gray, medium to fine-grained, well to moderately sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<1.5 cm) in clay matrix, sulfur stained.
13484.5-13486.3	Sandstone, medium to light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated, moderate stylolites, moderate horizontal and vertical burrows, sandstone lenses (.2-3 cm) and layers in with clay layers.
13486.3-13496	Sandstone, medium to light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<.1 cm) in clay matrix, occasional clay seam (<1 cm), sulfur stained.
13496-13503.5	Sandstone, medium to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated grading downward to heavily bioturbated, sandstone lenses and layers in clay matrix (1-3 cm toward top, <.5 cm at bottom), sulfur stained, occasional well-developed burrows.
13503.5-13505.8	Quartzite and sandstone, very light-gray to medium dark-gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to heavily burrowed (horizontal and vertical) interbedded with moderately stylolitic (7-10 cm) areas, sulfur stained.
13505.8-13506	Clayshale, greenish-gray, silt size, moderately to well-sorted, silica cement, clay matrix, extremely bioturbated sandstone at base grading into clayshale at top.
13506-13507	Sandstone, very light gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix at base, extensive burrows grading downward to moderately bioturbated, faint oxidizing.
13507-13510	Sandstone, very light gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix at base, moderately burrowed (horizontal and vertical) grading downward to extensively bioturbated, sulfur stained.

Depth (feet)	Description
13510-13513	Sandstone, medium dark-gray to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate to extensive stylolites, massive, sulfur stained.
13513-13513.8	Sandstone, medium to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderate to extensive bioturbation, stylolites, moderately burrowed, sulfur stained.
13513.8-13514.3	Sandstone, medium to dark-gray, medium-grained, well-sorted, well-rounded, silica cement, moderately burrowed, massive.
13514.3-13516	Quartzite and sandstone, pinkish gray to medium-light gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive horizontal and vertical burrows, extensive sulfur stained.
13516-13516.3	Sandstone, greenish-gray, silt size, moderately to well-sorted, silica cement, clay matrix, extensively bioturbated sandstone to clayshale, shale portions.
13516.3-13516.8	Sandstone, very light gray, well-sorted, well-rounded, silica cement, moderately burrowed, oxidized burrows at 45 degrees, slightly bioturbated, sulfur stained.
13516.8-13518.5	Sandstone, very light gray to white, medium light gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed interbedded with moderate to extensive stylolites (15 cm).
13518.5-13520.5	Quartzite and sandstone, light gray with medium light gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately burrowed, massive.
13520.5-13525	Quartzite and sandstone, medium to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensive sandstone burrows (vertical and horizontal), sulfur rich areas- yellow streaks- 10 cm pure sulfur bed at 13,522.
13525-13526	Sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, friable sandstone, massive, oxidized, sulfur rich, slightly bioturbated at base.

Depth (feet)	Description
13526-13532	Sandstone, light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<1 cm) in clay matrix, more sandstone toward base.
13532-13535.5	Sandstone, medium to light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, bioturbated clay matrix, interbedded bioturbated sandstone (lenses .5-3 cm) and quartzite sandstone (3-5 cm), massive, moderately burrowed (horizontal).
13535.5-13546	Sandstone, medium to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated, sandstone lenses increase in size downward (.5-1.5 cm), occasional sandstone layers (<.5 cm), occasional pyrite inclusions, occasional well-developed horizontal burrows.
13546-13548	No Core.
13548-13549	Quartzite and sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, occasional burrows, sulfur stained.
13549-13550.5	Sandstone, very light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, moderately burrowed, sandstone lenses and layers (<1.5 cm) in clay matrix.
13550.5-13551.4	Sandstone, light gray, medium to coarse-grained, moderately-sorted, well-rounded, silica cement, occasional burrows, green glauconite specks, occasional stylolites.
13551.4-13566	Quartzite and sandstone, medium-gray, medium-grained, well-sorted, well-rounded, silica cement, occasional stylolites, faint laminations, sulfur stained, slightly oxidized, coarsening downward.
13566-13570.5	Sandstone, yellowish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, very prominent cross-bedding and laminations, occasional stylolites, sulfur stained.
13570.5-13573.5	Sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate stylolites, moderately burrowed (horizontal) interbedded with prominent laminations at low angles (15-20 cm), sulfur stained.

Depth (feet)	Description
13573.5-13574	Sandstone, light gray to gray-black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<.5 cm) in black clay matrix.
13574-13582	Sandstone, medium-gray to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive stylolites, faint laminations, occasional layers of very coarse sandstone (13575-13570)-well rounded and poorly sorted (<2 cm), black, green and white quartzite, prominent sulfur stained.
13582-13586	Sandstone and quartzite, medium to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately laminated to massive, occasional stylolites, sulfur stained.

NDGS Well No. 1409
Leach Oil & Calvert, Patterson Land Co. #1
NWSE, Sec. 11, T. 140 N., R. 77 W.
Burleigh County

Depth (feet)	Description
6505-6509	Clayshale, greenish-gray to dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, friable, burrows, faint laminations, soft-sediment deformation, slickenslides, fissile, shaley partings.
6509-6510	Clayshale, greenish-gray to dark green-gray with yellowish-gray sandstone lenses, medium-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, fossil fragments, faint laminations, soft-sediment deformation, slickenslides, fissile, shaley partings, sandstone lenses (<.5 cm) throughout.
6510-6511	Clayshale, greenish-gray to dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, friable, burrows, faint laminations, soft-sediment deformation, slickenslides, fissile, shaley partings.

Depth (feet)	Description
6511-6512.5	Clayshale, greenish-gray to dark green-gray with yellowish-gray sandstone lenses, medium-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, fossil fragments, faint laminations, soft-sediment deformation, slickenslides, fissile, shaley partings, sandstone lenses (<.2 cm) throughout, brown clay in areas, increasing sandstone downwards.
6512.5-6515	Interbedded sandstone and clayshale, yellowish-gray to medium brown, green clayshale, medium to fine-grained, moderately to poorly-sorted, rounded, slightly calcareous, clay matrix, moderately bioturbated, moderately burrowed, sandstone and clay-shale layers and lenses churned up, pyrite nodules (<1.5 cm), soft-sediment deformation, occasional phosphate nodules (<.4 cm), extensive amount of green clay stringers.
6515-6515.5	Sandstone, yellowish-gray to greenish-gray with brownish-black clasts, medium to fine-grained, moderately-sorted, rounded, slightly calcareous, quartzite clasts (<.3 cm) incorporated in a sandstone matrix, moderate bioturbation and burrows, pyrite nodules (<1 cm), occasional clay stringers.
6515.5-6516.2	Quartzitic sandstone, medium-light gray to light-olive gray, medium to fine-grained, well-sorted, rounded, silica cement, massive, slight bioturbation and burrows, occasional areas of horizontal burrows (<1 cm), faint laminations, orange stained.
6516.2-6517	Quartzitic sandstone, medium-light gray to light-olive gray, medium-grained, moderately to well-sorted, rounded, silica cement, slight bioturbation, moderate to extensive burrows increasing downward, moderate stylolites.
6517-6518	Sandstone, light gray with medium-light gray burrows, coarse-grained, very well-sorted, well-rounded, silica cement, massive, moderate burrows, slight bioturbation.
6518-6520	Quartzitic sandstone, medium-light gray to light-olive gray, medium-grained, moderately to well-sorted, rounded, silica cement, moderate bioturbation, moderate to extensive burrows increasing downward, moderate stylolites.

NDGS Well No. 2010
Carter Oil Co., Dallas D. Moore #1
NWNE, Sec. 7, T. 163 N., R. 102 W.
Divide County

Depth (feet)	Description
10863-10868	Interbedded siltstone and clayshale, medium gray to medium-dark gray, <silt in size, silica cement, clay matrix, abundant phosphate nodules.
10868-10877.5	Clay and shale, medium-dark gray with dark-greenish gray burrows, silica cement, clay matrix, occasional to moderate burrows (vertical and horizontal), platy partings, more silt downward.
10877.5-10880	Interbedded silt and clayshale, medium-light gray to olive gray, <silt in size, silica cement, clay matrix, faint soft sediment deformation, occasional phosphate nodules toward base.
10880-10884	No Core.
10884-10887	Silty-clayshale, medium-dark gray, <silt in size, silica cement, clay matrix, faint laminations.
10887-10888	Clayshale, dark gray, silica cement, clay matrix, platy partings, fissile.
10888-10893	Sandstone, medium to light gray, medium-dark gray clay matrix, medium to fine-grained, well-sorted, sub-rounded, silica cement, clay matrix, heavily to moderately bioturbated, sulfur stained, interbedded, friable, sandstone lenses (1 cm) in clay matrix. Siltstone, silt size to fine-grained, well-sorted, rounded, silica cement, clay matrix heavily bioturbated, consolidated.
10893-10895.5	Clayshale with silt lenses, dark-green gray to light olive gray, <silt size, silica cement, clay matrix, heavily bioturbated, sandstone lenses (.5-3 cm) in clay matrix, occasional well-developed burrows.
10895.5-10899	Clayshale, dark gray, <silt in size, silica cement, clay matrix, massive, siderite filled fractures, shaley partings.
10899-10900	Siltstone, medium to dark gray, silt to very fine-grained, silica cement, clay matrix, sandstone lenses (<1 cm), poorly sorted.

Depth (feet)	Description
10900-10903	Sandstone, yellow-gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive stylolites, moderately bioturbated, horizontal and vertical burrows, sandstone lenses (<.5-6 cm) in clay matrix.
10903-10904	Quartzite and sandstone, very light gray to white, fine to very-fine-grained, well-sorted, well-rounded, silica cement, extensive stylolites, occasional to moderately burrowed, faint laminations, grading downward to more massive.
10904-10908.3	Sandstone, yellowish gray, fine-grained, well-sorted, rounded, silica cement , clay matrix, extensive bioturbations, very friable, occasional burrows, sandstone nodules and lenses (<1 cm) in clay matrix.
10908.3-10909.5	Sandstone, light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensive stylolites, moderately burrowed (horizontal and vertical), large sandstone lenses separated by stylolites (1-5 cm).
10909.5-10913.5	Sandstone, very light gray, medium to fine-grained, moderately sorted, rounded, silica cement, clay matrix, friable, porous, heavily to moderately bioturbated, sandstone lenses (.5-1.5 cm) in clay matrix- becoming larger downward into sandstone layers, sulfur stained.
10913.5-10920	Sandstone, very light gray, medium to fine-grained, well-sorted, sub-rounded, silica cement, clay matrix in areas, slightly bioturbated, moderate stylolites, moderately to heavily burrowed (horizontal and vertical), friable in areas, grading downward to massive.
10920-10923.5	Quartzite and sandstone, very light gray, fine to very fine grained, very well-sorted, well-rounded, silica cement, occasional stylolites, black specks, massive, faint laminations, occasional burrows, grading to quartzite.
10923.5-10925.3	Sandstone, light gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate bioturbations, extensive stylolites, sandstone lenses (<.5-3 cm) in clay matrix.
10925.3-10926	Silty clayshale, very light gray siltstone lenses (<.3 cm) in grayish-black clay matrix, <silt size, silica cement, clay matrix.

Depth (feet)	Description
10926-10930.5	Sandstone, very light gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix downward, sandstone grading downward form slight to heavily bioturbated, stylolites, and burrowed.
10930.5-10937	Sandstone, light olive gray, fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, sandstone lenses (<1 cm) in clay matrix, occasional sandstone nodules and lenses (3-5 cm), occasional burrows, soft sediment deformation.
10937-10940	Interbedded sandstone and clayshale, light gray to grayish-black, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, moderately to extensively bioturbated, moderately burrowed, sandstone lenses (<1.5 cm) in clay matrix, clayshale with <.2 cm sandstone lenses, interbedded moderately bioturbated sandstone and extensively bioturbated sandstone-clayshale.

NDGS Well No. 2373
Amerada Petroleum Corp., Antelope Unit "A" No. 1
NESE, Sec. 1, T. 152 N., R. 95. W
McKenzie County

Depth (feet)	Description
14057-14060.8	Sandstone, light gray grading downward to gray-black, fine-grained, well-sorted, sub-rounded to rounded, silica cement, clay grading downward to a shale matrix, heavily bioturbated, vertical worm burrows.
14060.8-14066.8	Sandstone, medium gray, medium- to fine-grained, moderately- to well-sorted, rounded to sub-rounded, silica cement, occasional horizontal oxidized worm burrows, occasional stylolites, low angle laminations.
14066.8-14076.5	Sandstone, medium light gray, medium- to fine-grained, moderately- to well-sorted, rounded, silica cement, occasional stylolites, faint laminations.
14076.5-14088.5	Sandstone, very light gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, prominent stylolites spaced at approximately 20 cm intervals, very prominent cross-bedding, occasional yellow sandstone nodules < 0.5 cm.

Depth (feet)	Description
14088.5-14092.3	Sandstone, light gray, medium- to fine-grained, well-sorted, well-rounded, laminated, silica cement, occasional stylolites, shaley partings, sulfur stained.
14092.3-14107	Sandstone, medium gray, medium- to course-grained, well-sorted, well-rounded, silica cement, massive, occasional stylolites, sulfur staining, pyrite nodules (2 cm x 6 cm).
14107-14108.5	Clayshale, grayish black, very fine-grained, non-calcareous cement, heavily bioturbated, contains sandstone lenses (<1 cm), grades into below.
14108.5-14110.5	Sandstone, light gray, very fine- to fine-grained, well sorted, rounded to well-rounded, silica cement, stylolites, faint low-angle laminations, vertical and horizontal burrows, grades into below.
14110.5-14111.5	Clayshale, grayish-black, very fine-grained, non-calcareous cement, heavily bioturbated, contains sandstone lenses (<1 cm).
14111.5-14116.5	Sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, vertical and horizontal burrows, prominent laminations, cross-bedding, stylolites, slight bioturbation, sulfur staining in places.
14116.5-14120	Sandstone, dark gray, fine-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated sandstone becoming clayshale with sandstone lenses.
14120-14123.5	Sandstone, light olive-gray to greenish-gray, fine-grained, well-sorted, rounded to well-rounded, silica cement, clay matrix, heavily bioturbated, friable, dirty, black phosphate nodules (<.5 mm), brown oxidized specks on weathered surface.
14123.5-14124.5	Clayshale, greenish-gray, very fine-grained, non-calcareous, black phosphate nodules, laminated, soft sediment deformation.
14124.5-14125.5	Sandstone, light greenish-gray to very light gray, medium- to fine-grained, poorly-sorted, rounded, silica cement, heavily bioturbated, occasional phosphate nodules.

Depth (feet)	Description
14125.5-14129	Sandstone, greenish-gray to very light gray, medium- to fine-grained, poorly-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, vertical and horizontal burrows, pyrite specks, oxidized specks, sulfur stained, friable, shaley inclusions (1.5 cm).
14129-14146	No Core
14146-14152.8	Clayshale, interbedded medium greenish-gray & dusky red, non-calcareous, shale partings, finely laminated.
14152.8-14154.5	Interbedded sandstone and shale; Sandstone, dark gray, medium-grained, well-sorted, rounded, silica cement; clayshale, medium greenish-gray, finely laminated, non-calcareous, occasional shale lenses in sandstone.
12154.5-14158.5	Sandstone, dusky red to medium gray, fine- to course-grained, moderately- to poorly-sorted, rounded, occasional cross-laminations, calcite, hematite and silica cement, occasional clay lenses and layers.
14158.5-14159.8	Sandstone, grayish-red to dusky red, medium-grained, well-sorted, well-rounded, silica and hematite cement, massive, occasional faint laminations.
14159.8-14162	Quartzite-sandstone, light brown to grayish-red, medium-grained, well-sorted, rounded, silica cement, occasional thin green clay layer, areas of friable dusky red sandstone.
14162-14171.5	Sandstone, very dark red, medium- to fine-grained, moderately sorted, sub-rounded to rounded, silica and hematite cement, faint laminations, glauconite layers, lenses and nodules (<3 cm), occasional bioturbated layer, occasional clay stringers and layers (<3 mm).
14171.5-14175	Quartzite-sandstone, dusky red and grayish pink, medium- to fine-grained, moderately- to well-sorted, rounded to well-rounded, silica and hematite cement, glauconite layers, lenses and nodules (<2 cm), occasional clay stringer, areas of extensive bioturbation, glauconite filled burrows.

