NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

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Stratigraphy of the Winnipeg and Deadwood Formations in North Dakota

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Clarence G. Carlson

Grand Forks, North Dakota, 1960

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ACKNOWLEDGMENTS

The writer is sincerely grateful to his advisor, Dr. F. D. Holland, Jr., Associate Professor of Geology at the University of North Dakota, for suggesting the problem, for his many suggestions and criticisms, and continued interest through all phases of the study.

He is deeply indebted to Dr. W. M. Laird, State Geologist of North Dakota, for permission to undertake graduate study and thesis work while being employed with the North Dakota Geological Survey. All of the facilities of the North Dakota Geological Survey were made available and these were an invaluable aid in the study. Appreciation is expressed to other members of the geological staff of the North Dakota Geological Survey for helpful suggestions during the course of the study and to Ronald Gutenberg for drafting most of the illustrations.

Appreciation is also expressed to Dr. Mark Rich, Assistant Professor of Geology at the University of North Dakota, for reading the manuscript and for his suggestions and criticisms.

ABSTRACT

The Deadwood formation includes all of the pre-Winnipeg sedimentary rocks of North Dakota, which range in thickness from an erosional edge in the subsurface of eastern North Dakota to at least 1,000 feet in northwestern North Dakota. It is composed of sandstone, shale, and carbonates of Late Cambrian to Early Ordovician age. Wells which have penetrated complete sections of the Deadwood formation are limited to the eastern half of North Dakota with the exception of a few wells in northwestern North Dakota and a few wells near the borders of the state in adjacent states and provinces. Therefore, facies relationships are not entirely clear, but sedimentation appears to have been continuous from Late Cambrian to Early Ordovician time, so a further division of the pre-Winnipeg sedimentary rocks into Late Cambrian and Early Ordovician formations, thus restricting the Deadwood formation to rocks of Late Cambrian age, is not feasible.

Conodonts were obtained from the upper part of the Deadwood formation from three wells in northwestern North Dakota. These conodonts are brownish-black in color, rather than the usual amber color, and are mostly simple cone types (Distacodidae), although a few compound forms such as <u>Coleodus</u> <u>simplex</u> Branson and Mehl and <u>Neocoleodus</u> sp. are also present. This fauna is not closely allied to any previously described fauna, but it is probably of Early Ordovician age based on the predominance of the Distacodidae.

The Winnipeg formation consists of sandstone, shale, and siltstone, which range in thickness from an erosional edge in the subsurface of southeastern North Dakota to a maximum of 357 feet in northwestern North Dakota. The Winnipeg lies unconformably on the Deadwood formation except in northwestern North Dakota, where it may lie conformably on the Deadwood formation, and in northeastern North Dakota, where it lies nonconformably on Precambrian rocks. It is overlain conformably by the Red River formation.

The Winnipeg formation is divided into three members which are, in ascending order: 1) Black Island member, composed of very fine to medium-grained, clean, quartzose sandstone; 2) Icebox member, composed of greenish-gray, non-calcareous shale; and 3) Roughlock member, composed of light greenish-gray to very light gray, calcareous siltstone, very fine-grained sandstone, and calcareous shale.

The Winnipeg formation is Middle Ordovician in age, based on comparisons of the conodont fauna of the Winnipeg formation to Middle and Late Ordovician conodont faunas of the Upper Mississippi Valley. These comparisons show that the lower part of the Icebox member contains a fauna similar to the Glenwood formation, the middle and upper part of the Icebox member contain a fauna similar to the Decorah formation, and the Roughlock fauna resembles the Decorah fauna more closely than that of the Galena formation. Therefore, the Black Island member is probably Chazyan, the Icebox member is Blackriveran to lower Trentonian, and the Roughlock member is Trentonian.

INTRODUCTION

General Introduction

The petroleum industry has been mainly interested in rocks of the Madison group (Mississippian) in North Dakota because about 98 per cent of the oil produced in North Dakota to date has been produced from these rocks. However, recent development has proved increasing reserves of petroleum in rocks of Devonian and Silurian age, and minor amounts of oil have been produced from the Red River formation of Ordovician age. Although no commercial production has been obtained from pre-Red River sedimentary rocks, oil shows have been reported from these rocks in two areas of the state; and Lower Paleozoic rocks will undoubtedly become increasingly important in future petroleum exploration in North Dakota. Therefore, it is the purpose of this paper to present detailed lithologic descriptions of the pre-Red River sedimentary rocks of North Dakota, to show the facies relationships of these rocks, and to show the correlations of the lithologic units from the subsurface of the Williston Basin to the areas of outcrop on the margins of the Basin.

Since pre-Red River sedimentary rocks do not crop out within the state of North Dakota and the previous nomenclature for these units has been extended from the outcrop areas of Manitoba and South Dakota, parts of adjacent states and provinces were included in the area studied. The location of these outcrop areas with respect to North Dakota and the Williston Basin is shown on the general outline map (Fig. 1) of the area.

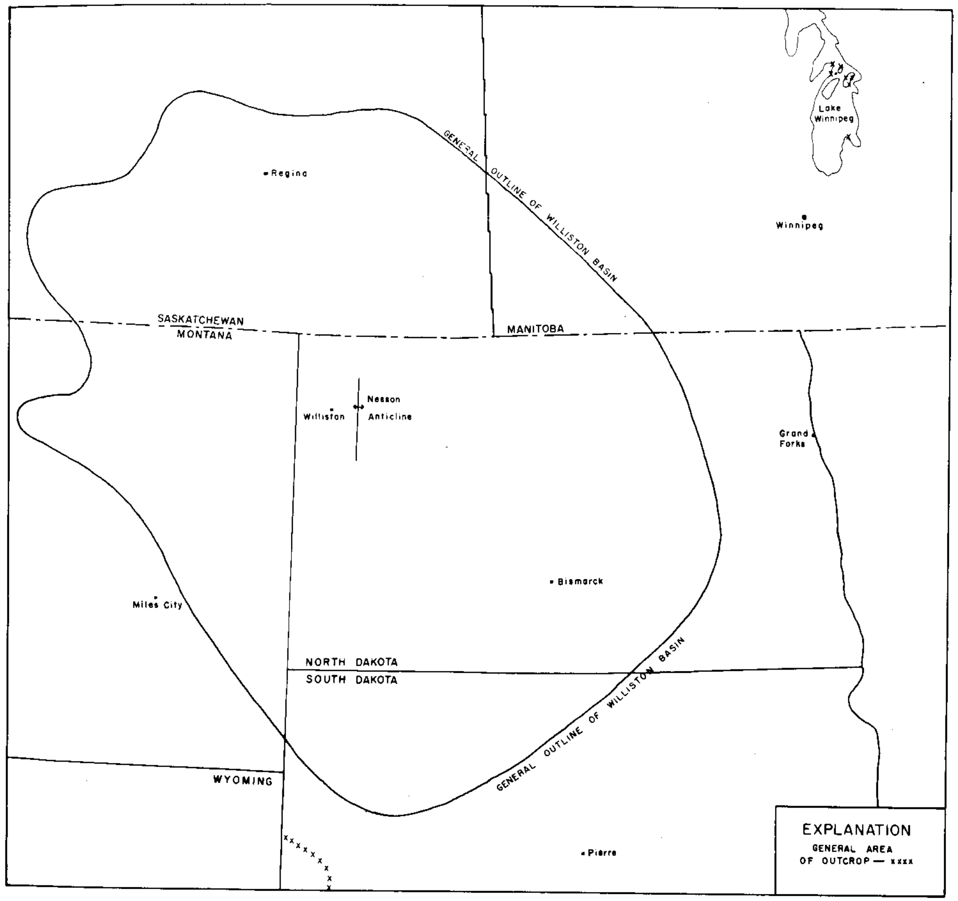


Figure 1 - Map showing the location of the Williston Basin and the areas of outcrop of the pre-Red River sedimentary rocks in Manitoba and South Dakota

Previous Work

Manitoba:

The term Winnipeg sandstone was first used by Dowling (1895, p.66) in reference to the rocks underlying the Ordovician limestones and overlying the Precambrian rocks in the Lake Winnipeg area of Manitoba. He did not designate a type section and none has since been designated because no one has found a complete section of the Winnipeg formation exposed at any one locality. Dowling (1900, p. 54) gave descriptions from field notes of Tyrell of parts of the Winnipeg formation which are exposed on Deer, Black, Elk, and Big (now Hecla) Islands and from Grindstone Point in the Lake Winnipeg area. Dowling estimated the thickness of the Winnipeg formation to be about 100 feet in this area and assigned a "Black River" age to the Winnipeg formation. This age assignment was based partly on lithologic similarity of the Ordovician section of Manitoba to the Ordovician section of southeastern Minnesota and partly on the few fossils which he found.

Wallace and McCartney (1928) made textural and heavy mineral studies of the sandstone of the Winnipeg formation. They found that heavy minerals constitute less than one per cent of the sample and are composed mainly of very stable minerals. Kerr (1949) listed wells which had penetrated the Winnipeg formation in Manitoba and gave lithologic descriptions of cuttings from these wells. Macauley and Leith (1951, p. 1462) briefly summarized the fauna of the Winnipeg formation in Manitoba and concluded that it is probably Late Ordovician in age based on the similarities of the Winnipeg fauna to those of the overlying Red River and Stony Mountain formations.