Depth (feet)	Description
14175-14176.5	Quartzite-sandstone, dusky red to grayish-red, medium- to fine-grained, moderately- to well-sorted, rounded, silica and hematite cement, cross-laminations, occasional clay lenses and layers (<4 mm), moderately burrowed.
14176.5-14176.8	Sandstone, dark gray, medium- to course-grained, moderately-sorted, sub-rounded, silica cement, faint laminations.
14176.8-14181	Sandstone, dusky red to grayish-red, medium-grained, moderately- to well-sorted, rounded, silica and hematite cement, cross-laminations, slightly bioturbated, moderately burrowed, large glauconite nodule (8 cm).
14181-14184.8	Sandstone, dusky red to grayish-red, medium- to fine-grained, moderately- to well- sorted, rounded to sub-rounded, silica cement, extensively burrowed, feeding burrow pattern, low-angle laminations, grading finer-grained and grayer downward into below.
14184.8-14188.8	Quartzite-sandstone, greenish-gray to very light gray, medium-grained, well-sorted, rounded, silica cement, interbedded extensively burrowed areas to single vertical burrowed to massive.
14188.8-14190	Quartzite-sandstone, light brown and very light gray, medium- to course-grained, well sorted, rounded, silica cement, very prominent low-angle laminations.
14190-14190.8	Sandstone, grayish-red with yellowish-gray laminations, fine-grained, well-sorted, rounded, silica cement, very fine laminations, clay stringers and layers (<2 mm), occasional yellowish-gray sandstone nodules and layers.
14190.8-14192.5	Interbedded sandstone and clayshale; Sandstone, dusky red, medium- to course-grained, moderately sorted, well-rounded, silica and hematite cement, clay matrix in areas, grading finer-grained downward, interlaminated sandstone and greenish-gray clayshale at 2-10 cm intervals.
14192.5-14193	Interbedded quartzite and sandstone; Quartzite, yellowish gray, massive; Sandstone, dusky red, medium- to fine-grained, well-sorted, rounded, silica cement, friable.

Depth (feet)	Description
14193-14196	Clayshale, dark reddish-brown and grayish-green, non-calcareous, finely interlaminated red and green clayshale with occasional sandstone lenses, becoming more greenish downward grading into a finely laminated greenish-gray clayshale.
14196-14198	Sandstone, dark reddish-brown, coarse-grained, moderately- to well-sorted, sub-angular to sub-rounded, quartz and hematite cement, faint laminations, occasional green shale lens, friable.
14198-14198.5	Clayshale, greenish-gray with small red laminations, non-calcareous, finely laminated.
14198.5-14199	Quartzite-sandstone, very pale-orange, fine-grained, well-sorted, well-rounded, silica cement, massive, abrupt contact with below.
14199-14200	Sandstone, dark reddish-brown, coarse- to medium-grained, moderately- to well-sorted, sub-angular to sub-rounded, silica cement, friable.
14200-14201	Clayshale, intercalated dark reddish-brown and greenish-gray laminations, non-calcareous.
14201-14205.8	Sandstone, dusky red, coarse- to fine-grained, moderately- to well-sorted, sub-rounded to rounded, silica and hematite cement, very prominent cross-stratification, grading finer downward, grading from massive to more laminated downward.
14205.8-14206.5	Sandstone, very light gray to white grading downward to pale-red and purple, medium-grained, well-sorted, well-rounded, silica-cement, very prominent thin laminations.
14206.5-14209	Interbedded clayshale and sandstone, grayish-green, fine-grained, moderately-sorted, rounded to well-rounded, silica cement, stylolites prominent, very prominent cross-bedding and laminations, glauconitic-rich sandstone.
14209-14253	No Core.
14253-14257.5	Sandstone, light olive-gray grading downward to light gray, medium-grained, well-sorted, well-rounded, silica cement, very prominent low-angle laminations, black phosphate nodules, occasional burrows, occasional stylolites.

Depth (feet)	Description
14257.5-14263.5	Sandstone, medium gray to dark gray, medium-grained, well-sorted, well-rounded, calcite cement, clay matrix, extensively bioturbated, faint laminations, occasional burrows.
14263.5-14268	Sandstone, yellowish-gray, medium- to coarse-grained, well-sorted, well-rounded, silica cement, extensively burrowed (horizontal) to massive.

NDGS Well No. 2602
Texaco Inc., Seth A. Garland #5
SWNE, Sec. 6, T. 153 N., R. 95 W.
McKenzie County

Depth (feet)	Description
13733-13735	Sandstone, light olive-gray with grayish-black clay matrix, fine to medium-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix in areas, friable, moderately bioturbated, stylolites, occasional vertical burrows, sandstone lenses and layers (<0.5-2.5 cm) in clay matrix.
13735-13739	Sandstone, light olive-gray in grayish-black clay matrix, fine to medium-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix, friable, extensive bioturbated, stylolites, sandstone lenses (<1.5 cm) in clay matrix.
13739-13744	Sandstone, light gray with grayish-black clay matrix, medium-grained, well-sorted, rounded, silica cement, clay matrix, abundant black phosphate specks (1-2 mm), moderately to extensive bioturbated, occasional stylolites, moderate horizontal and vertical burrows, sandstone lenses and nodules in clay matrix.
13744-13749.3	Sandstone, medium-gray, fine to medium-grained, well-sorted, rounded, silica cement, sandstone nodule with abrupt contact above and below.
13749.3-13751	Sandstone, light olive-gray with gray-black clay matrix, fine to medium-grained, moderately sorted, sub-rounded, silica cement, clay matrix, sulfur staining, heavily bioturbated, sandstone lenses (<1.5 cm) in clay matrix.

Depth (feet)	Description
13751-13754	Sandstone, greenish-gray in grayish-black matrix, fine to coarse-grained, poorly to moderately-sorted, sub-angular to sub-rounded, silica cement, clay matrix, green sulfur staining, moderately to heavily bioturbated, sandstone lenses (0.5-3 cm) in clay matrix.
13754-13755.5	Sandstone, light olive-gray, fine to medium-grained, moderately-sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated, sandstone lenses (<0.8 cm) in clay matrix.
13755.5-13757.8	Sandstone, light olive-gray to light-gray in gray-black clay matrix, fine to medium-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix, sulfur staining, interbedded, heavily bioturbated sandstone, black clay layers (1 cm), sand lenses and layers (1.5 cm).
13757.8-13758.5	Sandstone, medium-gray, fine to medium-grained, well-sorted, rounded, silica cement, sandstone lenses and layers (0.5-5 cm), slightly bioturbated, slightly burrowed.
13758.5-13760	Sandstone, light-medium gray, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, moderately bioturbated, moderate to extensive horizontal and vertical burrows, sandstone layers and lenses (0.1-1 cm) in clay matrix.
13760-13762	Sandstone, light olive-gray to light-gray, fine to medium-grained, well-sorted, well-rounded, silica cement, clay matrix, sulfur staining, moderately bioturbated, sandstone lenses and layers (<3 cm) in clay matrix, occasional stylolites.
13762-13763	Interbedded clayshale and heavily bioturbated sandstone, dark-gray to black, very fine-grained, well-sorted, well-rounded, silica cement, clay matrix, clayshale with occasional extensively bioturbated sandstone layers.
13763-13775.5	Sandstone, light-medium gray with grayish-black clay matrix, fine to medium-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix, heavily bioturbated sandstone, occasional burrows and stylolites, sandstone lenses and layers in clay matrix, areas of extensively bioturbated clayshale layers (<5 cm).

Depth (feet)	Description
13775.5-13780.5	Sandstone, light-medium gray with grayish-black clay matrix, fine-medium grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix, interbedded, moderately to extensive bioturbated sandstone and sandstone layers (<2 cm), burrowed, stylolites.
13780.5-13781	Sandstone, light-olive green to greenish-gray, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, moderate to heavily bioturbated sandstone, slightly glauconite, faint burrows.
13781-13783.5	Sandstone, light-olive gray, fine to medium-grained, well-sorted, well-rounded, silica cement, sulfur staining, occasional phosphate nodules (<1.5 cm), very light-gray sandstone nodule (8 x 4 cm), moderately to extensively bioturbated, massive, moderate horizontal and vertical burrows.
13783.5-13784	Sandstone, light to medium-gray with gray-black clay, fine to medium-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated, sandstone lenses and nodules (0.5-4 cm).
13784-13785	Sandstone grading downward to shaley sandstone, light-greenish gray, grading downward to dark-green gray, fine to medium-grained grading downward to clay, well-sorted, well-rounded, silica cement, grading down to a clay matrix, slightly bioturbated sandstone, small stylolites, sulfur staining, grading downward into clay-sandstone.
13785-13786	Sandstone, very light-gray, medium-grained, well-sorted, well-rounded, silica cement, slightly bioturbated, extensive stylolites, quartzite nodules at base (<2 cm).
13786-13787	Sandstone, light-gray grading downward to gray-black matrix, medium-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, sandstone lenses (<0.5 cm) and layers (<1 cm), clay matrix.
13787-13788.5	Sandstone, light olive-gray to greenish-gray, medium-grained, well-sorted, rounded, silica cement, moderately bioturbated, quartz nodules (<1 cm).

Depth (feet)	Description
13788.5-13789.5	Sandstone, light olive-gray to greenish-gray, medium-grained, well-sorted, rounded, silica cement, moderate stylolites, slightly bioturbated.
13789.5-13795.5	Sandstone, very light-gray to light-gray, fine to medium-grained, well-sorted, rounded, silica cement, slight to extensive stylolites, slightly bioturbated, occasional areas of extensive bioturbation with green clay matrix (<2 cm), moderate burrows, clean sandstone.
13795.5-13796	Sandstone, light-gray, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation and stylolites, sulfur staining.
13796-13796.8	Sandstone, light-gray with olive-gray burrows, fine to medium-grained, well-sorted, rounded, silica cement, extensive horizontal and vertical burrows, occasional stylolites, slight to no bioturbation, sulfur staining.
13796.8-13797	Sandstone, medium-gray, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, sandstone lenses (<0.5 cm) in clay matrix, one large sandstone nodule (4 x 5 cm).
13797-13798.8	Sandstone, very light-gray to light olive-gray with medium to dark gray burrows, fine to medium-grained, well-sorted, well-rounded, silica cement, moderate to extensive horizontal and vertical burrows, moderately to slightly bioturbated, occasional stylolites, extensive sulfur staining.
13798.8-13799.3	Quartzitic sandstone, medium to medium-light gray grading downward to dark-gray, fine-grained, well-sorted, rounded, silica cement, slight stylolites, moderate burrows grading upward, massive.
13799.3-13800.8	Sandstone, light-gray with medium-dark gray burrows, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, moderatly stylolitic grading to slightly stylolitic at the base, slight to extensive burrows grading downward, moderate bioturbation, sulfur staining.

Depth (feet)	Description
13800.8-13801	Quartzitic sandstone, light-gray with medium-light gray burrows, fine to medium-grained, well-sorted, rounded, silica cement, massive, slight burrows, faint, occasional stylolites.
13801-13802	Sandstone, light-olive gray, medium-grained, well-sorted, rounded, silica cement, clay matrix, sulfur staining, extensive bioturbation, moderate stylolites, sandstone lenses (<2 cm) in clay matrix.
13802-13803	Quartzitic sandstone, light gray, medium-grained, well-sorted, rounded, silica cement, moderately burrowed, well-cemented, occasional stylolites, slightly bioturbated.
13803-13804	Sandstone, white to very light-gray, medium-grained, well-sorted, rounded, silica cement, clay matrix, extensive sulfur, extensive bioturbation, occasional stylolites, extensive burrows.
13804-13806	Sandstone, very light-gray with medium-gray burrows, medium-grained, well-sorted, sub-rounded, silica cement, extensively burrowed, slight stylolites, slightly bioturbated, sulfur staining.
13806-13807	Sandstone, light olive-gray to grayish-green, medium-grained, well-sorted, rounded, silica cement, clay matrix, sulfur staining, extensively bioturbated, moderate stylolites, faint burrows.
13807-13810	Sandstone, light-gray, fine to medium-grained, medium to well-sorted, rounded, silica cement, clay matrix, moderately to extensively bioturbated and burrowed, occasional stylolites, sulfur stained, oxidized, sandstone lenses and layers (<2 cm) in clay matrix.
13810-13814	No core
13814-13820.8	Sandstone, light to medium-gray in gray-black clay matrix, fine to medium-grained, medium to well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, occasional stylolites, sandstone lenses (<0.5 cm) and layers (<0.8 cm) in clay matrix.
13820.8-13822.3	Sandstone, light to medium-gray with gray-black matrix, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, moderate to extensive bioturbation, occasional stylolites, extensively burrowed, sandstone lenses and layers (<2.5 cm) in clay matrix.

Depth (feet)	Description
13822.3-13828.8	Sandstone, light-gray with gray-black matrix, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, moderate burrows, moderate stylolites, sandstone lenses (<1 cm) and layers (<1 cm) in clay matrix.
13828.8-13829.5	Sandstone, light olive-gray with black matrix, fine to medium-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, clay matrix with sandstone lenses (<0.5 cm).
13829.5-13831.5	Sandstone, medium-gray, fine to medium-grained, well-sorted, rounded silica cement, clay matrix, extensive bioturbation, moderate stylolites, occasional burrows, sandstone lenses (<1 cm) in clay matrix.
13831.5-13832.3	Clayshale, grayish-black with light-olive gray sandstone lenses, silica cement, clay matrix, extensively bioturbated sandstone grading downward to clayshale, clayshale with occasional sandstone lenses (<0.3 cm).
13832.3-13833	Sandstone, light-gray with black matrix, fine to medium-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, burrows, and stylolites, sandstone lenses (<1.5 cm) in clay matrix.
13833-13836	Quartzitic sandstone, light olive-gray, medium-grained, well-sorted, well-rounded, silica cement, faint laminations, massive, occasional stylolites.
13836-13838.5	Sandstone, medium to dark-gray, fine-grained, medium to well-sorted, rounded, silica cement, extensive stylolites, faint laminations, sulfur staining.
13838.5-13839	Sandstone, light-gray with black matrix, fine to medium-grained, medium to well-sorted, rounded, silica matrix, clay, extensive bioturbation and burrows, stylolites.
13839-13848	Quartzitic sandstone, medium to dark-gray, fine to medium-grained, well-sorted, rounded, silica cement, occasional stylolites, cross-bedding and laminations, sulfur staining.
13848-13850	Sandstone, light-gray with black matrix, fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation, moderate burrows and stylolites.

Depth (feet)	Description
13850-13851.8	Quartzitic sandstone, medium to dark-gray, fine to medium-grained, well-sorted, rounded, silica cement, occasional stylolites, faint-moderate laminations and cross-bedding, sulfur staining.
13851.8-13854.8	Quartzitic sandstone, light-gray, fine to medium-grained, well-sorted, rounded, silica cement, very prominent laminations and cross-bedding, occasional-moderate stylolites.
13854.8-13855.3	Sandstone, light olive-gray with medium to dark-gray burrows, medium-grained, moderately sorted, rounded, silica cement, extensive burrows, moderate bioturbation, sulfur staining, friable.
13855.3-13859	Sandstone, medium to light-gray, medium-grained, well-sorted, well-rounded, silica cement, grading downward from slightly to extensively stylolitic, very prominent laminations and cross-bedding, occasional heavily bioturbated areas (<2 cm).

NDGS Well No. 3268
Amerada Petroleum Corporation, Scoria Unit #8
NESW, Sec. 10, T. 139 N., R. 101 W.
Billings County

Depth (feet)	Description
12605-12615.5	Sandstone, yellowish-gray to light greenish-gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, friable, moderately bioturbated and burrowed, occasional shale and siltstone layer (<10 cm), slight stylolites, occasional phosphate nodules (<.2 cm), occasional light gray quartz layer (<3 cm).
12615.5-12616.3	Clayshale, medium-dark gray, noncalcareous, clay matrix, shaley partings, fissile, sandstone lenses toward base.
12616.3-12617.8	Interbedded sandstone and quartzitic sandstone, white to light-green gray, fine-grained, well-sorted, well-rounded, silica cement, quartzitic sandstone is massive with faint laminations, areas of green sandstone, slightly bioturbated, clay stringers.
12617.8-12618.3	Clayshale, medium-dark gray, noncalcareous, clay matrix, shaley partings, fissile, sandstone lenses toward base.

Depth (feet)	Description
12618.3-12622	Sandstone, yellow-gray to light green-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, slight to moderate bioturbation, moderately burrowed, moderate amount of clay stringers, occasional phosphate nodules (<.7 cm).
12622-12622.3	Quartzitic sandstone, white, fine-grained, well-sorted, well-rounded, silica cement, massive.
12622.3-12623	Quartzitic sandstone, dusky red with medium-gray layers (<.5 cm), medium to coarse-grained, well-sorted, well-rounded, silica cement, massive, structureless.
12623-12624.5	Sandstone, light greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive to moderate bioturbation, moderately burrowed, extensive stylolites.
12624.5-12631	Interbedded sandstone and clayshale, white to light green-gray and greenish-gray to dark green-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, interbedded sandstone and shale at variable thicknesses, slight to moderate bioturbation, occasional to moderately burrowed, occasional stylolites, soft-sediment deformation, occasional phosphate nodules.
12631-12632	Limestone, light gray to medium-dark gray, medium to fine-grained, moderately to well-sorted, well-rounded, calcareous cement, moderate bioturbation, extensive stylolites, occasionally to moderately burrowed.

NDGS Well No. 6086
Amoco Prod. Co., Berent Selle #1
NENE, Sec. 7, T. 145 N., R. 94 W.
Dunn County

Depth (feet)	Description
14070-14074.5	Sandstone, very light gray to light gray, black matrix, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderate to extensive bioturbation, extensive burrows, moderate stylolites, occasional clay stringers, increasing clay downward.

Depth (feet)	Description
14074.5-14075	Clayshale and sandstone, light olive-gray and black, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, extensively bioturbated sandstone grading to clayshale with sandstone lenses (<.1 cm).
14075-14075.6	Sandstone, light olive-gray to light gray, medium to fine-grained, moderately-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and burrows, occasional stylolites, dirty.
14075.6-14076.3	Clayshale and sandstone, light olive-gray and black, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, extensively bioturbated sandstone grading to clayshale with sandstone lenses (<.1 cm).
14076.3-14078.2	Interbedded sandstone and clayshale, medium-light gray and black, medium to fine-grained, moderately-sorted, well-rounded, silica cement, noncalcareous, clay matrix, interbedded finely laminated black clayshale (<1 cm) and moderately bioturbated, burrowed, and stylolitic sandstone, burrowed throughout, abrupt contact with below.
14078.2-14079.5	Sandstone, white, pink-gray, yellowish-gray with greenish and grayish clay stringers, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, moderately bioturbated, occasional to moderately burrowed, extensive green and gray clay stringers and layers (<.2 cm), oxidized specks, occasional stylolites.
14079.5-14082.6	Sandstone, very light gray to light gray, black matrix, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderate to extensive bioturbation, extensive burrows, moderately stylolitic, occasional clay stringers, increasing clay downward, increasing bioturbation downward.
14082.6-14088.4	Sandstone, medium gray with black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated sandstone with clay matrix, increasing in clay downward, decreasing in sandstone downward, occasionally to moderately burrowed, occasional pyrite nodules (<.5 cm).

Depth (feet)	Description
14088.4-14089.6	Interbedded clayshale and quartzitic sandstone, very light gray to light gray with black, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix in areas, slight bioturbation, extensive burrows, occasional stylolites, massive quartzitic sandstone interbedded with black, finely-laminated clay layers (<1.3 cm), decrease in clay layers downward, abrupt contact with below.
14089.6-14092	Sandstone, white to light green-gray with greenish-gray clay stringers, medium to fine-grained, well-sorted, well-rounded, silica cement, slight to moderate bioturbation, moderately burrowed-decreasing downward, extensive clay stringers, oxidized specks.
14092-14093.4	Interbedded clayshale and sandstone, medium-gray to greenish-gray clay and yellowish-gray to light greenish-gray sandstone, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, slightly bioturbated, occasional to moderately burrowed, occasional stylolitic sandstone with clay stringers and layers (<1 cm), occasional pyrite specks and nodules (<.2 cm), occasional phosphate nodules (<.5 cm), oxidized specks.
14093.4-14095	Quartzitic sandstone, white to light-olive gray with medium-dark gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, massive quartzitic sandstone, moderate to extensive vertical and horizontal burrows, slightly bioturbated, glauconite, oxidized specks.
14095-14096.2	Interbedded clayshale and sandstone, medium-gray to greenish-gray clay and yellowish-gray to light greenish-gray sandstone, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, slightly bioturbated, occasional to moderately burrowed, occasional stylolitic sandstone with clay stringers and layers (<1 cm), occasional pyrite specks and nodules (<.2 cm), occasional phosphate nodules (<.5 cm), oxidized specks.
14096.2-14097.6	Quartzitic sandstone, white to light green-gray, medium to fine-grained, very well-sorted, well-rounded, silica cement, slight bioturbation, extensive burrows (vertical and horizontal), occasional stylolites.

Depth (feet)	Description
14097.6-14098	Quartzitic sandstone, white to light-gray, black matrix in areas, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, interbedded (20 cm) massive, faint laminations, occasional burrowed quartzitic sandstone and extensively bioturbated, moderately burrowed and stylolitic quartzitic sandstone, occasional black clay layers and stringers increasing downward.

NDGS Well No. 6264
Tom F. Marsh, Funston #1
NENE, Sec. 9, T. 139 N., R. 76 W.
Burleigh County

Depth (feet)	Description
6080-6083	Sandstone, light olive-gray to olive-gray, medium-grained, well-sorted, rounded, silica cement, massive, somewhat friable, structureless, porous.
6083-6085	Sandstone, light olive-gray to olive-gray, light gray filled burrows, medium-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation, slight to moderate burrows, rare stylolites, phosphate nodules (<.3 cm), rare clay stringers filling fractures.
6085-6087	Sandstone, light olive-gray to olive-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, somewhat friable, faint laminations and cross-bedding, occasional phosphate specks, porous.
6087-6088	Sandstone, light olive-gray to olive-gray, light gray filled burrows, medium-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation, slight to moderate burrows, rare stylolites, phosphate nodules (<.3 cm), rare clay stringers filling fractures.
6088-6089	Sandstone, light olive-gray to olive-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, somewhat friable, faint laminations and cross-bedding, occasional phosphate specks, porous.

Depth (feet)	Description
6089-6089.5	Sandstone, light olive-gray to olive-gray, light gray filled burrows, medium-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation, slight to moderate burrows, rare stylolites, phosphate nodules (<.3 cm), rare clay stringers filling fractures.
6089.5-6090	Clayshale, olive-green to dark olive-green, noncalcareous, clay matrix, finely laminated, soft-sediment deformation, shaley partings, fissile, slightly bioturbated, sandstone lenses and layers (<.5 cm) increasing downward.
6090-6090.8	Sandstone and clayshale, yellow-gray sandstone and greenish-gray clay, medium to fine-grained, moderately-sorted, rounded, silica cement, noncalcareous, clay matrix, moderately bioturbated and burrowed, sandstone with clay lenses and stringers grading downward to clayshale with sandstone lenses.
6090.8-6092	Clayshale, grayish-olive, noncalcareous, clay matrix, shaley partings, very fissile, disintegrates in water, finely laminated.
6092-6099	Quartzitic sandstone and clayshale, yellow-gray and greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, glauconitic, slight to moderate bioturbation, occasional burrows, clay stringers and layers increasing downward, occasional pyrite nodules (<.5 cm).

NDGS Well No. 6401
Shell Oil Co., Wisdahl #23-10
NESW, Sec. 10, T. 163 N., R. 87 W.
Renville County

Depth (feet)	Description
9244-9253	Clayshale, dark gray to gray-black, noncalcareous, clay matrix, occasional to moderate siltstone lenses (<.2 cm), occasional phosphate nodules (<.5 cm), occasional pyrite nodules (<.3 cm), bioturbated, soft sediment deformation, shaley partings, fissile.
9253-9258.6	Clayshale, light olive-gray to green-gray, noncalcareous, clay matrix, occasional siltstone lenses (<.2 cm), soft sediment deformation, shaley partings, pink material filling fractures, fissile.

Depth (feet)	Description
9258.6-9263	Clayshale, medium dark gray to dark gray, noncalcareous, clay matrix, occasional siltstone lenses (<.2 cm), soft sediment deformation, fissile, shaley partings, pink material filling fractures.
9263-9264	Clayshale, olive-gray to grayish black, noncalcareous, clay matrix, sandstone lenses and nodules (<2 cm), soft sediment deformation, pink-red inclusions (<1 cm).
9264-9265.3	Clayshale, gray-black, noncalcareous, clay matrix, finely laminated, shaley partings, fissile.
9265.3-9266	Sandstone, olive-gray, medium to fine-grained, moderately-sorted, rounded, silica cement, clay matrix in areas, large sandstone nodules (<3 cm) in black clay matrix, moderate stylolites.
9266-9268	Quartzitic sandstone, yellow-gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive to faintly laminated, occasional stylolites, moderately burrowed, clean sandstone.
9268-9268.8	Quartzitic sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, slight to moderate burrows, extensive stylolites, slight sulfur stained.
9268.8-9269	Quartzitic sandstone, yellow-gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive to faintly laminated, occasional stylolites, slightly to moderately burrowed.
9269-9269.7	Quartzitic sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, slight to moderate burrows, extensive stylolites, slightly sulfur stained.
9269.7-9271	Quartzitic sandstone, yellow-gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive to faintly laminated, occasional stylolites, slightly to moderately burrowed.
9271-9271.5	Brecciated sandstone (arkose), yellow-gray to light olive-gray and dusky-black breccia, very fine to .8 cm in size, very poorly-sorted, sub-angular to sub-rounded, silica cement, silica matrix, bioturbated quartzite, sandstone and orange feldspar subangular chunks, very fine to <.8 cm in matrix, pyrite filled.

Depth (feet)	Description
9281-9281.5	Sandstone, yellow-gray to light olive-gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, occasional to extensive stylolites, moderately bioturbated, occasional clay layers (<.4 cm), friable, moderately burrowed.
9281.5-9285.5	Interbedded sandstone and clayshale, light olive-gray to yellow-gray and grayish-black, medium to fine-grained, moderately to poorly-sorted, sub-rounded, silica cement, clay matrix in areas, 2 cm bands of all slightly bioturbated, moderately stylolitic and burrowed sandstone and black clayshale, finely laminated, soft-sediment deformation, orange-brown sandstone nodules and specks, increase in black clay towards base with sandstone lenses and thin layers (<.3 cm).
9285.5-9291.5	Clayshale, dark gray to gray-black, noncalcareous, clay matrix, finely laminated, shaley partings, fissile, occasional sandstone lenses and layers (<.7 cm).
9291.5-9293.5	Sandstone, greenish-gray, fine to very coarse-grained, very poorly-sorted, sub-rounded, silica cement, extensive glauconite, massive quartzitic grains and nodules (<.5 cm) in sandstone matrix, occasional clay lenses (<1 cm), occasional phosphate nodules (<.3 cm).

NDGS Well No. 6684
Shell Oil Co., Osterberg #21-2
NENW, Sec. 2, T. 161 N., R. 85 W.
Renville County

Depth (feet)	Description
9050-9056.4	Sandstone, white grading downward to light olive-gray, medium to fine-grained, well-sorted, moderately to well-rounded, silica cement, slight bioturbation, occasional stylolites, occasionally to moderately burrowed, faint laminations.
9056.4-9061.5	Sandstone, light gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate stylolites, slightly to moderately bioturbated, moderately burrowed, dusky-red sandstone inclusions (<.2 cm) increasing toward base.

Depth (feet)	Description
9061.5-9065	Sandstone, very light gray to medium gray, medium to fine-grained, moderately to poorly-sorted, rounded, silica cement, clay matrix, moderately to extensively bioturbated, moderate stylolites, occasional burrows, sulfur stained orange, sandstone lenses in clay matrix (<2 cm).
9065-9070.8	Sandstone, grayish-green grading downward to white, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, black clay stringers and layers throughout (<5 cm) every 15 cm, moderate sulfur staining, clay increasing downward.
9070.8-9072.8	Sandstone, white to light olive gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, dark green-gray clay matrix increasing downward, moderately to extensively bioturbated and burrowed, extensively stylolitic.
9072.8-9073.4	Sandstone, white to light gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, slightly bioturbated increasing downward to moderately bioturbated, slight burrows increasing downward to moderate burrows, moderate stylolites, oxidized burrows, dusky-red sandstone inclusions (<.2 cm).
9073.4-9077.5	Sandstone, white to yellowish-gray, black matrix, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, extensively bioturbated and stylolitic, moderately burrowed.
9077.5-9085.2	Quartzitic sandstone, medium light gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, occasional stylolites, moderately burrowed, occasional areas of extensive bioturbation (<5 cm), pyrite nodules (<2 cm), phosphate nodules (<1 cm), oxidized burrows, faint laminations and cross-bedding.
9085.2-9085.7	Sandstone, yellow-gray to light olive-gray, medium to coarse-grained, moderately to well-sorted, well-rounded, silica cement, slight to moderate bioturbation, extensively burrowed, extensive phosphate nodules and sulfur stains.

Depth (feet)	Description
9085.7-9087.2	Sandstone, light gray to yellow-gray, dark gray matrix, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated sandstone to clayshale with sandstone lenses in areas, extensive stylolites, sulfur stained, abrupt contact with bottom.
9087.2-9088.4	Sandstone, medium to light gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly bioturbated, moderate burrows, occasional stylolites, sulfur.
9088.4-9091	Sandstone, light gray to medium gray, medium to coarse-grained, very well-sorted, well-rounded, silica cement, massive, slight laminations, occasional stylolites, slightly bioturbated.
9091-9110	No Core.
9110-9111.5	Sandstone, very light gray to light olive-gray, medium to coarse-grained, very well-sorted, well-rounded, silica cement, clay matrix in areas, slightly to moderately bioturbated, moderately to extensively stylolitic, slightly to extensively burrowed, sulfur stained, dark greenish-gray clay filled burrows and stringers.
9111.5-9114.4	Sandstone, light gray to light olive-gray, medium to coarse-grained, very well-sorted, well-rounded, silica cement, moderate to extensive horizontal burrows, massive, sulfur stained.
9114.4-9114.8	Clayshale, dark olive-gray to dark gray, sandstone lenses, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, extensively bioturbated, sandstone lenses in clay matrix.
9114.8-9115	Sandstone, yellow-gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, sulfur stained, occasional phosphate nodules (<.5 cm).
9115-9117.3	Sandstone, light gray to light olive-gray, medium to fine-grained, moderately-sorted, moderately to well-rounded, silica cement, clay matrix in areas, moderately bioturbated, slightly to moderately stylolitic, moderately burrowed, extensive orange sulfur staining, pyrite nodules (<.5 cm).

Depth (feet)	Description
9117.3-9118	Siltstone to clayshale, dark olive-gray, silt size, well-sorted, well rounded, silica cement, clay matrix, sandstone lenses in silty clayshale, phosphate nodules (<3 cm) increasing downward, large quartz nodule (2 cm), green clay layer towards base.
9118-9119	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay stringers at top, massive, moderately burrowed, heavily stained oxidation.
9119-9119.5	Sandstone, white to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive horizontal burrows, sulfur stained.
9119.5-9124.3	Quartzitic sandstone, very light gray to white, medium to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolites, prominent low angle laminations and cross-bedding, rare horizontal burrows.
9124.3-9128	Sandstone, very light gray to white, medium to fine-grained, well-sorted, well-rounded, silica cement, faint low angle laminations, moderate to extensive clay stringers and layers (<.2 cm), dusky-red nodules (<.2 cm), occasional stylolites.
9128-9128.7	Clayshale, dark greenish-gray, noncalcareous, clay matrix, finely laminated layers, occasional white sandstone lenses.
9128.7-9129	Sandstone, white to pink-gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, soft sediment deformation in clay layers and stringers, slight bioturbation, dusky-red specks (<1 cm).
9129--9129.7	Clayshale, dark greenish-gray, noncalcareous, clay matrix, finely laminated layers, occasional white sandstone lenses.
9129.7-9130	Sandstone, white to pink-gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, soft sediment deformation in clay layers and stringers, slight bioturbation, dusky-red specks (<1 cm).
9130-9131.4	Clayshale, dark greenish-gray, noncalcareous, clay matrix, finely laminated layers, occasional white sandstone lenses, occasional dusky-red specked sandstone.

Depth (feet)	Description
9131.4-9132.3	Clayshale, medium light gray to brownish-gray, noncalcareous, finely layered with fine-grained sandstone, phosphate nodule.
9132.3-9132.8	Interbedded sandstone and shale, dark gray to dark olive-gray, medium to fine-grained, moderately to poorly-sorted, rounded, silica cement, clay matrix in areas, clay stringers and layers in dirty sandstone.
9132.8-9133.2	Brecciated sandstone, light gray to light olive-gray, medium to fine-grained, moderately to poorly-sorted, rounded, silica cement, sandstone clasts (<2.5 cm) in a sandstone matrix, oxidized.
9133.2-9134	Sandstone, medium gray to medium yellow-brown, medium to fine-grained, poorly-sorted, rounded, silica cement, massive, phosphate specks throughout, extensively mixed up, glauconite, gradational with below.
9134-9134.8	Sandstone, medium light gray to medium gray, medium to fine-grained, well-sorted, rounded, silica cement, sandstone nodules with the above for matrix, moderate to extensive stylolites grading downward, phosphate nodules, glauconite specks.
9134.8-9139.8	Sandstone, medium gray to medium dark gray, medium to fine-grained, well-sorted, rounded, silica cement, interbedded massive with faint laminations and moderately stylolitic, slight to moderately bioturbated, glauconite specks throughout, occasional pale-yellow to moderate reddish-orange sandstone clasts, finely laminated.
9139.8-9140.1	Sandstone, light gray matrix with medium gray sandstone clasts, medium to fine-grained, moderately to well-sorted, rounded, silica cement, occasional stylolites, slightly brecciated, glauconite, finely laminated in areas.
9140.1-9146.7	Sandstone, medium gray to medium dark gray, medium to fine-grained, well-sorted, rounded, silica cement, interbedded massive with faint laminations and moderately stylolitic, slightly to moderately bioturbated, glauconite specks throughout, occasional pale-yellow to moderate reddish-orange sandstone clasts, finely laminated.

Depth (feet)	Description
9146.7-9149	Sandstone, medium light gray to medium gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, large glauconite specks, massive, slightly to moderately bioturbated, moderately stylolitic.
9149-9159.8	Sandstone, medium gray to medium dark gray, medium to fine-grained, well-sorted, rounded, silica cement, interbedded massive with faint laminations and moderately stylolitic, slight to moderately bioturbated, glauconite specks throughout, occasional pale-yellow to moderate reddish-orange sandstone clasts, finely laminated.
9159.8-9160.6	Sandstone, light gray to light green, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, massive, extensive stylolites, glauconite rich.
9160.6-9170	No Core.
9170-9173	Sandstone, greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, very prominent laminations and cross-bedding, occasional stylolites.