Baillie (1952, p. 7) divided the Winnipeg formation of the Lake Winnipeg area into two units. He said,

> The basal unit consists of pure fine-grained well-sorted unfossiliferous friable quartzose sandstone and is at least 45 feet thick. The upper unit is composed of bluish-green fossiliferous shale that contains thin hard sandstone beds, and sandstone that contains numerous shaly partings. The upper unit is about 35 feet thick.

He included in his report ten measured sections and a compilation of the faunal lists for the Winnipeg formation of Manitoba. Baillie was uncertain whether the Winnipeg formation is Mohawkian or Cincinnatian in age.

Genik (1951, unpublished thesis), working in the outcrop area of Manitoba and in the subsurface of the Williston Basin, divided the Winnipeg formation into three members which he named in ascending order: Black Island, Grindstone Point, and Deer Island members. Subsequently Kupsch (1953, p. 11) used Genik's three member terminology for the Winnipeg formation of the east-central Saskatchewan outcrop area. Later, Genik (1954, p. 1) divided the Winnipeg formation into two members.

> The basal unit, termed the Black Island member, consists of white to grey sandstone with local interstratified greenish shale and rare limey strata. The Black Island member ranges in thickness from a few to more than 300 feet. The upper unit, termed the Deer Island member, consists of interbedded grey sand and greyish green to slightly purplish fossiliferous shale and minor limestones. The Deer Island member ranges in thickness from a few to more than 250 feet.

Thus Genik used the terms Black Island and Deer Island members as equivalent to the basal and upper units of the Winnipeg formation as defined by Baillie, but Genik's (1954) Deer Island member is equivalent to Kupsch's Grindstone Point and Deer Island members. Although Genik (1954) applied the terms Black Island and Deer Island members throughout the Williston Basin his definitions of these members in the subsurface were rather sketchy. It appears from his isopach maps that, in central North Dakota, where he shows a thickness of over 400 feet for the Winnipeg formation that his Black Island member actually included a considerable thickness of pre-Winnipeg rocks. Therefore, if these terms are to be used in the subsurface without confusion, they must be more clearly defined.

Macauley (1955, p. 49) reviewed the usage of the term Winnipeg sandstone and formally defined the Winnipeg formation as "The shale and sandstone section which underlies the Red River formation and overlies the Precambrian complex in Manitoba." He did not designate a type section, but he suggested that the California Standard Daly No. 15 - 18 well, located in Lsd 15, sec. 18, T. 10, WPM, might be used as the type well, or that the Union Aanstad No. 1 well, located in the NW 1/4 sec. 29, T. 158 N., R. 62 W., Ramsey County, North Dakota, might be a better well since much of the shale and sandstone was cored in that well. Macauley considered Genik's member names unnecessary and merely divided the Winnipeg formation into two units, a basal sandstone facies and an overlying shale facies.

Macauley (1952, unpublished thesis) described 33 species of macrofossils from the Winnipeg formation. Brachiopods, corals, and cephalopods are most common, but a few species of gastropods, bryozoans, pelecypods, and trilobites were also described. Most of these species have a reported range from Middle to Upper Ordovician, but some of these species have been listed as Middle Ordovician species (Shimer and Shrock, 1944) e. g., Hallopora multitabulata (Ulrich), Rhinidictya mutabilis (Ulrich), Climacograptus typicalis Hall, and Cyclospira bisulcata (Emmons). However, Macauley considered the Winnipeg fauna to be younger than the Stewartville fauna (Trenton) of the Upper Mississippi Valley and introductory to the Red River fauna. One example which he presented to

support this idea concerned the genus Streptelasma. He thought that a new Winnipeg species of Streptelasma was a more advanced form than Streptelasma corniculum Hall of the Stewartville, but less advanced than Streptelasma profundum (Conrad) or Streptelasma robustum (Whiteaves) of the Red River formation.

Macauley (1955, p. 52) placed the Winnipeg formation in the Upper Ordovician for the following reasons:

> The Winnipeg contains a fauna which is present throughout the entire Manitoba Ordovician and also throughout the Mohawkian of Minnesota and Illinois. The Red River contains, in addition, a large fauna, especially cephalopods, which was derived from the present Arctic area.
>
> . . . .
>
> The numerous species in the Winnipeg, which are also common to the Middle Ordovician of Minnesota and Illinois and to the remainder of the Manitoba Ordovician, should be considered as ranging throughout the Middle and Upper Ordovician and are diagnostic of that time interval. The presence of Upper Ordovician fossils throughout the Manitoba Ordovician indicates a Richmondian age for the Winnipeg, Red River and Stony Mountain formations, even though forms previously considered as diagnostic of Trenton are also present.

Fleming (1957) presented an isopach and structure map of the Winnipeg formation in Manitoba.

Andrichuk (1959) made a study of the Lower Paleozoic rocks of southern Manitoba. He (1959, p. 2349) noted a sand body in the upper part of the Winnipeg formation in the vicinity of Carmen, southwest of Winnipeg, Manitoba, which is "up to 90 feet thick, averaging 30 miles wide and more than 125 miles long." Andrichuk rejected the two member subdivision of previous writers and arbitrarily separated an "upper 100 foot slice" from the basal section of the Winnipeg formation to show the distribution of upper and basal sandstones of the Winnipeg formation. He considered the Lake Winnipeg outcrop section to be included in his "upper slice"; because the surface section is less than 100 feet thick, and it is composed predominately of sandstone.

South Dakota:

The term Deadwood formation was first used by Darton (1901, p. 505) in reference to the Cambrian rocks of the Black Hills area of South Dakota. Darton used the term as though Jaggar (1901) had previously defined the Deadwood formation. Jaggar (1901, p. 176-181) had referred to Cambrian rocks with a type locality at Deadwood, South Dakota, but he did not use the term Deadwood formation in his report.

Darton (1904, p. 382) assigned a Middle Cambrian age to the Deadwood formation based on faunal studies by Walcott and gave the following generalized description of the Deadwood formation of the Deadwood, South Dakota area:

20 to 45	feet of green shale
5 to 12	feet of hard, massive sandstone
200 to 400	feet of gray shales with layers of flaggy limestone, limestone conglomerate and sandstone
30	feet of coarse, dark brown sandstone
30	feet of basal conglomerate

Darton and Paige (1925, p. 6) gave the following description of the type section of the Deadwood formation on Whitewood Creek below Deadwood, South Dakota:

	Feet
Sandstone, buff and gray, slabby, with fucoids; overlain by Whitewood limestone	20
Shale, olive green, soft and flaky	25
Sandstone, white, quartzitic; contains annelid trails and borings [Skolithos quartzite]	15
Sandstone, red, more massive in upper portion, with interbedded green shale and dolomite breccia; contains much glauconite and many fucoid markings	100
Limestone, flaggy, dolomitic, gray, with scattered lenses of flat-pebble limestone conglomerate; interbedded with green fissile shale	220
Sandstone, red, limy, and soft brown shale	17
Sandstone, brown to buff, quartzitic above, cross-bedded in places; 3 inches of conglomerate of quartz pebbles and green shale, with fragments of Obolus shells, at the base; lies unconformably on schist	32
	429

After a re-examination of the faunal evidence, Darton and Paige assigned a Late Cambrian age to the Deadwood formation.

Meyerhoff and Lochman (1934, p. 99) reported a Crepicephalus faunal zone (Dresbachian stage) 48 feet above the base of the Deadwood formation in Whitewood Canyon. Continuing their studies (1935, p. 352) they reported five Upper Cambrian faunal zones from the Deadwood formation of the northern Black Hills, but no horizon higher than the Crepicephalus zone in the southern Black Hills. The same writers (1936, p. 386) reported seven faunal zones of the Croixian series including five zones above the Crepicephalus zone from the Deadwood formation in South Dakota and eastern Wyoming.

Furnish, Barragy and Miller (1936) reported scolecodonts and conodonts from the siltstone (sandstone of Darton) and shale units overlying the quartzitic sandstone ("Scolithus quartzite" of writers) in the upper part of the Deadwood formation at the type section. They found no other fossils than Skolithos[1/], usually spelled Scolithus, in the quartzitic sandstone beds. Furnish, Barragy and Miller assigned a "Middle (?) Ordovician" age to the shale and siltstone units overlying the quartzitic sandstone beds and transferred these units from the Deadwood formation to the overlying Whitewood formation. They did not transfer the quartzitic sandstone unit because they noted that:

> It is difficult to "draw a line" between the Scolithus and the underlying beds. Near Deadwood, where the entire member is exposed in a fresh roadcut, quartzitic beds with "worm borings" seem to grade into underlying sandy beds.

1/ Howell (1940) has pointed out that the original spelling by Haldeman (1840) was Skolithos. According to Article 19 of the Rules of Zoological Nomenclature the original orthography of a name should be retained unless an error is evident. Therefore the original spelling is herein retained.

They also noted that the contact with the overlying green shale is abrupt. They suggested that the reddish color and silicification of the quartzitic sandstone below might be "the result of a period of exposure." Therefore, they left the quartzitic sandstone in the Deadwood formation.

The Deadwood formation had been considered to be Late Cambrian in age until Lochman and Duncan (1950, p. 351) reported early Lower Ordovician trilobites from the upper part of the Deadwood formation in Spearfish Canyon in the northern Black Hills, South Dakota.