NDGS Well No. 7020
Texas Pacific Oil Co., William Steckler #1
SENE, Sec. 5, T. 137 N., R. 88 W.
Grant County

Depth (feet)	Description
10282-10287	Clayshale, dark green-gray, noncalcareous, clay matrix, fossil fragments, occasional burrows, trilobite and brachiopod fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, disintegrates in water.
10287-10289.3	Clayshale, olive-gray to dark gray, noncalcareous, clay matrix, fossil fragments, occasional burrows, trilobite and brachiopod fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, disintegrates in water.

Depth (feet)	Description
10289.3-10295	Clayshale, dark green-gray grading downward to olive-gray to greenish-black, noncalcareous, clay matrix, fossil fragments, occasional burrows, trilobite and brachiopod fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, disintegrates in water.
10295-10302.5	Clayshale, greenish-gray, noncalcareous, clay matrix, fossil fragments, occasional burrows, trilobite and brachiopod fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, disintegrates in water.
10302.5-10305.8	Clayshale, dark greenish-gray, noncalcareous, clay matrix, fossil fragments, occasional burrows, trilobite and brachiopod fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, disintegrates in water.
10305.8-10306.5	Clayshale with sandstone lenses, greenish-gray to dark greenish-gray, white to yellow-gray, silt-sized, noncalcareous, silica cement, clay matrix, shaley partings, fissile, soft-sediment deformation, slightly bioturbated, occasional to extreme amounts of sandstone lenses (<.5 cm) in clay matrix.
10306.5-10308.2	Quartzitic sandstone, light gray to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly to moderately bioturbated sandstone, occasional clay layer (<2 cm), large pyrite nodules (<3 cm).
10308.2-10308.8	Quartzitic sandstone, very light gray to medium light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation in areas, occasional to moderate vertical burrows.
10308.8-10309.7	Sandstone, white to yellowish-gray, green clay, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive amount of clay stringers and layers, occasional phosphate nodules (<1 cm).
10309.7-10310.4	Quartzitic sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, occasionally to moderately burrowed, massive, occasional phosphate specks, faint laminations.

Depth (feet)	Description
10310.4-10311	Quartzitic sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, moderately burrowed, extensive amount of clay stringers.
10311-10311.3	Sandstone, light olive-gray to dark gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, moderately to heavily bioturbated, moderately burrowed, sandstone lenses in clay matrix.
10311.3-10311.8	Quartzitic sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation, occasionally to moderately burrowed, massive, occasional phosphate specks, faint laminations.
10311.8-10313.5	Interbedded quartzitic sandstone and clayshale, very light gray to yellow-gray and dark green-gray to gray-black, medium to fine-grained, well-sorted, rounded, silica cement, noncalcareous, clay matrix in areas, massive quartzitic sandstone with occasional clay layers towards top, grading down to clayshale with occasional sandstone layers grading into pure clayshale, shaley partings, fissile, slight bioturbation in areas, soft-sediment deformation.
10313.5-10314.3	Clayshale with sandstone lenses, olive-gray to dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clayshale with sandstone lenses toward top, grading down to pure clayshale, slightly to moderately bioturbated at top, soft-sediment deformation towards base, occasional burrows.
10314.3-10314.6	Sandstone, yellow-gray, medium-grained, well-sorted, well-rounded, silica cement, extensive amounts of phosphate nodules (<1 cm), occasional stylolites, slight bioturbation, occasional burrows.
10314.6-10315.6	Clayshale, dark green-gray with greenish-gray burrows, noncalcareous, silica cement, horizontal burrows, shaley partings, fissile, extensive amount of phosphate specks and nodules (<.2 cm), soft-sediment deformation.
10315.6-10316.4	Sandstone, yellowish-gray, medium to fine-grained, well-sorted, rounded, silica cement, slight bioturbation, occasional to moderate stylolites, moderately burrowed increasing downward.

Depth (feet)	Description
10316.4-10317	Sandstone, light gray, olive-gray clay matrix, medium to fine-grained, well-sorted, rounded, silica cement, noncalcareous, clay matrix, slightly to moderately bioturbated, occasional burrows, sandstone lenses and discontinuous layers in clay matrix.
10317-10318	Intermixed clayshale and sandstone, greenish-gray and yellow-gray, medium to fine-grained, well-sorted, rounded, silica cement, noncalcareous, clay matrix, sandstone lenses and nodules in clayshale, extensive amounts of phosphate specks and nodules (<.2 cm).

NDGS Well No. 7087
Shell Oil Co., Svangstu #24-18
SESW, Sec.18, T. 163 N., R. 95 W.
Divide County

Depth (feet)	Description
11150-11150.3	Sandstone, medium gray, black matrix, medium to fine-grained, moderately sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated, moderately to extensively stylolitic, occasional burrows, occasional clay lenses (<.4 cm).
11150.2-11150.9	Clayshale, grayish black, noncalcareous, clay matrix, finely laminated, shaley partings, occasional silt lenses, pyrite nodules and lenses (<.2 cm), abrupt contact with bottom.
11150.9-11151.6	Sandstone, light gray to light-olive gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately burrowed, extensive stylolites, occasional pyrite nodules (<.3 cm), areas of extensive concentric pyrite nodules (<.3 cm).
11151.6-11152	Quartzitic sandstone, very light-gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive burrows, slight to moderate bioturbation and stylolites.
11152-11153.4	Interbedded quartzitic sandstone and extensively bioturbated sandstone, medium-light gray to light-olive gray, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive stylolites, moderately burrowed, pyrite nodules (<3 cm).

Depth (feet)	Description
11153.4-11154	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive burrows, slight bioturbation, occasionally to moderately stylolitic.
11154-11155.5	Sandstone, light gray to medium gray, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, occasional clay layers and lenses (<.3 cm)
11155.5-11155.8	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive burrows, slight bioturbation, occasionally to moderately stylolitic.
11155.8-11155.9	Sandstone, light gray to medium gray, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, occasional clay layers and lenses (<.3 cm)
11155.9-11158	Quartzitic sandstone, very light gray to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, faint laminations and cross-bedding, moderately burrowed, occasional stylolites, occasional pyrite nodules (<.5 cm), oxidized specks.

NDGS Well No. 7146
Chevron U.S.A., Inc., Naaden #1
NWNE, Sec. 15, T. 136 N., R. 75 W.
Emmons County

Depth (feet)	Description
5260-5270	Clayshale, dark green-gray, noncalcareous, clay matrix, fossil fragments common-echinoderms, occasional brachiopods increasing downward, moderate horizontal burrows, shaley partings, fissile, soft-sediment deformation.
5270-5275	Clayshale, dark green-gray, noncalcareous, clay matrix, fossil fragments common, echinoderms, extreme amount of brachiopods, shaley partings, fissile, soft-sediment deformation.
5275-5281	Clayshale, dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, occasional brachiopods, shaley partings, fissile, soft-sediment deformation.

Depth (feet)	Description
5281-5283.5	Clayshale, dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, occasional brachiopods, extreme amount of horizontal worm burrows, shaley partings, fissile, soft-sediment deformation.
5283.5-5285.5	Clayshale, dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, occasional brachiopods, shaley partings, fissile, soft-sediment deformation, large pyrite nodule (<3 cm) towards base.
5285.5-5291.3	Clayshale, light olive to dusky yellow-green, noncalcareous, clay matrix, occasional fossil fragments, increasing downward, echinoderms towards base, occasional brachiopods, shaley partings, fissile, soft-sediment deformation.
5291.3-5292.5	Clayshale, dark green-gray, noncalcareous, clay matrix, occasional fossil fragments, occasional brachiopods, occasional horizontal burrows, echinoderms, shaley partings, fissile, soft-sediment deformation.
5292.5-5298	Clayshale, light olive to dusky yellow-gray, noncalcareous, clay matrix, occasional fossil fragments, occasional brachiopods, shaley partings, fissile, soft-sediment deformation.
5298-5299	Clayshale with sandstone lenses, dark green-gray to green-gray, yellow-gray sandstone lenses, medium to fine-grained, well-sorted, rounded, silica cement, noncalcareous, clay matrix, occasional fossil fragments, shaley partings, fissile, soft-sediment deformation, occasional sandstone lenses (<.8 cm) in a clay matrix.
5299-5301.8	Clayshale, grayish-olive, noncalcareous, clay matrix, occasional fossil fragments, echinoderms, horizontal worm burrows, shaley partings, fissile, soft-sediment deformation.
5301.8-5306.4	Clayshale with sandstone lenses, dark green-gray to green-gray, yellow-gray sandstone lenses, medium to fine-grained, well-sorted, rounded, silica cement, noncalcareous, clay matrix, occasional fossil fragments, shaley partings, fissile, soft-sediment deformation, occasional sandstone lenses (<.8 cm) in a clay matrix, increasing downward.

Depth (feet)	Description
5306.4-5307.7	Sandstone, light olive-gray to greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight bioturbation and occasional burrows increasing downward to moderate, occasional phosphate nodules and stylolites, pyrite nodules (<.5 cm).
5307.7-5325	No core.
5325-5330	Sandstone, yellow-gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, moderate bioturbation and burrows, occasional clay stringers and stylolites, occasional pyrite nodules.

NDGS Well No. 8088
Mobil Oil Corporation, William Bernhardt #1
NWNE, Sec. 28, T. 141 N., R. 93 W.
Stark County

Depth (feet)	Description
12386-12387.5	Quartzitic sandstone, yellow-gray to light olive-gray, medium-grained, very well-sorted, well-rounded, silica matrix, slight bioturbation, massive, occasionally to moderately burrowed, faint laminations, occasional stylolites, occasional phosphate and pyrite nodules (<.3 cm), clean sandstone.
12387.5-12387.6	Clayshale, black, noncalcareous, clay matrix, finely-laminated, mud cracks, soft sediment deformation.
12387.6-12390.3	Sandstone, pinkish-gray to yellowish-gray, medium to fine-grained, very well-sorted, well-rounded, silica cement, extensive bioturbation grading downward to slightly bioturbated, extensive burrowing grading downward to moderately burrowed, moderate stylolites grading downward to occasional stylolites, slightly sulfur stained, pyrite nodules (<.3 cm).
12390.3-12390.8	Quartzitic sandstone, very light gray to light olive-gray, medium to fine-grained, very well-sorted, well-rounded, silica cement, very prominent cross-stratification and high angle laminations, herring-bone cross-stratification, sulfur stained.

Depth (feet)	Description
12390.8-12392	Interbedded sandstone and clayshale, yellowish-gray and black, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, interbedded extensively bioturbated and stylolitic, moderately burrowed, clay stringers sandstone and black, finely-laminated, soft-sediment deformed clayshale, pyrite nodules (<2 cm).
12392-12395	No core.
12395-12397.5	Quartzitic sandstone, very light-gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, interbedded massive, faintly laminated, moderately burrowed quartzitic sandstone and moderately to extensively bioturbated, extensive gray clay stringers in quartzitic sandstone, moderately burrowed throughout, occasional black clay stringers and layers (<.2 cm).
12397.5-12398	Clayshale, medium-light gray to medium-dark gray, noncalcareous, clay matrix, slightly bioturbated, soft-sediment deformation, occasional sandstone lenses (<.2 cm), occasional stylolites.

NDGS Well No. 8090
Amerada Hess Corp., Grimestad #4-6
NESE, Sec. 6, T. 152 N., R. 95 W.
McKenzie County

Depth (feet)	Description
14470-14479	Sandstone, medium dark gray grading to light gray downward, medium- to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolite, very prominent cross-laminations and low angle laminations, slightly sulfur stained.
14479-14484	No Core.
14484-14484.5	Siltstone and clayshale, medium dark gray, silt-sized, well-sorted, well-rounded, silica cement, clay matrix, soft sediment deformation of clay, finely laminated, abrupt contact with below.
14484.5-14485.5	Clayshale, black, contains silty lenses which are well-sorted, well-rounded, silica cemented, and have a clay matrix, massive, shaley partings.

Depth (feet)	Description
14485.5-14488.3	Sandstone, medium gray and grayish-black, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, moderately stylolitic, grayish black sandstone clasts within medium gray sandstone, interbedded large sandstone clasts, small sandstone clasts, sandstone layers, heavily bioturbated sandstone and clayshale.
14488.3-14488.8	Sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, moderately bioturbated, moderately stylolitic.
14488.8-14492.3	Sandstone, medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated grading downward to grayish-black clay, sandstone lenses (<5 mm) incorporated in black-clay matrix, soft sediment deformation toward base.
14492.3-14493.5	Siltstone grading downward into a clayshale, light olive-green, very fine-grained to silt-sized, well-sorted, silica cement, non-calcareous, heavily bioturbated, siltstone lenses in a clay matrix toward the top with shaley partings toward the base.
14493.5-14496	Sandstone, greenish-gray with light olive-gray burrows, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive vertical burrows (5 mm-1 cm), moderately bioturbated at top becoming less downward.
14496-14497.3	Siltstone grading downward to a clayshale, dark greenish-gray, silt-sized, well-sorted, well-rounded, silica cement, non-calcareous, black phosphate specks, soft sediment deformation, siltstone lenses and thin layers towards the base.
14497.3-14500	Sandstone, greenish-gray with light olive-gray burrows, medium- to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately burrowed both vertically and horizontally, slight bioturbation.
14500-14503	Clayshale, dark grayish-green, non-calcareous, faint iron staining, soft sediment deformation, shaley partings.

Depth (feet)	Description
14503-14510.8	Interbedded sandstone and clayshale, dark greenish-gray clay with light gray sandstone lenses and layers, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, heavily spotted with phosphate specks and nodules (<5 mm), soft sediment deformation, increase in the amount of sand downward.
14510.8-14513	Interlaminated sandstone and silty-clayshale, greenish-gray and medium dark gray, fine- to medium-grained, moderately-sorted, rounded, silica cement, non-calcareous, clay matrix, soft sediment deformation in clay, occasional phosphate nodules, increase in clay content downward, shaley partings.
14513-14615	No Core.
14615-14617.3	Sandstone, dark gray, fine-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, faint sandstone lenses and layers in black clay matrix.
14617.3-14619	Sandstone, light gray, medium- to coarse-grained, moderately- to well-sorted, rounded to well-rounded, silica cement, very prominent cross-bedding, moderately burrowed (horizontally and vertically), slightly bioturbated.
14619-14623	Sandstone, medium dark gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated, very prominent burrows, sandstone layers and lenses in clay matrix, occasional calcite nodules (<1 cm).
14623-14639.5	Sandstone, dark gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, heavily bioturbated, soft sediment deformation in clay matrix, small calcite nodules (3 mm), becoming more clay-rich downward, glauconitic.
14639.5-14643	Sandstone, medium gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, sandstone nodules, lenses and layers (<7 cm) incorporated in the clay matrix, increase in black clay downward.

NDGS Well No. 8169
Gulf Oil Corp., Leviathan #1-21-1B
NENW, Sec. 21, T. 138 N., R. 92 W.
Stark County

Depth (feet)	Description
11336-11339	Clayshale, dark green-gray to olive-gray, noncalcareous, clay matrix, fossil fragments, shaley partings, fissile, soft-sediment deformation.
11339-11343.6	Clayshale with sandstone lenses, olive-gray to dark gray, noncalcareous, calcareous sandstone lenses, clay matrix, shaley partings, fissile, soft-sediment deformation, sandstone lenses (<1 cm) in clay matrix, decreasing in sandstone downwards.
11343.6-11343.8	Sandstone, grayish-green with olive-gray burrows, medium to fine-grained, moderately-sorted, rounded, noncalcareous, silica cement, clay matrix, moderately bioturbated, mixed up, moderately burrowed.
11343.8-11345.3	Clayshale grading downward to sandstone, grayish-black to white, medium to fine-grained, moderately to well-sorted, well-rounded, noncalcareous, silica cement, clay matrix, black clayshale with sandstone lenses grading down to a moderately bioturbated sandstone with clay stringers.
11345.3-11351.8	Intermixed sandstone and clayshale, green-gray with black phosphate specks, medium to fine-grained, well-sorted, well-rounded, noncalcareous, silica cement, clay matrix, intermixed sandstone and clayshale, slightly bioturbated, green clay stringers and layers throughout, extensive areas of black phosphate specks throughout, shaley partings and fissility increasing downward.
11351.8-11352.3	Clayshale, dark gray, silty, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, phosphate nodules (<.2 cm).
11352.3-11354.2	Clayshale with sandstone lenses, dark green-gray, greenish-gray sandstone, medium to fine-grained, well-sorted, well-rounded, noncalcareous, silica cement, clay matrix, shaley partings, fissile, soft-sediment deformation, slight bioturbation, occasional to moderate sandstone lenses (<.5 cm), phosphate nodules (<.2 cm).

Depth (feet)	Description
11354.2-11355.4	Clayshale, dark gray to greenish-gray, silty, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, phosphate nodules (<.2 cm).
11355.4-11356.6	Quartzitic sandstone, white to very light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, faint cross-laminations, slightly bioturbated, occasional burrows and stylolites, occasional phosphate nodules (<.3 cm).
11356.6-11363	Sandstone with clayshale layers, white to yellow-gray, greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix in areas, interbedded moderately bioturbated sandstone with green clayshale stringers and green fine-laminated clayshale, more bioturbation towards top becoming more layered downward, moderately burrowed and bioturbated, occasionaly stylolitic.
11363-11363.3	Clayshale, greenish-gray to dark green-gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation.
11563.3-11364	Sandstone, white to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation, occasional burrows and clay stringers and lenses (<.3 cm).
11364-11365.3	Clayshale, medium-dark gray to dark green-gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation.
11365.3-11366.8	Clayshale with sandstone lenses, grayish-black and yellow-gray sandstone, noncalcareous, silica cement, clay matrix, slight bioturbation in areas, shaley partings, fissile, interbedded clayshale and sandstone, sandstone layers and lenses (<1 cm).
11366.8-11369	Quartzitic sandstone, very light gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, faint laminations and cross-laminations, massive, occasional burrows and shale layers (<1 cm).
11369-11378	Sandstone, light olive-gray to dusky yellow, medium-grained, moderately to well-sorted, moderately to well-rounded, silica cement, finely laminated, slightly bioturbated.

190

NDGS Well No. 8468
Pennzoil Company & Depco, Beicegel Creek #27-42 BN
SENE, Sec. 27, T. 146 N., R. 101W.
McKenzie County

Depth (feet)	Description
13777-13777.1	Sandstone, light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, moderate stylolites, moderate burrows, occasional clay stringers.
13777.1-13777.2	Clayshale, medium gray, noncalcareous, clay matrix, slight bioturbation, soft sediment deformation, finely laminated.
13777.2-13780	Sandstone, light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, moderate to extensive stylolites, moderately burrowed, becoming more bioturbated - grading into below.
13780-13781.3	Sandstone, light-olive gray to brownish-gray, medium to fine-grained, moderate to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, extensive burrows, extensive stylolites.
13781.3-13783	Sandstone, light gray to medium gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, slightly bioturbated, moderately to extensively stylolitic, occasionally to moderately burrowed, occasional horizontal oxidized burrows.
13783-13784.2	Sandstone, light-olive gray to brownish-gray, medium to fine-grained, moderate to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, extensively burrowed, extensively stylolitic.
13784.2-13785.5	Sandstone, light gray to medium gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, moderately to extensively burrowed, moderately stylolitic, slight bioturbation, moderate sulfur staining, abrupt contact with below.
13785.5-13788.4	Sandy clayshale, medium-light gray to medium gray with light-olive gray sandstone lenses, medium to fine-grained sandstone, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, gray clay matrix with sandstone lenses (<1 cm) incorporated, moderate bioturbation, moderate burrows, black phosphate nodules (<2 cm).

Depth (feet)	Description
13788.4-13787.1	Sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly bioturbated, occasionally burrowed, moderate gray clay stringers and layers (<.2 cm), phosphate nodules (<1 cm).
13787.1-13789.6	Sandstone grading downward to clayshale, yellow-gray and medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix increasing downward, moderate stylolites and bioturbation grading downward to extensive, moderate burrows, extensive clay stringers and layers at top grading down to clayshale with sandstone lenses.
13789.6-13792.2	Sandstone, yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly bioturbated, occasionally burrowed, moderate gray clay stringers and layers (<.2 cm) grading down to less, phosphate nodules (<1 cm), friable toward base.
13792.2-13792.7	Quartzitic sandstone, medium-light gray quartzitic sandstone in yellow-gray sandstone matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate to extensive burrows, slightly bioturbated, oxidized specks.
13792.7-13795.4	Sandstone, light gray to yellow-gray, black clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately to extensively stylolitic and burrowed (increasing downward), oxidized towards base.
13795.4-13799.7	Sandstone, yellow-gray to light-olive gray, medium-grained, well-sorted, well-rounded, silica cement, slight bioturbation, moderate to extensive burrows, occasional stylolites, occasional to moderate gray clay stringers and layers (<.2 cm), oxidized surface, occasional phosphate nodules (<.4 cm).
13799.7-13801	Clayshale grading downward to sandstone, medium-light gray to green-gray and yellow-grain, fine-grained, moderately to well-sorted, rounded, silica cement, noncalcareous, clay matrix, extensive to moderate bioturbation and clay stringers - grading downward, moderate burrows toward base, clay layers and stringers with sandstone lenses towards top grading downward to sandstone with occasional clay stringers.

Depth (feet)	Description
13801-13802.3	Sandstone, yellow-gray to light-olive gray, medium-grained, well-sorted, well-rounded, silica cement, slight bioturbation, moderately to extensively burrowed, occasional stylolites, occasional to moderate gray clay stringers and layers (<.2 cm), oxidized surface, occasional phosphate nodules (<.4 cm).
13802.3-13802.6	Sandstone grading down to clayshale, yellow-gray to light-olive gray and medium-light gray to green-gray clay, fine-grained, moderately to well-sorted, rounded, silica cement, noncalcareous, clay matrix, above sandstone grading down to moderately bioturbated, burrowed clayshale, phosphate nodules.
13802.6-13803	Sandstone, yellow-gray, fine-grained, well-sorted, rounded, silica cement, slightly to moderately bioturbation, occasionally to moderately burrowed, occasional clay stringers and layers (<.2 cm).
13803-13805.8	Quartzitic sandstone, yellow-gray to light-olive gray, medium-grained, well-sorted, well-rounded, silica cement, slight bioturbation, extensive burrows, occasional stylolites, occasional to moderate gray clay stringers and layers (<.2 cm), oxidized surface, occasional phosphate nodules (<.4 cm).
13805.8-13807.5	Sandstone, light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, slight bioturbation, slightly to moderately burrowed, occasionally to moderatey stylolitic, occasional gray to black clay stringers and layers.
13807.5-13809	Quartzitic sandstone, yellow-gray to medium-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensively burrowed, slight bioturbation, occasional phosphate nodules, medium gray sandstone nodules (<4 cm) incorporated in quartzitic sandstone.

193
NDGS Well No. 8613
Exxon Corporation, Adolf Geist #1
SWSW, Sec. 20, T. 144 N., R. 93 W.
Dunn County

Depth (feet)	Description
13713-13714.3	Sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive clay stringers and nodules throughout (green), oxidized specks, phosphate nodules (<.2 cm).
13714.3-13715.5	Quartzitic sandstone, light green and medium-light gray burrows, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, massive, extensively burrowed, slightly bioturbated, occasional dark gray filled burrows, oxidized specks.
13715.5-13716.6	Sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive clay stringers and nodules throughout (green), oxidized specks, phosphate nodules (<.2 cm).
13716.6-13717	Clayshale and sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, sandstone lenses (<.2 cm) surrounded by a green clayshale, slight to moderate bioturbation, phosphate nodules (<.4 cm), increasing in sandstone downwards.
13717-13719	Sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive clay stringers and nodules throughout (green), oxidized specks, phosphate nodules (<.2 cm).
13719-13720	Quartzitic sandstone, white with dark-gray burrows, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, massive, moderately bioturbated, dark-green and white sandstone mixed, occasional green sandstone lenses, oxidized surface, extensive burrows.
13720-13720.4	Quartzitic sandstone, white, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, faint laminations, moderately burrowed.

Depth (feet)	Description
13720.4-13720.6	Sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive clay stringers and nodules throughout (green), oxidized specks, phosphate nodules (<.2 cm).
13720.6-13721.6	Quartzitic sandstone, white with dark-gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, faint laminations, slightly bioturbated in areas, occasionally to moderately burrowed.
13721.6-13722	Sandstone, greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated and burrowed, extensive clay stringers and nodules throughout (green), oxidized specks, phosphate nodules (<.2 cm).
13722-13722.2	Clayshale, medium to dark gray, silica cement, clay matrix, finely laminated, fissile.
13722.2-13723	Sandstone, very light gray to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, moderately burrowed, extensive amount of gray clay stringers, occasional gray-green clay layer (<1.5 cm), occasional massive quartzitic sandstone layer (<1.5 cm).
13723-13723.3	Clayshale, medium to dark gray, silica cement, clay matrix, finely laminated, fissile.
13723.3-13723.7	Sandstone, very light gray to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, moderately burrowed, extensive amount of gray clay stringers, occasional gray-green clay layer (<1.5 cm), occasional massive quartzitic sandstone layer (<1.5 cm).
13723.7-13724.5	Quartzitic sandstone, medium-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation, occasional stylolites.

Depth (feet)	Description
13724.5-13724.8	Sandstone, very light gray to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensivey bioturbated, moderately burrowed, extensive amount of gray clay stringers, occasional gray-green clay layer (<1.5 cm), occasional massive quartzitic sandstone layer (<1.5 cm).
13724.8-13728	Quartzitic sandstone, medium gray and very-light gray, medium-grained, well-sorted, well-rounded, silica cement, massive, faint laminations and cross-laminations, white quartzitic sandstone with medium-gray filled burrows.
13728-13728.8	Quartzitic sandstone, medium-gray and yellow-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, distinct laminations marked by red-gray and yellow-gray stratification sets.
13728.8-13729.6	Quartzitic sandstone, white to very-light gray, medium-grained, well-sorted, well-rounded, silica cement, occasional stylolites, very prominent cross-stratification and herringbone cross-stratification, very clean sandstone.
13729.6-13730.2	Sandstone, yellow-gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, slight to moderate bioturbation in areas, gray clay stringers and layers (<.4 cm) throughout, faint laminations, occasionally to moderately burrowed.
13730.2-13731	Quartzitic sandstone, white to light-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, prominent laminations, occasional stylolites, occasional pyrite nodules.
13731-31732	Quartzitic sandstone, white to yellow-gray, medium-grained, well-sorted, well-rounded, silica cement, slightly to moderately bioturbated, clay stringers, stylolites, slightly to moderately burrowed, oxidized.
13732-13732.7	Quartzitic sandstone, white to light-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, prominent laminations, occasional stylolites, occasional pyrite nodules.

Depth (feet)	Description
13732.7-13734	Sandstone, yellow-gray, black matrix, medium-grained, moderately to well-sorted, well-rounded, silica cement, noncalcareous, clay matrix increasing downward, extensive bioturbation, moderately to extensively burrowed, moderately stylolitic, clay stringers and layers increasing downward.
13734-13734.3	Quartzitic sandstone, white to light-gray, medium-grained, well-sorted, well-rounded, silica cement, massive, prominent laminations, occasional stylolites, occasional pyrite nodules.
13734.3-13735	Clayshale, dark gray to black, noncalcareous, clay matrix, fissile, slickenslides, occasional sandstone lenses (<.5 cm), pyrite specks.

NDGS Well No. 8663
Gulf Oil Corporation, Mormon Butte Fed. #2-25-2C
SENE, Sec. 25, T. 147 N., R. 98 W.
McKenzie County

Depth (feet)	Description
14504-14505.3	Sandstone, medium to light gray with black matrix, medium to fine-grained, well-sorted, sub-rounded, silica cement, clay matrix in areas, moderate bioturbation and stylolites, occasional burrows, sandstone lenses and layers (<2.5 cm).
14505.3-14505.8	Sandstone, medium gray, medium to fine-grained, well-sorted, sub-rounded, silica cement, slight bioturbation, moderately stylolitic, massive.
14505.8-14509	Sandstone, light gray to medium-light gray with black matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, sandstone lenses and layers in clay matrix (<.8 cm).
14509-14509.4	Sandstone, light olive gray, medium to fine-grained, well-sorted, rounded, silica cement, moderately bioturbated, moderately to extensively burrowed, gradation with below.
14509.4-14510	Quartzitic sandstone, light gray to dark gray, medium to fine-grained, well-sorted, rounded, silica cement, extensive bioturbation, moderately burrowed, extensive stylolites, oxidized specks.

Depth (feet)	Description
14510-14511.4	Sandstone, light greenish-gray with medium light gray clay stringers, medium to fine grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated and stylolitic, clay stringers and layers, moderately burrowed grading downward to extensive, oxidized specks.
14511.4-14512.4	Sandstone, light greenish-gray with medium light gray clay stringers, medium to fine grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation and stylolites, clay stringers and layers, extensively burrowed.
14512.4-14513.4	Sandstone, light green-gray with medium to light gray clay stringers and layers, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, clay stringers and layers (<1 cm), oxidized specks.
14513.4-14514	Sandstone, medium to dark-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate bioturbation, extensively stylolitic, moderately burrowed, clay stringers.
14514-14515.3	Sandstone, light olive-gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, extensive bioturbation and stylolites, few burrows, phosphate nodules (<.4 cm).
14515.3-14516.8	Clayshale, grayish-black, <silt size, clay cement, sandstone lenses in clay matrix (<.2 cm).
14516.8-14517.4	Sandstone, light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slight to moderate bioturbation, moderately stylolitic.
14517.4-14517.7	Sandstone, pinkish gray with green-gray clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, clay stringers and layers in sandstone.

Depth (feet)	Description
14517.7-14523.3	Interbedded extensively bioturbated sandstone and clayshale, light olive gray sandstone and grayish black clayshale, medium to fine grained sand, <silt size clay, well-sorted, well-rounded, silica cement, clay matrix, sandstone lenses in black clay matrix, clayshale contains sandstone lenses (<.2 cm), extensive stylolites and bioturbation.
14523.3-14524	Sandstone, light gray to light olive-gray with black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, sulfur stained, sandstone lenses (<1.5 cm) in clay matrix.
14524-14527.6	Sandstone, light olive-gray to light gray, pinkish-gray sandstone, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensive bioturbation and burrows, moderately stylolitic, clay stringers, slightly friable.
14527.6-14528.4	Quartzitic sandstone, light gray, greenish gray clay stringers, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated, extensively stylolitic, moderately burrowed, green clay stringers and layers (<.4 cm), sandstone lenses and layers (<1 cm), phosphate nodules (<.4 cm).
14528.4-14529	Quartzitic sandstone, very light gray to white, medium to fine-grained, well-sorted, well-rounded, silica cement, prominent low angle laminations, slightly to moderately stylolitic, burrowed, few phosphate nodules (<.3 cm).
14529-14531.8	Interbedded laminated quartzitic sandstone and moderately bioturbated sandstone, white to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate stylolites.
14531.8-14538.5	Quartzitic sandstone, greenish gray to pinkish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, slightly to extensively stylolitic, occasional to moderate clay stringers (green) and layers, occasional burrows and clay nodules (<.4 cm).

Depth (feet)	Description
14538.5-14539.7	Quartzitic sandstone, white to medium-dark gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive burrows, moderately bioturbated, oxidized specks.
14539.7-14543.2	Sandstone, greenish gray to light gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated, moderately stylolitic, clay stringers and layers throughout (<1.5 cm), pyrite nodules (<.7 cm).
14543.2-14548.6	Quartzitic sandstone, dark olive-gray to dark gray burrows, white massive, medium to fine-grained, well-sorted, well-rounded, silica cement, extensively burrowed (horizontal and vertical), moderate bioturbation.
14548.6-14549.8	Sandstone, light greenish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated, moderately to extensively stylolitic, burrowed, prominent clay stringers (green).
14549.8-14551.8	Interbedded clayshale and extensively bioturbated sandstone, light green-gray clayshale, dark green-gray sandstone, <silt size clayshale, medium to fine-grained sandstone, well-sorted, well-rounded, noncalcareous and silica cement, clay matrix, finely laminated clayshale and extensively bioturbated sandstone with green clay matrix.
14551.8-14552.9	Sandstone, light green-gray with dark green-gray matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately burrowed, green clay stringers, extensively stylolitic.
14552.9-14554	Interbedded clayshale and extensively bioturbated sandstone, light green-gray clayshale, dark green-gray sandstone, <silt size clayshale, medium to fine-grained sandstone, well-sorted, well-rounded, noncalcareous and silica cement, clay matrix, finely laminated clayshale and extensively bioturbated sandstone with green clay matrix.

Depth (feet)	Description
14554-14556.3	Sandstone, light green-gray to pink-gray, dark green-gray matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated, moderately burrowed, green clay stringers, sandstone lenses and layers (<1 cm) in clay matrix, gradational with below.
14556.3-14557.8	Clayshale, medium to dark gray, <silt size, noncalcareous, clay matrix, fissile, shale partings, finely laminated, soft sediment deformation, siltstone lenses (<.2 cm).
14557.8-14558.3	Sandstone, greenish-gray, dark green-gray clay stringers, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, moderately stylolitic and burrowed, clay stringers (<.2 cm).
14558.3-14559.8	Interbedded clayshale and extensively bioturbated sandstone, light green-gray clayshale, dark green-gray sandstone, <silt size clayshale, medium to fine-grained sandstone, well-sorted, well-rounded, noncalcareous and silica cement, clay matrix, finely laminated clayshale and extensively bioturbated sandstone with green clay matrix.
14559.8-14561.4	Sandstone, greenish-gray, dark green-gray clay stringers, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, moderate stylolites and burrows, clay stringers (<.2 cm), phosphate nodules (<1 cm) surrounded by pyrite (<1.5 cm).
14561.4-14563	Clayshale, grayish-black, <silt size, noncalcareous, clay matrix, finely laminated, lenses of green siltstone (<.2 cm), fissile, shaley partings.