LITHOLOGY Composite Section	DARTON, (1901, 1904, 1909)	DARTON and PAIGE, (1925)	FURNISH BARRAGY and MILLER, (1936)	MC COY, (1952)	BUTLER, and others, (1955)	CARLSON, (1959, This Paper)
Limestone, light gray to buff, mottled, medium crystalline, dolomitic.		WHITE	WOOD	FOR	MATION	
Siltstone, buff and light gray, slightly argill. Thickness 15 to 30 feet.				Roughlock formation	(D)	WINNIPEG FM. Roughlock member
Shale, olive green to greenish gray, soft. Thickness 25 to 70 feet.				Icebox formation	(C)	WINNIPEG FM. Icebox member
Sandstone, fine- to medium grained, moderately well sorted, rounded to sub-angular, quartzitic; contains Skolithos. Thickness 12 to 25 feet.				Aladdin sandstone	(B)	
Limestone, limestone cgl., shale and sandstone.					(A)	
Limestone, sandstone and shale; conglomerate at base. Thickness 4 to 500 feet.		DEAD	WOOD	FOR	MATION	

Figure 2 - Chart showing history of nomenclature applied to Cambro-Ordovician section of the Black Hills area, South Dakota.

McCoy (1952, p. 45) named the siltstone unit underlying the dolomitic limestone of the Whitewood formation, the Roughlock formation. He designated the type section as the section several hundred yards up the canyon wall in Spearfish Canyon, 2.4 miles above Maurice, South Dakota. The Roughlock formation is about 25 to 30 feet thick in the northern Black Hills area. McCoy's description of the Roughlock formation is as follows:

> The lower parts of the Roughlock formation are composed of moderately argillaceous quartzose siltstone. The middle beds become a very pure type of quartzose siltstone to a fine-grained sandstone. The contact with the Whitewood dolomite above is conformable and gradational.

The shale unit underlying the Roughlock formation and overlying the quartzitic sandstone unit was named the Icebox formation by McCoy (1952, p. 45). The type section, as designated by McCoy, is located in secs. 14 and 23, T. 5 N., R. 3 E., about 1/2 mile west of the junction of U. S. Highways 14A and 85, Lawrence County, South Dakota. He reported a thickness of 30 to 40 feet for the Icebox formation in the northern Black Hills outcrop area and, his description of the Icebox formation is as follows:

> The Icebox beds are lithologically a silty shale, greenish-gray to olive in color, usually fissile but occasionally splintery to platy, soft non-effervescent and characterized in the upper part by black phosphatic nodules several millimeters in diameter.

McCoy (1952, p. 46) placed the Icebox formation in the Blackriveran stage and the Roughlock formation in the Trentonian stage based on the microfauna, but no discussion of the microfauna was given. The term Aladdin sandstone was proposed by McCoy (1952, p. 46) for the quartzitic sandstone unit underlying the Icebox shale. The type section, as designated by McCoy is in sec. 14, T. 52 N., R. 63 W., in the Bear Lodge Mountains, Crook County, Wyoming. His description of the Aladdin sandstone is as follows:

The Aladdin sandstone is a quartzitic type sandstone which is occasionally calcareous. It is commonly 12 to 25 feet thick. Cross-bedding is common. Its textural characteristics may be described as hard, fine to medium-grained, moderately well-sorted, moderately porous, subangular to subrounded with good cementing.

McCoy interpreted the environment of deposition of the Aladdin sandstone as a marine sandstone except for a thicker section of reddish sandstone at Nemo, South Dakota, which he thought represented a deltaic deposit.

Butler, and others (1955, p. 38) rejected the names proposed by McCoy, but used the same rock units, giving them informal letter designations, and referred to these units as members of the Whitewood formation. They also included 20 feet of limestone, limestone pebble conglomerate, shale and sandstone, underlying the Aladdin or quartzitic sandstone beds in the Whitewood formation, thus limiting the Deadwood formation to rocks of Late Cambrian age. They then correlated the quartzitic sandstone and the underlying beds to the basal sandstone of the Winnipeg formation of the subsurface, the shale unit to the shale section of the Winnipeg formation in the subsurface, and the siltstone unit as a possible equivalent of the Lander sandstone of Wyoming.

Carlson (1959, p. 25) first applied the name Winnipeg to surface sections in South Dakota, and considered the Icebox and Roughlock as members of the Winnipeg formation.

Subsurface:

The first oil exploratory well to penetrate the Winnipeg and older rocks in North Dakota was the Glenfield Oil Company well drilled in 1928, and located in the SE 1/4 sec. 18, T. 146 N., R. 62 W., Foster County.

Laird, (1941) published sample descriptions of selected deep wells in North Dakota which included three wells penetrating the Winnipeg formation. Two of these descriptions were of water wells, one at Grafton,

drilled in 1885 and one at Hamilton, drilled in 1889, both located in northeastern North Dakota. The log of the Grafton well has 155 feet of gray, greenish-blue, and dark red shale which was designated Winnipeg and three feet of white sandstone which was called "Deadwood(?)" overlying gray granite (Laird, 1941; correlated by Kline). In the Hamilton well, 130 feet of blue shale was designated Winnipeg and five feet of white sandstone was correlated as "Deadwood (?)" overlying blue granite (Laird, 1941; correlated by Kline). These descriptions had been published previously (Upham, 1895, p. 77; Simpson, 1929, p. 246; and Barry and Melstad, 1908), but this was the first time that the term Winnipeg formation had been applied to these rocks in northeastern North Dakota. Also included in this report was a description of cuttings from the Glenfield well by the late J. B. Reeside, Jr., in which Reeside referred to the Winnipeg section as "pre-Richmond (?) Paleozoic." Kline (1942, p. 361) published sample descriptions of the Glenfield well in which she referred to the bottom 146 feet of sedimentary rocks as questionable Deadwood formation overlain by 130 feet of Winnipeg formation. Seager, and others, (1942, p. 1423) in a discussion of Kline's paper expressed the opinion that what Kline referred to as questionable Deadwood-Cambrian was actually Ordovician in age based on regional stratigraphic relationships and faunal evidence from the Carter Oil Company - Northern Pacific No. 1 well in Fallon County, Montana.

Towse (1952, p. 6) followed the usage of Seager, and others, (1942) and placed all of the pre-Red River sedimentary rocks of south-central North Dakota in the Winnipeg formation of Ordovician age.

Laird and Towse (1953) divided the pre-Red River sedimentary rocks of North Dakota into the Winnipeg (Ordovician) and Deadwood (Cambrian) formations, but they were uncertain as to the areal extent of the Deadwood formation. They stated, however, that the Deadwood formation was definately present in the southwestern part of the state and possibly extended to east- central North Dakota.

The North Dakota Geological Society (1954) divided the pre-Red River sedimentary rocks into three formations. At the base, they recognized a unit composed of shale, limestone, sandstone, and dolomite which range in thickness from 0 to 500 feet as the Deadwood formation of Cambrian age. Overlying the Deadwood formation, they recognized an unnamed formation composed of limestone, sandstone and shale of "Lower Ordovician (?) age" which ranges in thickness from 0 to 350 feet. They limited the Winnipeg formation to the sandstone and shale section overlying the unnamed formation and underlying the Red River formation.

Stocker (1956, p. 113) divided the pre-Red River sedimentary rocks of North Dakota into two formations, the Winnipeg and Deadwood. He agreed with the North Dakota Geological Society definition of the Winnipeg formation and then divided it into three members: an upper Winnipeg sandstone, a middle Winnipeg shale, and a lower Winnipeg sandstone. He referred to all of the pre-Winnipeg sedimentary rocks as the Deadwood formation of Cambrian or possibly Cambro - Ordovician age.

Porter and Fuller (1959) referred to all of the pre-Red River sedimentary rocks of the Williston Basin as comprised of the Winnipeg and Deadwood formations. They assigned a Late Cambrian to Early Ordovician age to the Deadwood formation and a Middle to Late Ordovician age to the Winnipeg formation.

The paleontology of the pre-Red River sedimentary rocks of the subsurface of the Williston Basin has received little study, therefore, the

age assignments of these rocks has been based largely on correlations of these rocks with the surface sections on the margins of the Basin. This approach has not been conclusive because the subsurface sections represent a more complete geologic record than does either of the outcrop areas and the age of some of these rocks in the surface sections are a subject of controversy.

The limited subsurface faunal studies began with Decker (1942, p. 123), who reported some graptolites from a core of the "Winnipeg" shale from a well in Harding County, South Dakota. Based on these graptolites, he correlated the shale with the Viola formation (Middle Ordovician) of Oklahoma.

Seager, and others, (1942, p. 1422) divided the pre-Red River section in the Carter Oil Company - Northern Pacific No. 1 well, Fallon County, Montana (Well H, Fig. 1) into 605 feet of Ordovician rocks and 219 feet of Cambrian rocks. They said the Ordovician rocks consisted "of interbedded green, sandy shale, sandy shaly limestone and sandstone." This section was considered to be Middle Ordovician on the basis of conodonts from the shale, however, the depth from which the shale containing conodonts was obtained was not reported. They correlated this Ordovician section with the lower Whitewood formation of the Black Hills, South Dakota.

Holland and Waldren (1955, p. 1574) reported conodonts from the basal sandstone of the Winnipeg formation from core chips of the Stanolind Oil and Gas Company - Waswick No. 1 well in north-central North Dakota (NDGS 105, Fig. 1). They suggested a Chazyan or Blackriveran age for the sandstone based on two genera which they reported, namely, Acontiodus and Microcoelodus.

Ross (1957) made a study of some Ordovician fossils from deep wells in eastern Montana. Since the pre-Winnipeg sedimentary rocks of eastern Montana are lithologically similar to the Deadwood formation of South Dakota and he could find no evidence of an unconformity in the pre-Winnipeg sedimentary rocks, he referred to all of these rocks as the Deadwood formation. In regard to the age of the Deadwood formation he reported as follows:

> Only Lower Ordovician fossils have been obtained from this pre-Winnipeg unit in the Shell Pine Unit No. 1 and Shell, Richey Area, Northern Pacific No. 1 wells. Information furnished by James L. Wilson of the Shell Oil Company for the Shell Southwest Richey Area No. 32-33B well indicates the presence of about 350 feet of Lower Ordovician and 390 feet of Upper Cambrian strata between the base of the Winnipeg formation and the basement rocks. The lower 207 feet of Early Ordovician and upper 158 feet of Cambrian strata are composed of green shale, . . .The intersystemic boundary has been located on faunal evidence only.

He discussed the age of the Winnipeg formation, but he did not consider the evidence to be conclusive for either a Late or Middle Ordovician age assignment.

Carlson (1959) referred to all of the pre-Winnipeg sedimentary rocks of North Dakota as the Deadwood formation and considered the Deadwood formation to be of Lake Cambrian to Early Ordovician age. He discussed the relationship of the Winnipeg formation of the subsurface to the surface sections in South Dakota and Manitoba and divided the Winnipeg formation of North Dakota into three members.

He noted that the upper two members could be traced through the subsurface of the Williston Basin to the northern Black Hills, South Dakota outcrop area where they were equivalent to the Roughlock and Icebox formations. Therefore, he applied the terms Roughlock member and Icebox member to the upper two members of the Winnipeg formation in the

subsurface of the Williston Basin. He noted that the lower member of the Winnipeg formation was absent in the Black Hills outcrop area. He then accepted the term Black Island member, which had previously been applied to this unit, for the lower member of the Winnipeg formation.

Present Study

Basis for Study:

The present study is based mainly on subsurface data obtained from exploratory oil wells in North Dakota, but it also includes surface studies in South Dakota and Manitoba. Prior to 1951, only ten exploratory oil wells and a few water wells had penetrated pre-Red River sedimentary rocks in North Dakota. However, exploration increased rapidly with the discovery of oil in northwestern North Dakota in April, 1951; and 2,567 oil exploration wells had been drilled in North Dakota by January 1, 1960. Of these, 127 wells had penetrated pre-Red River sedimentary rocks, and 90 of these had penetrated Precambrian rocks.

Since wells penetrating Precambrian rocks are limited to the eastern two-thirds of North Dakota with the exception of a few deep wells on the Nesson anticline in northwestern North Dakota, complete sections of the Deadwood formation are also limited to those areas. Therefore a few wells near the borders of the state in South Dakota, Montana, Saskatchewan, and Manitoba, which have penetrated the complete pre-Winnipeg sedimentary section were also included in the present study. Subsurface data for wells in North Dakota is furnished to the North Dakota Geological Survey under the oil and gas conservation laws of the state of North Dakota. This material, which is on open file with the North Dakota Geological Survey Grand Forks, North Dakota, furnished much of the basis for this study.

Some type of mechanical log (e. g., electrical, radioactivity, laterolog, etc.) is available in the files of the North Dakota Geological Survey for most of the wells which have been drilled in the state, including all but eleven of the wells which have penetrated pre-Red River sedimentary rocks. Mechanical logs from selected wells in adjacent states and provinces were also obtained and used.

The South Dakota Geological Survey has published sample descriptions for some deep wells in northern South Dakota. Samples of several other wells in South Dakota were examined through the courtesy of the South Dakota Geological Survey and surface sections of the Winnipeg formation (Whitewood formation of previous writers) were measured and sampled at two localities near Deadwood, South Dakota. The Deadwood-Winnipeg contact in Spearfish Canyon and south of Englewood Station in the northern Black Hills was also examined.

Surface studies in the Lake Winnipeg area of Manitoba began with the finding of poor exposures of the Winnipeg formation at Victoria Beach near the south end of Lake Winnipeg. This locality has the advantage of being easily accessible by automobile, but it is only during periods of low lake levels that the shale and sandstone are exposed at the water's edge on the lower parts of the beaches. Samples of the shale which contained numerous conodonts were collected from this locality in May, 1959. The stratigraphic position of these samples is difficult to determine because of the poor exposures at this locality although some inferences as to the bedrock can be made from an examination of the loose rocks along the beaches. The stratigraphy of the Winnipeg formation in the Manitoba surface section is more clearly shown on some of the islands to the north of Victoria Beach. Measured sections described by Baillie (1952)

were checked on Black, Punk, and Deer Islands and sections of the Winnipeg formation were measured on Punk and Deer Islands and samples were collected from these localities in July, 1959.

Samples of the shale and sandstone of the Winnipeg formation from the outcrop sections of Manitoba and South Dakota and from cores of several wells in North Dakota were broken down and examined for microfossils. Conodonts were the most abundant fossils, but some ostracodes were also obtained from a few samples. The sandstone lithofacies was generally unfossiliferous, but one sample from a thin bed within the upper shaly unit of the Winnipeg formation at Victoria Beach, Manitoba, contained some poorly preserved conodont specimens. Most of the samples of the shale lithofacies contained some specimens, although the samples were not uniformly fossiliferous. It was noted that samples containing fragments of other fossils and samples which had evidence of a diastem (i. e., concentrations of dark organic ? matter, phosphatic nodules, or wavy bedding in otherwise evenly bedded shale) were the most fossiliferous.

Core samples of the shale lithofacies of the Winnipeg formation were available for six wells from North Dakota in the storage facilities of the North Dakota Geological Survey. However, the shale is so well indurated in some areas that samples from three of the wells from the deeper parts of the Williston Basin could not be broken down. Therefore the collections of conodonts from the subsurface are limited to three wells in the eastern part of the state. Conodonts could probably be obtained from other wells in the eastern part of the state also, however, large samples would be necessary to obtain a sufficient number of specimens for significant stratigraphic information. The shale lithofacies from both the South Dakota and Manitoba outcrop areas yielded a sufficient number of specimens to aid in making regional correlations.

Methods of Study:

The writer examined well cuttings and cores of pre-Red River sedimentary rocks from about 50 wells with a binocular microscope with a nine power magnification. Particle size and roundness were estimated by visual comparison with a set of commercially prepared Wentworth scale sizes (Sand Gauge Folder, Geological Specialty Company, Oklahoma City, Oklahoma). Colors were determined by comparison with the Rock Color Chart (Goddard, and others, 1948) distributed by the Geological Society of America. Descriptions of the pre-Red River sedimentary rocks in sixty wells were available in North Dakota Geological Survey Circulars. The writer re-examined cuttings from twenty-two of these wells for which Circulars had previously been published. Appendix B contains sample descriptions for most of the wells examined by the writer. A few wells, from which the samples were very poor, or, where the writer's descriptions are very similar to the Circular descriptions are not included in the Appendix.

The locations of all oil exploration wells penetrating pre-Red River sedimentary rocks in North Dakota and selected wells from adjacent states and provinces are shown on the location map (Fig. 3). Well names and locations are given in Appendix A. North Dakota Geological Survey file numbers, hereinafter referred to as NDGS ____, are used for the wells in North Dakota with the wells arranged in numerical order in Appendix A. Arbitrary letter designations are used for the wells from adjacent states and provinces.

The thicknesses for the isopach maps were determined from the mechanical logs with all available logs being used. The formation and member tops, from which these thicknesses were computed are contained in Appendix C. The sand-shale ratios were also determined with the aid of mechanical logs.

Samples of the shale were broken down by soaking in Stoddard solution (dry cleaning fluid) or gasoline for several days, then dried, and soaked in water. The shale then disintegrated and the sample was wet sieved and dried. Material which passed through a 35 mesh sieve (Tyler screen equivalent) and was retained on a 100 mesh sieve was saved for separations using bromoform. The "heavies", concentrated by the bromoform method (Branson and Mehl, 1933, p. 12), were picked for conodonts with 12 power and then 72 power magnification. The concentrated heavy fraction was retained as a check on the completeness of the picking of the samples.

Cores of the sandstone of the Winnipeg formation were put through a jaw crusher and then sieved. Bromoform separations were then conducted on the 80 mesh and 100 mesh fraction, but no conodonts were obtained from them. The basal sandstone from the Manitoba outcrop area is very friable, so these samples were merely sieved and then bromoform separations conducted. These samples were also non-fossiliferous.