NDGS Well No. 8707
Home Petroleum Corporation, Kjelshus #2
SENW, Sec. 25, T. 161 N., R. 95 W.
Divide County

Depth (feet)	Description
12689-12701.3	Clayshale with sandstone lenses, grayish black and light olive gray, silt to very fine-grained, well-sorted, noncalcareous, silica cement, clay matrix, extensive bioturbation, sandstone lenses (<.3 cm) in a black clay matrix, soft sediment deformation.
12701.3-12707	Clayshale, black, noncalcareous, shaley partings, soft sediment deformation, occasional siltstone lenses.
12707-12708	Clayshale, interbedded grayish-black and dark green-gray, noncalcareous, soft sediment deformation, shaley partings.
12708-12710	Clayshale, black, noncalcareous, shaley partings, soft sediment deformation, occasional siltstone lenses.
12710-12739	No Core.
12739-12739.8	Sandstone, medium light gray and medium dark gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, extensively burrowed, moderately bioturbated, occasional stylolites, sulfur stained.
12739.8-12744.3	Sandstone, medium light gray to medium dark gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, moderately burrowed, occasional stylolites, slight to moderate sulfur staining.
12744.3-12746.3	Sandstone, medium light gray to medium dark gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, clay matrix in areas, moderate bioturbation, extensively burrowed occasional stylolites, extensive sulfur staining.
12746.3-12747	Sandstone, medium light gray to medium dark gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, clay matrix in areas, moderately to extensively bioturbated, moderately burrowed, occasional stylolites, slight to moderate sulfur staining.

Depth (feet)	Description
12747-12749.5	Sandstone, medium light gray to medium dark gray, medium to fine-grained, moderately-sorted, sub-rounded, silica cement, clay matrix in areas, moderate bioturbation, extensively burrowed occasional stylolites, extensive sulfur staining.
12749.5-12753	Sandstone, white to medium light gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, extensive burrows, slightly to moderately bioturbated, occasional stylolites, extensive orange sulfur staining.
12753-12758	Sandstone, medium light gray with gray-black matrix, medium to fine-grained, moderately-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated and burrowed, occasional well developed vertical burrows (<10 cm).
12758-12760.5	Sandstone, very light gray to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated and stylolitic, slightly burrowed, sandstone lenses (<2 cm).
12760.5-12762	Sandstone, very light gray to light gray, black clay matrix, medium to fine-grained, clay matrix, extensive bioturbation, moderately burrowed, sandstone lenses (<.8 cm) in clay matrix.
12762-12768	Sandstone, light gray to light olive-gray in black matrix, medium to fine-grained, moderately-sorted, well-rounded, silica cement, clay matrix in areas, extensively burrowed (horizontal and vertical), moderately bioturbated, moderate sulfur staining, pyrite nodules (<3 cm).
12768-12769.6	Quartzitic sandstone, very light gray, medium to coarse-grained, well-sorted, well-rounded, silica cement, extensively burrowed, extensive sulfur stain.
12769.6-12773	Sandstone, very light gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, extensively burrowed, moderately bioturbated, occasional stylolites, extensively sulfur stained.
12773-12773.4	Quartzitic sandstone, light gray to medium light gray, medium-grained, well-sorted, well-rounded, silica cement, faint laminations, massive, slight bioturbation, occasional stylolites, clean sandstone.

Depth (feet)	Description
12773.4-12774.7	Sandstone, light gray to light olive-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, extensive stylolites, occasional burrows.
12774.7-12776.6	Sandstone, light gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, slightly to extensively bioturbated areas, moderately to extensively burrowed, moderate stylolites.
12776.6-12782.6	Sandstone, very light gray to medium light gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix in areas, slight to moderate bioturbation and burrows, moderate to extensive stylolites, moderately sulfur stained.
12782.6-12783	Quartzitic sandstone, very light gray to light gray, medium-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed, massive.
12783-12786	No Core.
12786-12787.6	Sandstone, very light gray to light gray, medium-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, occasional grading downward to moderately burrowed, extensive sulfur stains, occasional stylolites.
12787.6-12788.3	Quartzitic sandstone, very light gray to light gray, medium-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed, massive.
12788.3-12791.2	Quartzitic sandstone, very light gray to medium gray, medium-grained, well-sorted, well-rounded, silica cement, extensively burrowed, continuous vertical burrows (15 cm), extensively sulfur stained, gradational with below.
12791.2-12794	Sandstone, light gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately to extensively burrowed-vertical (<5 cm) and horizontal, moderate bioturbation and stylolites, gradational with above and below, moderate sulfur staining.

Depth (feet)	Description
12794-12798.3	Sandstone, medium light gray to medium gray, black clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, clay stringers and layers, occasionally to moderately burrowed.
12798.3-12797	Sandstone, medium light gray to medium gray, black clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, clay stringers and layers, occasionally to moderately burrowed, pale reddish-brown oxidized surface.
12797-12798.8	Sandstone, very light gray to light olive-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated, moderate to extensive stylolites, sandstone lenses (<3 cm) in clay matrix, occasionally to moderately burrowed, slight sulfur stain.
12798.8-12801.5	Quartzitic sandstone, light gray to medium light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, faint laminations, occasional stylolites, slight bioturbation.
12801.5-12802.8	Sandstone, light green to medium light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, slight bioturbation and burrows, slightly to moderately stylolitic, pyrite specks and nodules (<1 cm).
12802.8-12803.8	Quartzitic sandstone, medium light gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, faint laminations, occasional stylolites, slight bioturbation in areas.

NDGS Well No. 8709
Shell Oil Company, Burbank BIA #23-8
NESW, Sec. 8, T. 147 N., R. 93 W.
Dunn County

Depth (feet)	Description
14256-14256.4	Quartzitic sandstone, very light gray, dark olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, occasional burrows, occasional stylolites, gradational burrowed zone with below.

Depth (feet)	Description
14256.4-14257.2	Quartzitic sandstone, very light gray, dark olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, extensively burrowed, moderate stylolites, slight bioturbation.
14257.2-14259	Interbedded quartzitic sandstone, extensively bioturbated sandstone and clayshale, very light gray with black clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, sandstone lenses and layers (<5 cm) in clay matrix, finely laminated black clayshale layers (<2 cm), pyrite nodules (<1.5 cm), gradational with above.
14259-14273.5	Sandstone, light gray to medium light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated, moderately to extensively stylolituc and burrowed, occasional pyrite nodules, occasional clay layers (<1 cm) and sand layers (<1 cm), sandstone lenses in clay matrix (.2 cm - 2 cm).
14273.5-14274.2	Sandstone, light gray to light olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly to moderately bioturbated, moderate stylolites, occasionally to moderately burrowed.
14274.2-14275.5	Sandstone, light gray to green gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated sandstone, moderately burrowed, sandstone lenses in clay matrix (<.5 cm).
14275.5-14275.8	Clayshale, medium-dark gray with greenish gray sandstone lenses, <silt size, noncalcareous cement, bioturbated, sandstone lenses (<.3 cm) in clay matrix, occasional phosphate nodules (<.5 cm).
14275.8-14277.5	Sandstone, very light gray to light olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate to extensive bioturbation, extensively burrowed, gradational with below.
14277.5-14279.4	Sandstone, very light gray to light olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, extensively burrowed, green clay stringers, increasing gradationally downward.

Depth (feet)	Description
14279.4-14279.8	Sandstone to clayshale, green-gray to light gray, fine grained to silt size, well-sorted, well-rounded, silica and noncalcareous cement, clay matrix, sandstone lenses in green clay matrix, extensive bioturbation, burrows and stylolites.
14279.8-14288.8	Sandstone, light gray with black clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately to extensively burrowed, sandstone lenses (.2 cm - 1 cm) in clay matrix, occasional sand nodule (<3 cm) and sand layer (<1 cm), sulfur stained.
14288.8-14289.3	Quartzitic sandstone, very light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately burrowed, slightly to moderately stylolitic, slightly bioturbated, sulfur stained.
14289.3-14289.9	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensive stylolites, slightly bioturbated and burrowed.
14289.9-14290.6	Quartzitic sandstone, very light gray to medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed, slight bioturbation, occasional microstylolites.
14290.6-14291	Sandstone, very light gray to light green gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, clay stringers (green) and layers (<2 cm) in sandstone.
14291-14291.2	Quartzitic sandstone, very light gray and light olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately burrowed, slightly bioturbated, massive.
14291.2-14292.6	Sandstone, very light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, extensive stylolites, moderately burrowed, sandstone lenses in clay matrix, clay matrix grading downward from greenish gray to black.
14292.6-14292.9	Clayshale, dark-green gray to medium-dark gray, <silt size, noncalcareous, clay matrix, soft sediment deformation, sandstone lenses (<.2 cm) in clay matrix, phosphate nodules (<.3 cm).

Depth (feet)	Description
14292.9-14295	Sandstone, white to very light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, interbedded sandstone layers and lenses with extensively bioturbated sandstone, slight to extensive bioturbation, burrows and stylolites, slightly laminated in sandstone layers.

NDGS Well No. 9256
Gulf Oil Corporation, Hutchinson 1-14-3A
NWSE, Sec. 14, T. 139 N., R. 93 W.
Stark County

Depth (feet)	Description
11885-11895.3	Clayshale, dark gray to greenish-black, noncalcareous cement, clay matrix, shaley partings, fissile, finely laminated, slight soft-sediment deformation increasing downward, massive, occasional pyrite nodules (<.3 cm), fractures.
11895.3-11899.8	Clayshale, greenish-gray to dark green-gray, noncalcareous cement, clay matrix, occasional fossil fragments, shaley partings, fissile, finely laminated, soft-sediment deformation, pyritized fossil fragments and burrows, occasional calcareous sandstone lenses (<.2 cm) towards base.
11899.8-11904.3	Clayshale with sandstone lenses, dark gray to dark green-gray, noncalcareous clayshale, calcareous sandstone lenses, clay matrix, shaley partings, fissile, finely laminated, soft-sediment deformation, white sandstone lenses (<2 cm) in clay matrix, increasing in sandstone downwards, slight bioturbation and occassional horizontal burrows.
11904.3-11904.9	Sandstone, light olive-gray, medium-dark gray, yellowish-gray and olive-gray, medium to fine-grained, moderately to well-sorted, well-rounded, noncalcareous, small sandstone lenses calcareous, moderately bioturbated, moderately to extensively burrowed, mixed up, oxidized specks.
11904.9-11905.6	Sandstone, light olive-gray to light green-gray, medium to fine-grained, moderately to well-sorted, well-rounded, noncalcareous, moderately bioturbated and burrowed, friable.

Depth (feet)	Description
11905.6-11908.2	Sandstone grading downward to clayshale, light olive-gray to yellowish-gray and greenish-gray, medium to fine-grained, well-sorted, well-rounded, noncalcareous, calcareous filled burrows, clay matrix, extensive vertical well defined burrows, moderate bioturbation, sandstone with clay stringers and occasional lenses and layers grading downward to a clayshale with occasional sandstone lenses, phosphate specks and nodules (<2 cm), soft-sediment deformation.
11908.2-11911.4	Quartzitic sandstone, white to yellowish-gray, medium-gray filled burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, clay stringers (green), moderately burrowed, slight bioturbation, oxidized around burrows.
11911.4-11916.7	Interbedded clayshale and sandstone, light gray, dark greenish-gray to light green-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, slight bioturbation, soft-sediment deformation, clayshale with sandstone lenses (<.2 cm), grading down to sandstone with clay layers and stringers, occasional phosphate nodules (<.4 cm), fissile, shaley partings.
11916.7-11917.6	Quartzitic sandstone, white to yellowish-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed, slight bioturbation, faint laminations, phosphate specks, occasional clay layers (<.5 cm).
11917.6-11919.8	Sandstone, yellow-gray, green clay stringers and layers, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, moderately to extensiveyl bioturbated and burrowed, green clay stringers and layers increasing downward.
11919.8-11921.7	Clayshale, dark gray to dark green-gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, extensive amount of phosphate specks and nodules (<.3 cm).

Depth (feet)	Description
11921.7-11923	Interbedded clayshale and sandstone, light gray, dark greenish-gray to light green-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix, slight bioturbation, soft-sediment deformation, clayshale with sandstone lenses (<.2 cm), grading down to sandstone with clay layers and stringers, occasional phosphate nodules (<.4 cm), fissile, shaley partings.
11923-11924.2	Quartzitic sandstone, yellowish-gray to pinkish-gray, medium-dark gray burrows, medium-grained, very well-sorted, well-rounded, silica cement, extensively burrowed, slight bioturbation, massive.
11924.2-11926.3	Quartzitic sandstone, white to pale yellow-brown, medium-grained, very well-sorted, well-rounded, silica cement, extensively burrowed, slightly bioturbated, massive, occasional pyrite nodules (<.5 cm).
11926.3-11929	Sandstone, yellow-gray, greenish-gray clay matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderate to extensive bioturbation, moderately burrowed, clay stringers and lenses toward top, increasing downward to clay matrix and clayshale below.
11929-11930	Clayshale, dark-gray, noncalcareous, clay matrix, shaley partings, fissile, soft-sediment deformation, finely laminated.
11930-11932.4	Interbedded sandstone and clayshale (<5 cm beds), light olive-gray and dark-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix in areas, slightly to moderately bioturbated and burrowed.
11932.4-11934.5	Sandstone, yellow-gray to light olive-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated and burrowed, occasional stylolites.
11934.5-11937	Interbedded quartzitic sandstone and green clayshale, white and green-gray to dark green-gray, medium-grained, well-sorted, well-rounded, silica cement, noncalcareous, clay matrix in areas, interbedded massive, faintly laminated quartzitic sandstone and finely laminated soft-sediment deformation clayshale layers and clay stringers, grading downward to green clayshale.

NDGS Well No. 9407
Gulf Oil Corp., Hoff 1-32-4B
NESW, Sec. 32, T. 139 N., R. 92 W.
Stark County

Depth (feet)	Description
11576-11582.8	Clayshale, dark green-gray, noncalcareous, clay matrix, occasional fossil fragments and horizontal burrows, shaley partings, fissile, finely laminated, soft-sediment deformation.
11582.8-11585	Clayshale, brownish-black to olive-black, noncalcareous, clay matrix, occasional fossil fragments and horizontal burrows, shaley partings, fissile, finely laminated, soft-sediment deformation.
11585-11589.3	Clayshale, medium gray to greenish-gray, noncalcareous, clay matrix, occasional fossil fragments and horizontal burrows-increasing downward, shaley partings, fissile, finely laminated, soft-sediment deformation, interbedded greenish-gray clayshale and olive black clayshale (<10 cm).
11589.3-11592.6	Clayshale with sandstone lenses, olive gray to dark olive-gray, noncalcareous, clay matrix, massive to finely-laminated clayshale with occasional calcareous cement, well-sorted, well-rounded sandstone lenses (<2 cm).
11592.6-11594.8	Clayshale with sandstone lenses, olive gray to dark olive-gray, noncalcareous, clay matrix, clayshale with an abundant amount of white to olive gray sandstone lenses, bioturbated, burrowed.
11594.8-11597.5	Clayshale with sandstone lenses, olive gray to dark olive-gray, noncalcareous, clay matrix, massive to finely-laminated clayshale with occasional calcareous cement, well-sorted, well-rounded sandstone lenses (<2 cm), decreasing amount of sandstone downwards.
11597.5-11599.6	Interbedded sandstone and clayshale, greenish-gray to dark greenish-gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, noncalcareous, massive sandstone with occasional green clayshale beds and stringers (<1 cm), bioturbated, moderate to extensive amount of phosphate nodules (<.7 cm), layers (<.3 cm) and specks.

Depth (feet)	Description
11599.6-11602.8	Interbedded clayshale and sandstone, greenish-gray to dark green-gray and white to light-gray, medium to fine-grained, well-sorted, well-rounded, calcareous sandstone, noncalcareous clayshale, clay matrix, whitish-gray sandstone with clay stringers and layers grading downward to a clayshale with occasional sandstone lenses (<.1 cm), moderate bioturbation, soft-sediment deformation towards base.
11602.8-11604.9	Silty clayshale, dark green-gray to greenish-black, black specks, very fine silt-size, well-sorted, noncalcareous, clay matrix, clayshale with very small lenses of silt, bioturbated, extensive amount of black phosphate nodules and specks (<.2 cm), soft-sediment deformation, increasing in siltstone downwards, shaley partings.
11604.9-11605.6	Sandstone, yellowish-gray to light olive-gray, medium to fine-grained, medium to well-sorted, rounded, silica cement, clay matrix in areas, moderately bioturbated, occasional burrows, gray clay stringers prominent, occasional stylolites.
11605.6-11606.3	Silty clayshale, dark green-gray to greenish-black, black specks, very fine silt-size, well-sorted, noncalcareous, clay matrix, clayshale with very small lenses of silt, bioturbated, extensive amount of black phosphate nodules and specks (<.2 cm), soft-sediment deformation, increasing in siltstone downwards, shaley partings.
11606.3-11607.3	Sandstone, yellow-gray, green clay stringers, medium to fine-grained, moderately to well-sorted, silica cement, clay matrix in areas, moderately bioturbated and burrowed, occasional green clay layers (<.5 cm) and stringers, friable, burrows filled with medium dark-gray sandstone.
11607.3-11610	Sandstone, white to light-gray with greenish-gray clay layers and lenses, medium to fine-grained, moderately to well-sorted, well-rounded, calcareous sandstone, noncalcareous clayshale, clay matrix in areas, sandstone lenses, nodules and layers in a green clay matrix (<2 cm), extensive phosphate nodules (<.5 cm), moderately bioturbated, slightly to moderately burrowed.

Depth (feet)	Description
11610-11611	Clayshale with sandstone lenses, greenish-gray, white to light-gray sandstone lenses, medium to fine-grained, moderately to well-sorted, well-rounded, noncalcareous clayshale, calcareous sandstone, clay matrix, slightly bioturbated, phosphate nodules (<.3 cm), soft-sediment deformation, shaley partings.

NDGS Well No. 9413
Texaco Inc., Haugland #1
SESE, Sec. 16, T. 163 N., R. 98 W.
Divide County

Depth (feet)	Description
11255-11255.4	Quartzitic sandstone, light gray with medium-gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to extensively burrowed, massive, occasional stylolites.
11255.4-11256.9	Sandstone, light gray to light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensive horizontal stylolites and thin clay stringers, slight to moderate bioturbation, occasional well developed burrows.
11256.9-11261.3	Quartzitic sandstone, light-olive gray to yellow-gray, medium-grained, very well-sorted, silica cement, massive, faint laminations, occasional stylolites - increasing downward, slightly bioturbated in areas, occasional burrows.
11261.3-11263	Quartzitic sandstone, light-olive gray to yellow-gray, medium-grained, very well-sorted, silica cement, finely laminated, extensive stylolites, occasional burrows, slightly bioturbated.
11263-11267.3	Quartzitic sandstone, light-olive gray to yellow-gray, medium-grained, very well-sorted, silica cement, finely laminated grading downward to massive, slight bioturbation grading downward to slight to moderate bioturbation, occasionally to moderately stylolitic, few burrows toward base, phosphate specks increasing downward, occasional pyrite nodules (<.5 cm) increasing downward.

Depth (feet)	Description
11267.3-11268.8	Quartzitic sandstone, light-olive gray to yellow-gray, medium-grained, very well-sorted, silica cement, moderate to extensive bioturbation, extensive stylolites, moderately burrowed, pyrite nodules and specks (<1 cm).
11268.8-11269	Clayshale, grayish black, noncalcareous, clay matrix, finely laminated with light olive gray sandstone lenses at top and base (<.4 cm).
11269-11270	Sandstone, light olive gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, extensively bioturbated and stylolitic, occasional small burrows, occasional clay stringers and thin layers (<.2 cm).
11270-11273.2	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, moderately grading downward to slightly bioturbated, occasionally to moderately stylolitic, moderately burrowed, pyrite and phosphate nodules (<2 cm) and specks.
11273.2-11273.9	Clayshale, black, noncalcareous, clay matrix, occasional sandstone filled burrows towards top, finely laminated, areas of sandstone lenses (<2 cm), shaley partings.
11273.9-11276.6	Sandstone, white to light-olive gray, medium to fine-grained, moderately to well-sorted, sub-rounded, silica cement, clay matrix in areas, moderately bioturbated, moderate to extensive stylolites, occasionally to moderately burrowed, occasional pyrite nodules (<1 cm) towards the top.
11276.6-11277.4	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive stylolites, clay stringers and layers (<.3 cm), moderate bioturbation and burrows, occasional pyrite nodules (<1 cm).
11277.4-11281.6	Clayshale, gray black with light olive gray sandstone lenses, noncalcareous, clay matrix, finely laminated black clayshale with an occasional to moderate amount of sandstone lenses (<.6 cm), slight to moderate bioturbation.

Depth (feet)	Description
11281.6-11282	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive stylolites, clay stringers and layers (<.3 cm), moderately bioturbated and burrowed, occasional pyrite nodules (<1 cm).
11282-11283.1	Clayshale, gray black with light olive gray sandstone lenses, noncalcareous, clay matrix, finely laminated black clayshale with an occasional to moderate amount of sandstone lenses (<.6 cm), slight to moderate bioturbation, areas of extreme pyrite nodules (<.2 cm).
11283.1-11283.8	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix in areas, slight bioturbation, extensive stylolites, occasional burrows and clay lenses (<.3 cm) and stringers.
11283.8-11285.3	Clayshale, black, noncalcareous, clay matrix, sandstone lenses from <.1 cm to 2 cm in a black clay matrix, moderate bioturbation.
11285.3-11286.7	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive stylolites, moderate bioturbation and horizontal burrows, black clay stringers.
11286.7-11288.2	Clayshale, dark-olive gray to black, noncalcareous, clay matrix, moderate bioturbation, moderate sandstone lenses (<.1 cm), soft sediment deformation, gradational.
11288.2-11289	Interbedded laminated clayshale and sandstone, black and light-olive gray, medium-grained, moderately sorted, rounded, silica cement, noncalcareous, clay matrix, thinly laminated sandstone and clayshale with occasional sandstone lenses, pyrite nodules (<1 cm), moderate bioturbation, soft sediment deformation.
11289-11291.2	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive stylolites, moderate bioturbation and horizontal burrows, black clay stringers.
11291.2-11292.2	Clayshale, dark-olive gray to black, noncalcareous, clay matrix, moderate bioturbation, moderate sandstone lenses (<.1 cm), soft sediment deformation, gradational.

Depth (feet)	Description
11292.2-11292.9	Sandstone, light-olive gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, clay matrix, extensive stylolites, moderate bioturbation and horizontal burrows, black clay stringers, extensive bioturbation, increase in clay downward into clayshale with sandstone lenses.
11292.9-11296.4	Sandstone, very light-white to medium-light gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, extensive stylolites, occasional burrows.
11296.4-11296.7	Quartzitic sandstone, white to light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive burrows, slight to moderate bioturbation, moderate stylolites.
11296.7-11298.3	Sandstone, very light-white to medium-light gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, moderate to extensive bioturbation, extensive stylolites, occasional burrows.
11298.3-11298.6	Clayshale, black, noncalcareous, clay, extensively bioturbated, sandstone lenses (<.3 cm) in black clay matrix.
11298.6-11300.3	Sandstone, light-olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, slightly bioturbated, moderately stylolitic and burrowed.
11300.3-11302.8	Clayshale, brownish-black, well-sorted, noncalcareous, clay matrix, massive, thinly laminated.
11302.8-11307.1	Clayshale with sandstone lenses, brownish-black to black, medium to fine-grained sandstone lenses, well-sorted, well-rounded, noncalcareous, silica cement, clay matrix, sandstone lenses and nodules, moderate bioturbation.
11307.1-11310	Quartzitic sandstone, very light-gray with medium-gray burrows, medium to coarse-grained, very well-sorted, well-rounded, silica cement, moderate to extensive burrows, slight to moderate bioturbation, occasional stylolites, massive in areas, clean.

NDGS Well No. 9622
Texaco Inc., Arnold Hagen State #1
NWNW, Sec. 10, T. 163 N., R. 98 W.
Divide County

Depth (feet)	Description
11168-11169.6	Quartzitic sandstone, very light gray to light gray, medium-grained, well-sorted, well-rounded, silica cement, massive, faint laminations and cross-bedding, occasional stylolites, occasional burrows (gray), slight bioturbation.
11169.6-11170	Sandstone, light gray to light-olive gray, medium-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, clay layers and stringers (<.2 cm), occasional burrows, slight sulfur stain.
11170-11172.2	Sandstone, light gray to medium-dark gray, medium-grained, moderately to well-sorted, well-rounded, silica cement, moderately bioturbated, extensively stylolitic, occasionally to moderately burrowed, extensive amounts of pyrite nodules (<1.5 cm), sulfur stained orange, phosphate nodules (<.8 cm).
11172.2-11172.8	Sandstone, very light gray to yellow-gray, medium to fine-grained, moderately sorted, moderately to well-rounded, silica cement, extensive vertical burrows, slight bioturbation, extensive sulfur staining (orange), friable.
11172.8-11173.4	Sandstone, light gray to medium-dark gray, medium-grained, moderately to well-sorted, well-rounded, silica cement, moderately bioturbated, extensively stylolitic, occasionally to moderately burrowed, extensive amounts of pyrite nodules (<1.5 cm), sulfur stained orange, phosphate nodules (<.8 cm).
11173.4-11177.9	Sandstone, light gray to light-olive gray, medium to fine-grained, moderately sorted, moderately to well-rounded, silica cement, extensively burrowed, slight to moderate bioturbation, occasional stylolites, pyrite and phosphate nodules, friable, sulfur stained orange.
11177.9-11180	Sandstone, light gray to medium-dark gray, medium to fine-grained, moderately-sorted, moderately to well-rounded, silica cement, clay matrix, extensively burrowed, prominent vertical burrows, moderately stylolitic, extensive pyritized nodules(<1 cm).

Depth (feet)	Description
11180-11180.7	Sandstone, very light gray to light gray, medium-dark gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive horizontal and vertical burrows, slight to moderate bioturbation, sulfur stained orange.
11180.7-11181.3	Sandstone, light gray, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderate burrows, sulfur stained.
11181.3-11182.3	Sandstone, white to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive vertical burrows (<1.5 cm, medium to light gray), slight bioturbation.
11182.3-11183	Sandstone, very light gray to light gray, medium-dark gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive horizontal and vertical burrows, slight to moderate bioturbation, sulfur stained orange.
11183-11184.6	Sandstone, white to yellow-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive vertical burrows (<1.5 cm, medium to light gray), slight bioturbation.
11184.6-11188	Sandstone, light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderately bioturbated, extensive burrows, moderately to extensively stylolitic, orange stained.
11188-11191.6	Quartzitic sandstone, white to yellow-gray, medium-grained, well-sorted, very well-rounded, silica cement, massive, extensive vertical burrows, slight bioturbation.
11191.6-11192.1	Sandstone, white to light-olive gray, heavily stained orange, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, moderate bioturbation, moderately to extensively burrowed.
11192.1-11192.5	Sandstone, white to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, occasional burrows, extensive stylolites, pyrite nodules (<.8 cm), extensive orange staining.

Depth (feet)	Description
11192.5-11194.5	Sandstone, light olive gray to medium-light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensively burrowed, slight to moderate bioturbation, slightly stylolitic, occasional pyrite nodules (<.8 cm), orange stained.
11194.5-11195	Sandstone, white to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, occasional burrows, extensive stylolites, pyrite nodules (<.8 cm), extensive orange staining.
11195-11195.7	Sandstone, light olive gray to medium-light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, extensively burrowed, slight to moderate bioturbation, slight stylolites, occasional pyrite nodules (<.8 cm), orange staining.
11195.7-11196.8	Sandstone, white to light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate bioturbation, occasional burrows, extensive stylolites, pyrite nodules (<.8 cm), extensive orange staining.
11196.8-11206	Quartzitic sandstone, light gray with medium-light gray to light-olive gray burrows, medium to fine-grained, well-sorted, well-rounded, silica cement, massive with occasional areas of slight to moderate bioturbation, extensively burrowed (<20 cm), extensive orange stained.
11206-11206.7	Sandstone, light gray to dark-greenish gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderate to extensive bioturbation, moderately burrowed, gradational with below.
11206.7-11208.8	Sandstone, greenish-gray to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, extensive vertical burrows, slight bioturbation, pyritized nodule and clay lenses toward base.
11208.8-11210	Sandstone, light gray to dark gray, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately burrowed, moderately stylolitic, extensive pyrite nodules (<.7 cm).

Depth (feet)	Description
11210-11212.4	Sandstone, medium-light gray to medium gray, black clay matrix, medium to fine-grained, moderately sorted, rounded, silica cement, clay matrix in areas, extensively burrowed, moderately bioturbated, moderate stylolites, occasional sandstone lenses (<4 cm), occasional pyrite nodules (<1 cm), sulfur stained.
11212.4-11215.4	Quartzitic sandstone, medium gray to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, interbedded massive quartzitic sandstone with <6 cm faint laminations and extensively burrowed, slightly to moderately bioturbated and moderately stylolitic quartzitic sandstone, sulfur stained, phosphate specks and nodules throughout, occasional pyrite nodules, increase burrowing downward.
11215.4-11216	Quartzitic sandstone, medium-light gray to medium gray, medium-grained, very well-sorted, well-rounded, silica cement, faint laminations, rare stylolites, massive, very clean.

NDGS Well No. 12589
Amerada Hess Corp., Mckeen #30-3
NESW, Sec. 30, T. 153 N., R. 94 W.
McKenzie County

Depth (feet)	Description
14352-14357.8	Sandstone, light gray, medium- to fine-grained, well-sorted, rounded, silica cement, moderately stylolitic spaced approximately every 15-20 cm, prominent cross-bedding and laminations, areas of minor bioturbation, sulfur stained, pyrite filled fractures towards the base.
14357.8-14358.8	Sandstone, medium gray, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated, sandstone lenses and nodules intermixed with black clay matrix, phosphate specks, sulfur stained.
14358.5-14363.1	Sandstone, light gray, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, heavily bioturbated, oxidized areas, abundant pyrite specks and nodules (<1 cm), occasionally well defined burrows, sandstone lenses and layers becoming larger downward in clay matrix, sulfur stained.

Depth (feet)	Description
14363.1-14370	Sandstone, medium gray, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, interbedded heavily bioturbated sandstone and laminated and cross-bedded sandstone (.5-6 cm), abrupt contact with below.
14370-14370.8	Sandstone, medium gray, medium- to fine-grained, well-sorted, rounded, silica cement, prominent cross-laminations and low angle laminations, occasional stylolites, abrupt contact with below.
14370.8-14378.3	Sandstone, medium gray, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, heavily bioturbated, occasional vertical stylolites, sandstone lenses (<1 cm) incorporated in clay matrix.
14378.3-14384.6	Sandstone, medium gray, medium- to fine-grained, well-sorted, rounded, silica cement, clay matrix, interbedded sandstone layers and nodules (1-3.5 cm), heavily bioturbated sandstone, and clayshale with 3 mm sandstone lenses.
14384.6-14384.8	Sandstone, light gray, medium- to fine-grained, well-sorted, well-rounded to rounded, silica cement, very prominent low-angle laminations, occasional stylolites.
14384.8-14388.3	Sandstone, light to medium gray, medium- to fine-grained, well-sorted, well-rounded to rounded, silica cement, clay matrix, extensive bioturbation, extensively stylolitic sandstone at top grading downward into bioturbated sandstone into extensively bioturbated sandstone to clay matrix with <5 mm sandstone lenses, clay (black) content increasing downward, abrupt contact with below.
14388.3-14391.7	Sandstone, medium to dark gray, medium- to fine-grained, medium-sorted, rounded to sub-rounded, silica cement, moderate amount of stylolites, faint laminations, rarely phosphate nodules, sulfur stained, dirty sandstone.
14391.7-14402	Sandstone, alternating (approximately every foot) medium dark gray, medium light gray, and light gray, medium- to fine-grained, medium- to well-sorted, sub-angular to subrounded, silica cement, stylolites, faint laminations and cross-bedded, alternating colors approximately every foot, light colors show laminations better.

Depth (feet)	Description
14402-14405.6	Sandstone, light gray grading downward to medium gray, medium- to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolites, very prominent cross-bedding and laminations (trough and tabular), sulfur stained.

NDGS Well No. 12699
Conoco Inc., Schultz 8 #3
SWNW, Sec. 8, T. 148 N., R. 100 W.
McKenzie County

Depth (feet)	Description
14325-14340.3	Clayshale, black, <silt size, well-sorted, non-calcareous cement, clay matrix, finely laminated shale, fissile, soft sediment deformation, occasional pyrite nodules (<.8 cm), linear features, filled in fractures, specks.
143402-14351.8	Clayshale, finely laminated shale, interbedded, medium to dark gray and black, <silt size, well-sorted, noncalcareous cement, clay matrix, soft sediment deformation, occasional pyrite nodules and specks, large pyrite nodule (3 cm x 5 cm), fissile, gradational with below.
144351.8-14352.4	Interbedded sandstone and clays, light olive gray to very light gray sandstone, black clay, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbated sandstone to pure clayshale, moderate stylolites, large pyrite nodules toward top (.5 cm to 4 cm), gradational with above and below.
14352.4-14353.8	Sandstone, medium to dark gray with black clay matrix, medium to fine-grained, moderately to well-sorted, well-rounded, silica cement, clay matrix, bioturbated sandstone, sandstone lenses and layers in clay matrix, burrowed, pyrite nodules and fractures, oxidized specks, gradational with above.
14353.8-14356.5	Quartzitic sandstone, medium gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, moderate stylolites, moderately stylolitic, moderately bioturbated, slightly burrowed-increasing downward, oxidized specks, gradational with below.

Depth (feet)	Description
14356.5-14358.4	Sandstone, medium gray and black matrix, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation, moderately to extensively burrowed, extensive stylolites, oxidized at base, sandstone lenses (<1 cm) in clay matrix.
14358.4-14359.8	Sandstone, very light gray to medium dark gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, slightly to extensively bioturbated , grading downward from slightly to extensively stylolitic, sulfur stained, sandstone lenses (<1.5 cm) in clay matrix.
14359.8-14364.2	Sandstone, very light gray to yellow gray, medium-grained, well-sorted, well-rounded, silica cement, moderately bioturbated, moderately to extensively stylolitic, moderate burrows toward base, medium light gray clay stringers and layers (<.5 cm), sulfur stained, glauconite, gradational with below.
14364.2-14367.2	Sandstone, light gray with black clay matrix, medium-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately bioturbated, extensive stylolites, moderately burrowed, sandstone lenses and layers (<2 cm).
14367.2-14369	Sandstone, light gray with black clay matrix, medium-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderate burrows, sandstone lenses (<.5 cm) in clay matrix, sulfur stained.
14369-14373.3	Sandstone, light gray with black clay matrix, medium-grained, well-sorted, rounded, silica cement, clay matrix, moderately to extensively bioturbated and stylolitic, moderately burrowed, sandstone lenses and nodules (<3 cm) in clay matrix.
14373.3-14375	Sandstone, yellow-gray to light olive gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate to extensive bioturbation, pyrite nodules (<.6 cm), slightly burrowed, friable, oxidized specks.