Conodonts were obtained from cores of the upper part of the Deadwood formation in three wells located in Williams County in northwestern North Dakota. These conodonts were found in cores of a very fine-to medium-grained, subrounded to subangular, quartzose sandstone firmly cemented with silica. These samples were broken in a jaw crusher and then sieved. The sample which passed through a 35 mesh sieve and was retained

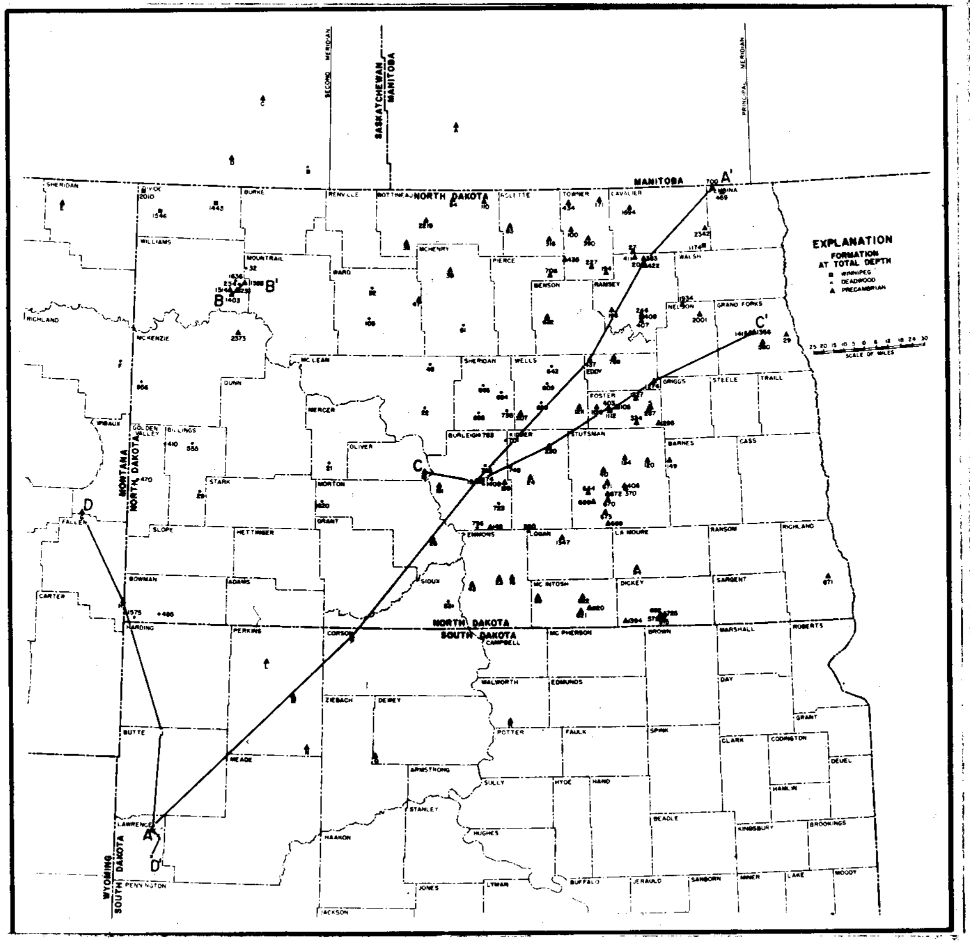


Figure 3 - Map showing the locations of exploratory wells penetrating pre-Red River formations in North Dakota and adjacent states and provinces.

on a 100 mesh sieve was retained and either directly hand picked or picked after concentrations with bromoform. Most of the specimens were freed from the matrix by this process; but some of the specimens still retain sand grains adhering to them, and many specimens were broken by the rough treatment.

STRATIGRAPHY

DEADWOOD FORMATION

Name and Definition

The Deadwood formation was named by Darton (1901, p. 505) with the type locality at Deadwood, South Dakota. At the type locality, the Deadwood formation is composed of limestone, sandstone and shale which lies nonconformably on Precambrian rocks and is overlain by the Winnipeg formation (Whitewood formation of previous writers) of Ordovician age. The Deadwood formation may be traced through the subsurface of northern South Dakota into the Williston Basin, so the term Deadwood formation has been extended to include all of the pre-Winnipeg sedimentary rocks in North Dakota and eastern Montana.

Thickness

The Deadwood formation ranges in thickness from 4 to 50 feet in the southern Black Hills to about 500 feet in the northern Black Hills. It thickens northward into the subsurface and ranges in thickness from 725 feet in the Carter Oil Company - Northern Pacific No. 1 well (Well H, Fig. 2) to 940 feet in the Shell Oil Company - No. 43-22A well (Well G, Fig. 2) in southeastern Montana.

The areal distribution of the Deadwood formation in North Dakota is shown on the isopach map (Fig. 4). The eastern limit is an erosional limit, with the Deadwood formation being absent in northeastern and southeastern North Dakota except for outliers such as are present underlying the Winnipeg formation in the subsurface in Grand Forks County

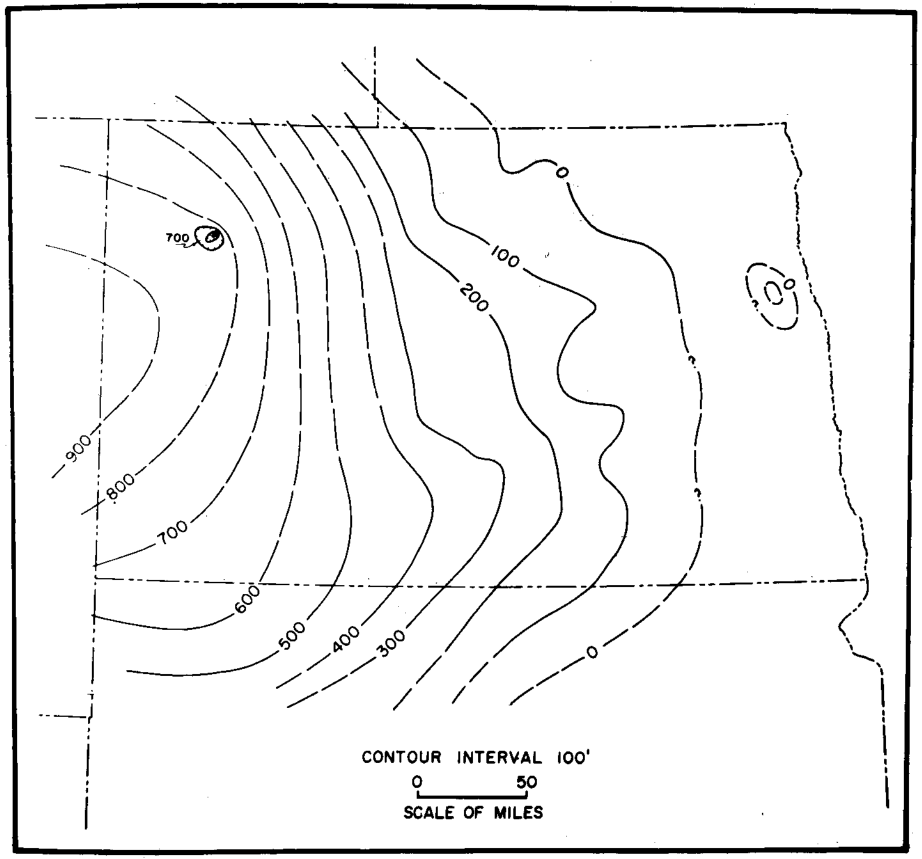


Figure 4 - Isopach map of the Deadwood formation.

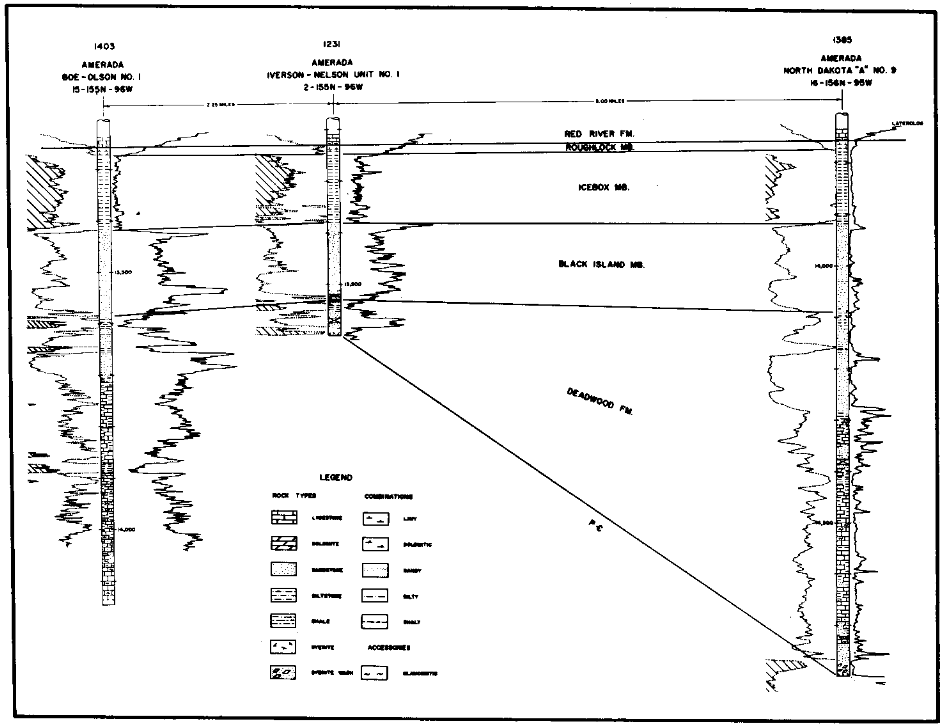


Figure 5 - Cross section along the line B- B' in Williams County, northwestern North Dakota, showing a topographic high on the Precambrian surface, using the Red River formation as a datum.

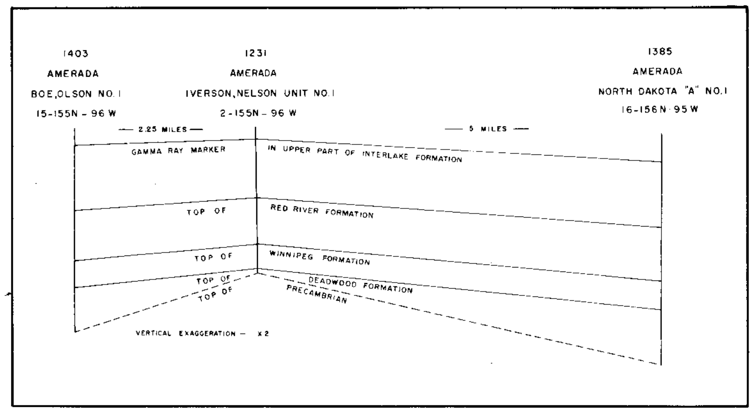


Figure 6 - Cross section along the line B - B' in Williams County, northwestern North Dakota, showing the topographic high on the Precambrian surface with reduced vertical exaggeration; sea level used as a datum.

in northeastern North Dakota. In the western one-third of the state, only five wells have penetrated the complete Deadwood formation and these are all in the Nesson anticline area of northwestern North Dakota. These wells show that the thickness of the Deadwood formation ranges from 61 feet in the Amerada Petroleum Corporation - Iverson, Nelson Unit No. 1 well (NDGS 1231) to 1,000 feet in the Amerada Petroleum Corporation Antelope Unit " A " No. 1 well (NDGS 2373). Therefore the isopach map shows only the general thickness of the Deadwood formation in the Nesson anticline area, since the detailed variations could not be shown on a map of such a large scale.

An example of these large variations occurs in the Beaver Lodge field in Williams County (Fig. 5), where the Deadwood formation ranges in thickness from 61 feet in the Amerada Petroleum Corporation - Iverson, Nelson Unit No. 1 well (NDGS 1231) to 695 feet in the Amerada Petroleum Corporation - North Dakota " A " No. 9 well (NDGS 1385).

A total of four wells have penetrated Precambrian rocks in the Beaver Lodge field; and these wells, together with another well which penetrates Precambrian rocks about 20 miles southeast of the Beaver Lodge field, provide the basis for an interpretation of this area. The lithology and mechanical log characteristics of the Deadwood formation in these wells show very little evidence of facies changes within the Deadwood formation. In the wells in which the Deadwood formation is thinner, most of the thinning appears to be accounted for by an absence of some of the lower beds which are present in the thicker sections of the Deadwood formation.

The present difference in elevation of the Precambrian surface between the Iverson, Nelson Unit No. 1 well and the North Dakota " A "

No. 9 well is 1,156 feet. Since the difference in thickness of the Deadwood formation in these wells does not account for the present difference in elevation of the Precambrian surface, the problem is whether part, or all of the present difference in elevation of the Precambrian surface was present at the time of deposition of the Deadwood formation. Two cross sections (Figs. 5 and 6) were constructed to show the relationships between the Lower Paleozoic rocks and the Precambrian surface. One cross section (Fig. 5) has a greatly exaggerated vertical scale, but it demonstrates that deposition was continuous across this basement high during the latter stages of Deadwood deposition and that the overlying Winnipeg formation thins slightly over the basement high. The second cross section (Fig. 6) was constructed with only a slight vertical exaggeration to show a more accurate picture of the relief of the Precambrian surface.

The Precambrian high coincides with the structural high of the Madison group (Mississippian) reservoir in the southwestern part of the Beaver Lodge field. A study of the overlying sedimentary section shows that all of the formations from the Winnipeg formation through the Interlake formation (Silurian) are slightly thinner in the Amerada Petroleum Corporation - Iverson, Nelson Unit No. 1 well than in the surrounding wells. The relationship of this thinning is shown in Table I, where the amount of increased thickness of each of the formations or units from the Winnipeg formation through a gamma ray marker in the upper part of the Interlake formation in each well was compared to the thickness of that formation or unit in the Iverson, Nelson Unit No. 1 well.

TABLE I - Thickness of Lower Paleozoic rocks in Beaver Lodge area, Williams County, northwestern North Dakota.

STRATIGRAPHIC UNITS	N. D. G. S. No. 1231		N. D. G. S. No. 1385			N. D. G. S. No. 1403			N. D. G. S. No. 1514		
	Depth	Thick.	Depth	Thick.	% Incr. Thick.	Depth	Thick.	% Incr. Thick	Depth	Thick.	% Incr. Thick.
Interlake fm.; Gamma ray marker	11,955	719	12,327	799	10.0	11,862	794	9.4	12,117	780	7.8
Red River formation	12,674	554	13,126	627	11.6	12,656	606	8.5	12,897	618	10.2
Winnipeg formation	13,228	300	13,753	347	13.5	13,262	334	10.1	13,515	357	15.9
Deadwood formation	13,528	61	14,100	695		13,596	549		13,872	584	
Precambrian	13,589		14,795			14,145?			14,456		

The problem of whether the present Precambrian high was tectonically active during deposition of the Deadwood formation or whether it was merely a topographic high on the Precambrian erosion surface cannot be determined with the present information because only one well has been drilled to the Precambrian on each of three sides of the Precambrian high. Therefore it cannot be determined whether the lower beds of the Deadwood formation were originally deposited over the Precambrian high and removed before deposition of the upper beds of the Deadwood formation were deposited, or whether these beds lap against the Precambrian high. The presence of "syenite wash" is an important consideration in interpretation of this Precambrian high because a syenite wash would not be expected if this were an erosional remnant of a peneplain surface. The writer has seen cuttings of this "wash" in only two wells and there is some question whether this is a true "wash", or merely cuttings of slightly weathered Precambrian rocks in these wells, however, in the Amerada Petroleum Corporation - Ulven Unit No. 1 well (NDGS 1514), a few pieces of feldspar were noted imbedded in limestone of the lower part of the Deadwood formation.

If the Precambrian high is due to tectonic movement, it must have been quite active to account for the large variations in thickness of the Deadwood formation and relatively inactive from the Middle Ordovician through the Silurian. It seems more plausable to the writer, based on the few available wells and regional considerations that the Precambrian high was a topographic high which was buried during the latter stages of Deadwood deposition and that the Lower Paleozoic sediments, beginning with the upper part of the Deadwood formation, were draped over this topographic high of the Precambrian surface, although the Precambrian

surface may not have had all of its present relief at that time. The possibility should not be overlooked however, that the relief on the Precambrian surface, in part at least, may have been due to crustal movements.

Lithology

The lithology of the Deadwood formation is quite variable so three widely separated wells were chosen from different areas of the state to show the lithology of the Deadwood formation in three different areas. These wells are the Amerada Petroleum Corporation - North Dakota "A" No. 9 well (NDGS 1385), located in the northeastern part of the state; the Continental Oil Company - Dronen No. 1 well (NDGS 145), located in the east-central part of the state; and since there is no well penetrating the complete Deadwood formation in the southwestern part of the state, the Carter Oil Company - Northern Pacific No. 1 well (Well H, Fig. 1), located in southeastern Montana is used for that area. The columnar sections show the generalized lithology for these wells with detailed descriptions included in Appendix B. The entire Deadwood formation was cored in the Continental Oil Company - Dronen No. 1 well (NDGS 145), however the cores and core chips are not available at the North Dakota Geological Survey, so these cores could not be examined. Descriptions of the cores are available in the well index files of the North Dakota Geological Survey and these descriptions were used because the writer felt that they were reliable and they provided more detailed information than could be obtained from cuttings. Sample descriptions of the Carter Oil Company - Northern Pacific No. 1 well were modified by sidewall core descriptions furnished by the Carter Oil Company.

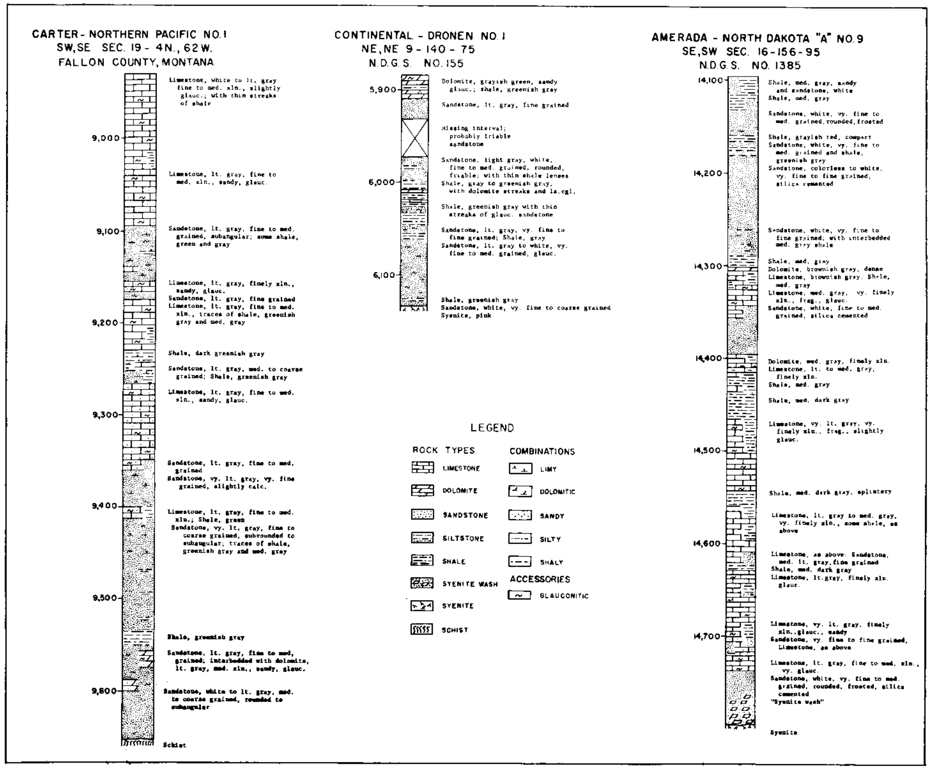


Figure 7 - Columnar sections of the Deadwood formation.