Depth (feet)	Description
14375-14381.8	Sandstone, light gray to light olive gray with medium light gray clay layers, medium to fine-grained, well-rounded, rounded, silica cement, clay matrix in areas, extensive stylolites, clay stringers and layers (<2 cm), moderate to extensive bioturbation, moderately burrowed, phosphate nodules (<.5 cm), oxidized specks, pyrite nodules (<.2 cm).
14381.8-14382.4	Clayshale, medium-light gray to greenish gray, <silt size, noncalcareous, clay matrix, phosphate nodules (<.5 cm), soft sediment deformation, fissile, shaley partings, stylolitic transition with below.
14382.4-14385.4	Sandstone, light gray with dark gray clay matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, occasional clay layers (<3 cm), sandstone layers and lenses (.2 cm-2.5 cm), moderate to extensive bioturbation, extensive stylolites, slightly burrowed, phosphate nodules (<.5 cm).
14385.4-14386.7	Sandstone, yellow gray to light gray, medium to fine-grained, well-sorted, rounded, silica cement, moderate bioturbation, extensive stylolites, moderately burrowed, oxidized specks.

NDGS Well No. 12726
Texaco Inc., Gov't. T. G. Dorough #9
NESW, Sec. 8, T. 151 N., R. 95 W.
McKenzie County

Depth (feet)	Description
14660-14663.1	Sandstone, yellow-gray with medium gray clay stringers, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, moderate bioturbation, extensive stylolites, slightly burrowed, occasional clay layers (<.5 cm), oxidizing specks, extensive clay stringers, gradational with below.
14663.1-14664	Sandstone, light olive gray to dark gray, medium to fine-grained, moderately to well-sorted, rounded, silica cement, extensive bioturbation, occasional stylolites, occasional burrows.

Depth (feet)	Description
14664-14666.7	Sandstone, very light gray with black clay matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbated, extensive stylolites, moderately burrowed, sandstone lenses and layers (<2 cm) in clay matrix.
14666.7-14668.2	Sandstone, very light gray with black matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix in areas, slight to moderate bioturbation, slight stylolites, extensively burrowed, gradational to below.
14668.2-14673.6	Sandstone, light gray with black matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensively bioturbated and burrowed, moderate stylolites, sandstone lenses and layers (<1 cm) in clay matrix.
14673.6-14674.1	Sandstone and clayshale, light gray with black clay stringers, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, extensive bioturbation.
14674.1-14687.5	Sandstone, medium to light gray with black clay matrix, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, interbedded, moderate to extensive bioturbation, burrows, and stylolites, sandstone lenses and layers (.1-2 cm) in clay matrix.
14687.5-14687.8	Clayshale, dark gray to gray black, <silt in size, noncalcareous, clay matrix, occasional sandstone lenses (<.1 cm).
14687.8-14688.6	Sandstone, medium gray, medium to fine-grained, well-sorted, rounded, silica cement, clay matrix, moderate to extensive bioturbation, extensive burrows, moderately stylolitic.

NDGS Well No. 12971
Amerada Hess Corp., Beaver Lodge-Devonian Unit #I-313A
NWSW, Sec. 20, T. 156 N., R. 95 W.
Williams County

Depth (feet)	Description
14014-14014.2	Quartzitic sandstone, light gray with medium-dark gray burrows, medium to fine-grained, very well-sorted, rounded, silica cement, faint laminations, slightly burrowed, occasional stylolites, oxidized specks, abrupt contact with below.

Depth (feet)	Description
14014.2-14015.4	Sandstone, light gray, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensive bioturbation and stylolites, moderately burrowed, sandstone lenses and layers (<1.5 cm) in clay matrix, gradational with below.
14015.4-14015.9	Clayshale, grayish-black, light olive green sandstone lenses, <silt size, well-sorted, noncalcareous, clay matrix, sandstone lenses (<.2 cm) in clay matrix, extensive bioturbation.
14015.9-14020.6	Sandstone, light gray to light olive green, black matrix, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, extensively bioturbated, moderately to extensively stylolitic and burrowed, occasional clay layers (<2 cm).
14020.6-14020.9	Sandstone, medium-light gray, medium to fine-grained, well-sorted, rounded, silica cement, moderately stylolitic, occasional burrows and black clay layers (<.5 cm), faint laminations.
14020.9-14021.4	Sandstone, medium to light-gray, medium to fine-grained, well-sorted, well-rounded, silica cement, clay matrix, moderately to extensively bioturbated, moderately burrowed, extensive stylolites, sandstone lenses and layers (<1.5 cm) in clay matrix, bioturbated and clean contact with below.
14021.4-14022.4	Sandstone, medium gray, medium to fine-grained, well-sorted, rounded, silica cement, well defined low angle laminations, occasional phosphate nodules (<.8 cm), sulfur stained.
14022.4-14026.6	Quartzitic sandstone, medium-dark gray to medium gray, medium-grained, very well-sorted, rounded, very well cemented (silica), massive, faint laminations, occasional stylolites, slight sulfur staining, gradational with below.
14026.6-14030.5	Quartzitic sandstone, medium gray to medium-light gray, medium-grained, very well-sorted, well-rounded, silica cemented very well, occasional stylolites, very prominent laminations and cross-bedding, herringbone cross-stratification, slightly sulfur stained.
14030.5-14038.3	Quartzitic sandstone, light gray to medium gray, very well-sorted, well-rounded, very well cemented (silica), massive, occasional stylolites, faint low angle laminations, cross-bedding, herringbone cross-stratification, sulfur stained.

Depth (feet)	Description
14038.3-14046.4	Quartzitic sandstone, light olive gray to medium-dark gray, medium-grained, very well-sorted, well-rounded, silica cement, occasional stylolites, prominent low angle laminations, cross-bedding, occasional burrows toward base, sulfur stained, phosphate specks increasing downward, pyrite nodules (<.5 cm).
14046.4-14047.2	Quartzitic sandstone, medium gray, medium-grained, well-sorted, well-rounded, silica cement, moderate stylolites, occasional horizontal burrows, low angle lamination, sulfur stained, abrupt contact with below.
14047.2-14048.6	Quartzitic sandstone, yellow-gray to light gray, medium-grained, well-sorted, well-rounded, silica cement, occasional stylolites, occasional horizontal burrows, low angle laminations, sulfur stained.
14048.6-14049.5	Quartzitic sandstone, light gray, medium-grained, well-sorted, well-rounded, silica cement, clay matrix in areas, slightly to moderately bioturbated, moderately to heavily burrowed, moderately stylolitic (vertical and horizontal), laminations.
14049.5-14049.8	Quartzitic sandstone, medium gray to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, massive, occasional stylolites, occasional horizontal burrows, sulfur stained.
14049.8-14050	Interbedded sandstone and pyrite disks, medium gray to medium-dark gray, medium to fine-grained, well-sorted, well-rounded, silica cement, occasional microstylolites, occasional burrows, sulfur stained, pyrite disks lined up and well-sorted (<.2 cm).
14050-14050.4	Quartzitic sandstone, medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, occasional stylolites, faint laminations, massive.
14050.4-14053.8	Quartzitic sandstone, light gray to medium-light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, occasionally to moderately stylolitic, slightly bioturbated, moderately burrowed, very prominent vertical burrows, slightly laminated and sulfur stained.

Depth (feet)	Description
14053.8-14054.5	Quartzitic sandstone, light gray to medium-light gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderate stylolites, slightly bioturbated, moderately burrowed, faint laminations and sulfur stained.
14054.5-14055	Quartzitic sandstone, medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, moderately to extensively stylolitic, very prominent horizontal laminations, sulfur stained, slightly bioturbated areas.
14055-14056	Quartzitic sandstone, medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, very prominent horizontal laminations, planar bedding, occasional areas of extensive stylolites, sulfur stained.
14056-14056.7	Quartzitic sandstone, medium gray, medium to fine-grained, well-sorted, well-rounded, silica cement, low angle to 20° angle laminations, cross-bedding, moderate stylolites following low angle laminations, slight sulfur staining, rare horizontal burrows.
14056.7	Pyrite disk layer (<.1 cm), occurred along fracture surface.
14056.7-14057.4	Sandstone, medium gray to medium-dark gray, medium-grained, well-sorted, well-rounded, silica cement, occasional stylolites, laminations, cross-bedding, herringbone cross-bedding, sulfur stained.

REFERENCES CITED

Anderson, D. B., 1988, Stratigraphy and Depositional History of the Deadwood Formation (Upper Cambrian and Lower Ordovician), Williston Basin, North Dakota: unpub. Master of Science thesis, University of North Dakota, Grand Forks, 330 p.

Andrichuck, J. M., 1959, Ordovician and Silurian stratigraphy and sedimentation in southern Manitoba, Canada: American Association of Petroleum Geologists Bulletin, v. 43, p. 2333-2398.

Baillie, A.D., 1952, Ordovician and Silurian stratigraphy and sedimentation in southern Manitoba, Canada: American Association of Petroleum Geologists Bulletin, v. 43, p. 2333-2398

Ballard, F.V., 1963, Structural and stratigraphic relationships in the upper Paleozoic rocks of eastern North Dakota: North Dakota Geological Survey Bulletin 40, 42p.

Boardman, R. S., 1987, Fossil Invertebrates: Blackwell Scientific Publications, 713 p.

Carlson, C. G., 1958, The stratigraphy on the Deadwood-Winnipeg interval in North Dakota and northwestern South Dakota: *in* Saskatchewan Geological Society and North Dakota Geological Society, Second International Williston Basin Symposium, Regina, p. 20-26.

Carlson, C.G., 1960, Stratigraphy of the Winnipeg and Deadwood Formations in North Dakota: North Dakota Geological Survey Bulletin 35, 149 p.

Carlson, C. G., 1964, Facies relationships of the Winnipeg Group in eastern North Dakota: *in* Saskatchewan and North Dakota Geological Societies, Third International Williston Basin Symposium p. 45-50.

Carlson, C.G. and Anderson, S.B., 1965, Sedimentary and tectonic history of North Dakota part of the Williston Basin: American Association of Petroleum Geologists Bulletin, v.49, No. 11, p 1833-1846.

Carlson, C. G., and Thompson, S. C., 1987, Stratigraphy of the Deadwood Formation and Winnipeg Group in the Williston Basin: *in* Rocky Mountain Association of Geologists, Symposium on the Williston Basin, p. 71-80.

Clifton, H.E., Hunter, R. E., and Phillips, R. L., 1971, Depositional structures and processes in the non-barred, high energy nearshore: Journal of Sedimentary Petrology, v. 41, p 651-670.

Dowling, D. B., 1895, Notes on the stratigraphy of the Cambro-Silurian rocks of eastern Manitoba: The Ottawa Naturalist, v. 9, p. 65-74.

Dowling, D. B., 1900, Geology of the west shore and islands of Lake Winnipeg: Canada Geological Survey Annual Report, v. 11, Report F, 100 p.

Ellingson, J. B. and LeFever, R. D., 1995, Depositional Environments and History of the Winnipeg Group (Ordovician), Williston Basin, North Dakota: *in* Montana Geological Society, North Dakota Geological Society, and the Saskatchewan Geological Society, Seventh International Williston Basin Symposium.

Folk, R.L., 1959, Practical petrographic classification of Limestones: American Association of Petroleum Geologists Bulletin, v. 43, p. 251-384.

Foster, N. H., 1972, Ordovician: In: Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region United States of America: Rocky Mountain Association of Petroleum Geologists, p. 76-86.

Fuller, J. G. C. M., 1961, Ordovician and contiguous formations in North Dakota, South Dakota, Montana and adjoining area of Canada and the United States: American Association of Petroleum Geologists, v. 45, p. 1334-1363.

Genik, G. J., 1951, A regional study of the Winnipeg Formation: unpub. Master of Science Thesis, University of Manitoba, 75 p.

Genik, G. J., 1954, A regional study of the Winnipeg Formation: Alberta Society of Petroleum Geologists Journal, v. 2, p. 1-5.

Gerhard, L. C., Anderson, S. B., LeFever, J. A., and Carlson, C. G., 1982, Geological development, origin, and energy mineral resources of Williston Basin, North Dakota: American Association of Petroleum Geologists Bulletin, v. 66, 989-1020.

Gerlach, T. R., 1994, Evaluation of a Possible Subsurface Impact Crater: the Newporte Structure, Northwestern Renville County, North Dakota: unpub. Master of Science thesis, University of North Dakota, Grand Forks, 139 p.

Gilbert, C. M., 1954, Sedimentary rocks: *in* Williams, H., Turner, F. J., and Gilbert, C. M., Petrography: and introduction to the study of rocks in thin section: San Francisco, W. H. Freeman and Company, p. 251-384.

Goddard, E. N., Trask, P. D., Deford, R. K., Rove, O. N., Singewald, J. T. Jr., and Overbeck, R. M., 1963, Rock-color chart: Boulder, Colorado, Geological Society of America.

Golden Software, Inc., 1994, User's Guide to SURFER for Windows, 450 p.

Heckel, P. H., 1972, Recognition of ancient shallow marine environments, *in* Rigby, J. K. and Hamblin, W. K., ed., Recognition of ancient sedimentary environments: Society of Economic Paleontologists and Mineralogists Special Publication Number 16, p. 226-286.

Higgins, A. C. and Austin, R. L., 1985, A stratigraphical index of conodonts: Ellis Horwood limited for the British Micropaleontological Society, New York, 263 p.

Holland, F. D., Jr., and Waldren, C. H., 1955, Conodonts in the Winnipeg Formation (Ordovician) of North Dakota (Abstract): Geological Society of America Bulletin, v.66, p.1574.

Johnson, H. D., 1978, Shallow siliciclastic seas, *in* Reading, H. G., ed., Sedimentary environments and facies: New York, Elsevier Scientific Publishing Company, p. 60-68.

Kessler, L. G., II, 1991, Subsidence Controlled Stratigraphic Sequences and the Origin of Shelf Sand Ridges, Winnipeg Group (Middle Ordovician) Manitoba, Saskatchewan, North Dakota: *in* Saskatchewan, North Dakota and Montana Geological Societies, Sixth International Williston Basin Symposium, p. 1-13.

Kupsch, W. O., 1953, Ordovician and Silurian stratigraphy of east-central Saskatchewan: Saskatchewan Geological Survey Report Number 10, 62 p.

Laird, W. M., 1941, Selected deep well records: North Dakota Geological Survey Bulletin 12, 31 p.

Laird, W. M., 1956, The Williston Basin - a backward look with a view to the future: *in* First International Williston Basin Symposium, Bismarck, North Dakota, Conrad Publishing Company, p. 14-22.

LeFever, R. D., Thompson, S. C., and Anderson, D. B., 1987, Earliest Paleozoic history of the Williston Basin in North Dakota: Saskatchewan and North Dakota Geological Societies, Fifth International Williston Basin Symposium, p. 22-36.

Lindstrom, M., 1964, Conodonts: Amsterdam, Elsevier Scientific Publishing Company, 196 p.

McCoy, M. R., 1952, Ordovician sediments in the northern Black Hills: Billings, Montana, Billings Geological Survey 3rd Annual Field Conference Guidebook, p. 44-47.

North American Commission on Stratigraphic Nomenclature, 1983, North American stratigraphic code: American Association of Petroleum Geologists Bulletin, v. 67, p. 841-875.

Oberg, R., 1966, Winnipeg conodonts from Manitoba: Journal of Paleontology, v. 40, p. 130-147.

Potter, P. E., Maynard, J. B., and Pryor, W. A., 1980, Sedimentary environments: New York, Springer-Verlag, 549 p.

Reineck, H. E. and Singh, I. B., 1980, Depositional sedimentary environments: New York, Springer-Verlag, 549 p.

Ross, R. J., 1976, Ordovician sedimentation in the western United States: *in* Bassett, M. G., ed., The Ordovician System: Cardiff, Wales, Proceedings of a Paleontological Association Symposium, p. 73-105.

Stanley, S. M., 1989, Earth and Life Through Time, 2nd ed.: W. H. Freeman and Company, New York, 689 p.

Sweet, W. C., 1982, Conodonts from the Winnipeg Formation (Middle Ordovician) of the northern Black Hills, South Dakota: Journal of Paleontology, v. 56, p. 1029-1059.

Thompson, S. C., 1984, Depositional environments and history of the Winnipeg Group (Ordovician), Williston Basin, North Dakota: unpub. Master of Science thesis, University of North Dakota, Grand Forks, 225 p.

Tucker, M. E., 1982, The Field Description of Sedimentary Rocks: Geological Society of London Handbook, 112 p.

Turner, P., 1980, Continental red beds: Amsterdam, Elsevier Scientific Publishing Company, 5622 p.

Vigrass, L. W., 1971, Depositional framework of the Winnipeg Formation in Manitoba and eastern Saskatchewan: Geological Association of Canada, Special Paper Number 9, p. 225-234.

Wilson, J. L., 1975, Carbonate facies in geologic history: New York, Springer-Verlag, 471 p.