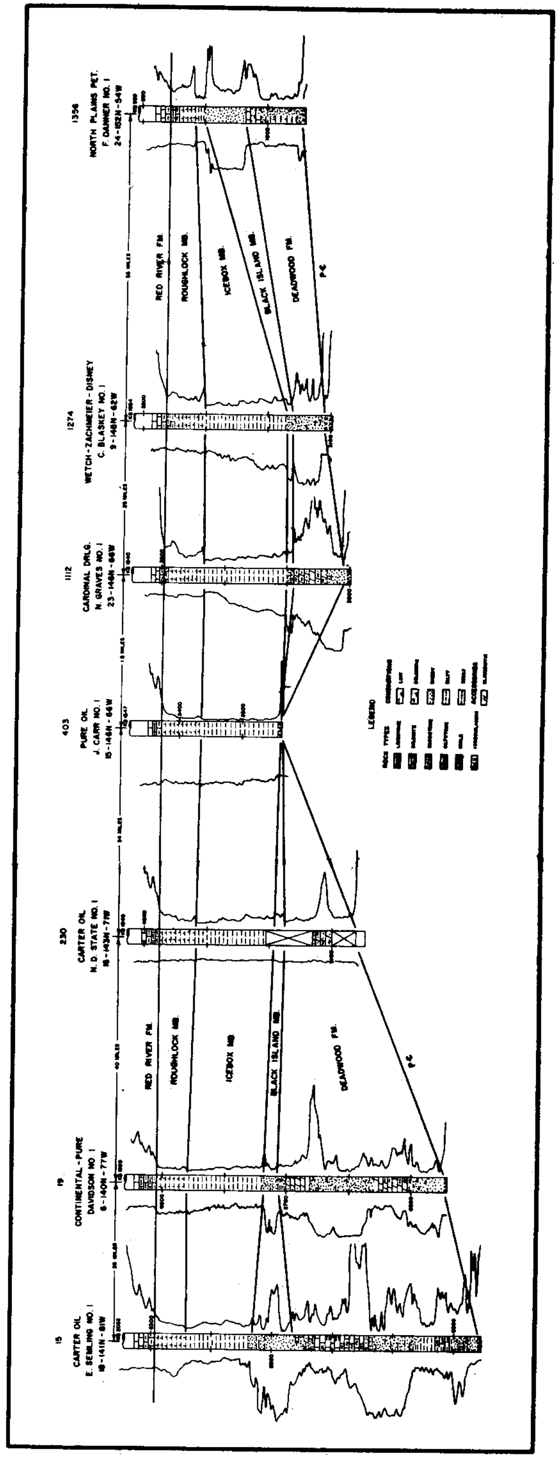


Figure 8 - Cross section along the line C - C' from central to eastern North Dakota.

A quartzose sandstone of variable thickness is present at the base of the Deadwood formation in every well in east-central North Dakota. This sandstone is usually composed of well rounded, often frosted, medium- to coarse-grained, poorly cemented, quartzose sandstone. This basal sandstone unit is overlain by a shale and carbonate unit consisting of light gray, fine- to medium-crystalline, sandy, glauconitic limestone, dolomite and greenish gray shale with minor amounts of sandstone. The sand content increases toward the southeast, grading into a glauconitic, dolomitic sandstone near the erosional edge in southeastern North Dakota. The shale and carbonate unit is overlain by a sandstone unit composed of fine- to medium-grained, glauconitic, slightly calcareous sandstone. In central North Dakota, where the Deadwood formation is thicker, the upper sandstone unit is overlain by limestone or dolomite, light gray, fine- to medium-crystalline, with scattered traces of glauconite and greenish gray shale.

In southeastern Montana, the sequence of a clean, quartzose, basal sandstone overlain by a shale and carbonate unit and then another sandstone unit is also present; although the shale and carbonate unit contains more interbedded sandstone than does the similar unit in the eastern part of the state. The upper part of the Deadwood formation in southeastern Montana is predominantly a light gray, fragmental, glauconitic limestone, sandy in part and containing thin bands of greenish gray shale.

A "syenite wash" of variable thickness overlying the Precambrian rocks has been reported by petroleum geologists (Petroleum Information; drilling reports) from four wells in northwestern North Dakota. Cuttings

of this interval consist of orange-pink, fresh-looking, angular fragments of syenite. "Syenite wash" is overlain by rounded, fine- to medium-grained, quartzose sandstone in the Amerada Petroleum Corporation - North Dakota "A" No. 9 well. The sandstone is overlain by a thick unit of light gray, fragmental, slightly glauconitic limestone interbedded with greenish gray and medium gray shale. The upper part of the Deadwood formation is composed mainly of a clean, quartzose sandstone similar to the lower member of the overlying Winnipeg formation, but it is less well sorted, more firmly cemented with silica, and separated from the lower member of the Winnipeg formation by beds of grayish red, greenish gray and medium gray shale.

Facies Relationships

The writer did not subdivide the Deadwood formation into members because some of the facies relationships are still somewhat doubtful, but some generalizations about the facies relationships can be made. The Deadwood formation was deposited on a Precambrian surface of low, but variable relief. One monadnock (?) in northwestern North Dakota and two "monadnocks" of lesser relief in eastern North Dakota have been partially outlined by drilling. The relief of the "monadnocks" in the eastern part of the state is only about 100 feet. These "monadnocks" were recognized from exploratory wells which show the Winnipeg formation lying on Precambrian rocks in areas where all of the surrounding wells have ± 100 feet of Deadwood formation underlying the Winnipeg formation. A clean, quartzose sandstone of variable thickness is present at the base of the Deadwood formation in nearly every well. In eastern North Dakota, the Deadwood formation may generally be subdivided into a basal

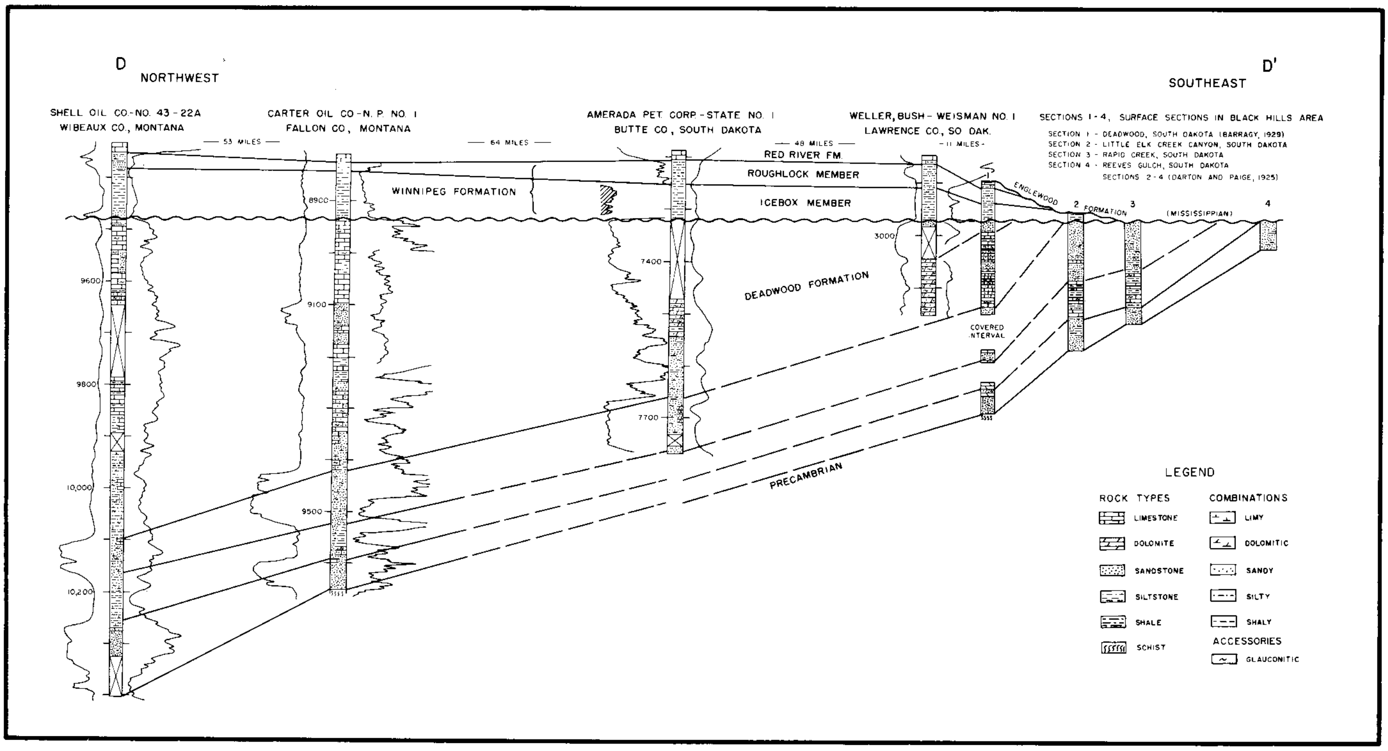


Figure 9 - Cross section along the line D - D' from the Black Hills, South Dakota, to southeastern Montana.

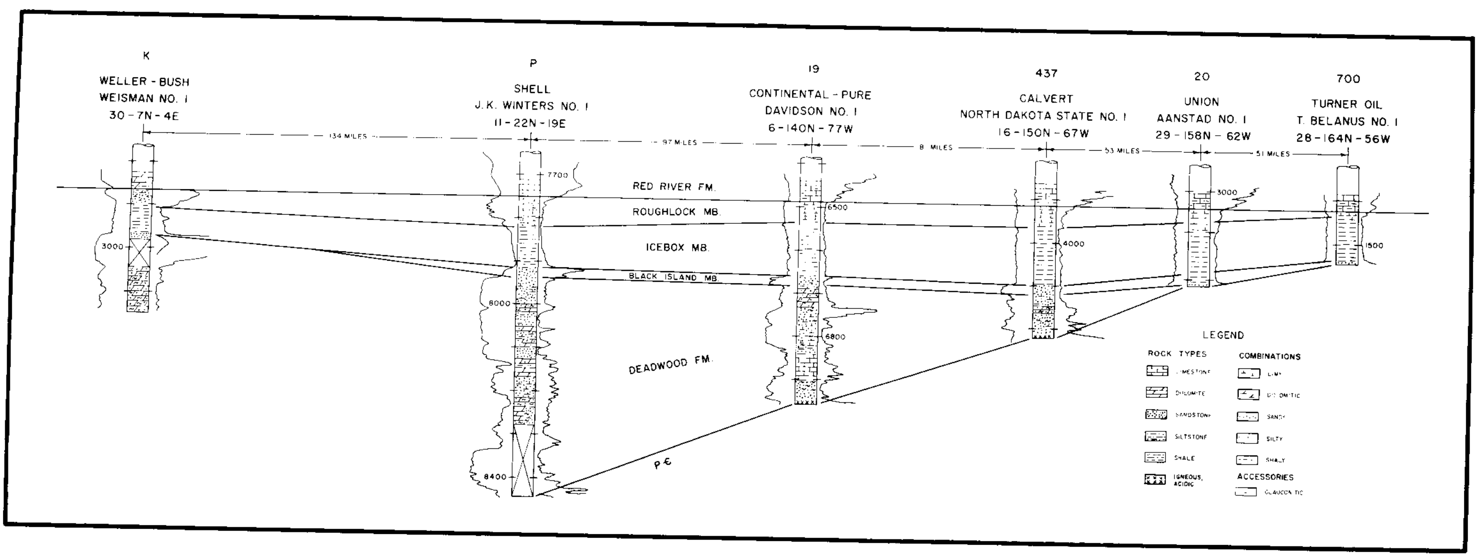


Figure 10 - Cross section along the line A - A' from northwestern South Dakota to northeastern North Dakota.

sandstone unit overlain by a shale and carbonate unit and then another sandstone unit. A similar sequence in southeastern Montana may be traced through the subsurface to the outcrop sections in the Black Hills (see Fig. 9) with a fair degree of certainty. Whether these similar sequences are physical equivalents cannot be demonstrated at the present time, but the similarity is striking. It is also noteworthy that the basal sandstone is non-glauconitic in all of these areas, whereas the upper sandstones and carbonates are all more or less glauconitic.

Cross sections of the Deadwood formation in eastern North Dakota (Figs. 8 and 10) show the Winnipeg formation lying on successively lower beds of the Deadwood formation eastward in North Dakota. This truncation of beds shows that the thinning of the Deadwood formation eastward is due mainly to pre-Winnipeg erosion.

The cross section from southeastern Montana to the Black Hills area (Fig. 9) shows a truncation of beds, indicating that the thinning of the Deadwood formation towards the Black Hills is also due mainly to pre-Winnipeg erosion.

The Deadwood formation could be divided into three lithologic units in the Nesson anticline area, a thin basal sandstone, a carbonate and shale unit, and an upper sandstone unit, but their physical equivalence to lithologic units of the Deadwood formation in the eastern and southern part of the state is problematical, so their usefulness is very limited.

Relations to Adjacent Strata

The Deadwood formation lies nonconformably on Precambrian rocks and is overlain unconformably by the Winnipeg formation, except, perhaps

in northwestern North Dakota where the Winnipeg formation may be conformable with the underlying Deadwood. The angular discordance is slight, but on regional cross sections it may be readily recognized (see Figs. 8 and 10) by the truncation of beds of the Deadwood formation.

The contact between the Winnipeg and Deadwood formations is not difficult to determine in most of the western part of the state, because the Winnipeg formation usually lies on carbonates of the Deadwood formation in this area. However, along the Nesson anticline and in the eastern part of the state, where the Winnipeg formation locally overlies sandstones of the Deadwood formation the contact is sometimes more difficult to determine.

In the Nesson anticline area, sandstones in the upper part of the Deadwood formation are similar in compostion and texture to the overlying sandstone of the Winnipeg formation, however, the sandstones of the Deadwood formation have been more firmly cemented with silica than the sandstones of the Winnipeg formation and are separated from the sandstones of the Winnipeg formation by beds of shale.

In the eastern part of the state the sandstones of the Deadwood formation often contain glauconite, whereas the sandstones of the Winnipeg formation never contain glauconite. However, the occurrence of glauconite within the Deadwood formation is somewhat erratic, so other criteria must be used to separate the sandstones of the Winnipeg and Deadwood formations when glauconite is not present in the Deadwood formation. Color and cementing materials are other characteristics which are useful for differentiating between the sandstones. Sandstones of the Winnipeg formation are generally colorless or white, poorly cemented, sometimes containing minor amounts of clay, whereas the sandstones of the Deadwood formation are generally orangish-pink or some shade of orange and usually have a calcareous or ferruginous cement.

Paleontology

Fossils are rare in cuttings and cores of the Deadwood formation; however, fragments of brachiopods were noted by the writer in cores of the Deadwood formation from the Amerada Petroleum Corporation - Boe, Olson Unit No. 1 well (NDGS 1403), although no identifiable specimens were obtained.

However, conodonts were obtained from cores of sandstone of the upper part of the Deadwood formation from three wells in Williams County. Nine specimens were obtained from core chips of the interval from 13,934 to 13,936 feet in the Amerada Petroleum Corporation - Ulven Unit No. 1 well (NDGS 1514); about 70 specimens were obtained from core chips of the interval from 13,994 to 13,996 feet in the Amerada Petroleum Corporation - Peterson, Davidson Unit No. 1 well (NDGS 1636), and about 220 specimens were obtained from core chips of the interval from 14,166 to 14,171 feet in the Amerada Petroleum Corporation - North Dakota "A" No. 9 well (NDGS 1385).

Conodonts obtained from the Deadwood formation are mostly simple cone types, but some blade and bar types are also present. These conodonts are brownish-black in color, rather than the usual amber color, and are not translucent. This caused some difficulties in identification because most conodont workers have used a classification based on internal structure. However, Hass (1959, p. 377) proposed a classification

based on external form. This classification was based partially on his studies of the morphology of conodonts in which he found that the growth axes of conodonts are reflected in the external form. Hence, in most cases a determination of the internal structure is unnecessary. Since a determination of the internal structure of the specimens from the Deadwood formation was impossible, the writer used the classification proposed by Hass for his identification.

The collections from the Deadwood formation have not been completely studied as yet, and the writer does not place as much confidence in his identifications of specimens from the Deadwood fauna as he does in his identifications of conodonts from the Winnipeg formation. Although some of the species identifications may be in error the writer is reasonably confident of the generic identifications. The following specimens have been identified from the Deadwood:

Acodus erectus Pander,
Acodus brevis Branson and Mehl
Acontiodus triangularis Pander
Coleodus simplex Branson and Mehl
Drepanodus arcuatus Pander
Drepanodus subarcuatus Furnish
Leptochirognathus sp.
Microcoelodus (?) *symmetricus* Branson and Mehl
Neocoleodus sp.
Oistodus sp.
Ptiloconus n. sp.

Age and Correlation

The exact relationship of the surface section of the Deadwood formation to the pre-Winnipeg rocks of the subsurface still presents problems both as to age and physical equivalence. The Deadwood formation in the Black Hills was considered by most workers to be Late Cambrian in age based on the faunal studies of Meyerhoff and Lochman (1934, 1935, 1936) until Lochman and Duncan (1950, p. 351) reported Early Ordovician trilobites from the upper part of the Deadwood formation in the northern part of the Black Hills. Since no evidence of an unconformity has been found between the rocks containing a Late Cambrian fauna and the rocks containing the Early Ordovician fossils, the Deadwood formation is now generally considered to be of Late Cambrian to Early Ordovician age in the northern Black Hills area.

The pre-Winnipeg sedimentary rocks of the subsurface are similar lithologically to the Deadwood formation of the surface section (see Fig. 9) so there has been no question about the validity of applying the term Deadwood formation to these rocks in the subsurface. The only question has been whether the Deadwood formation should be restricted to rocks of Late Cambrian age and whether the type section of the Deadwood formation includes part of the Winnipeg formation of the subsurface. The problem involving the relationship of the Winnipeg formation of the subsurface to the type section of the Deadwood formation will be deferred to the discussion of the Winnipeg formation; however, the writer's interpretation is shown on the cross section (see Fig. 9). This cross section shows some tentative relationships of the Deadwood formation based on subsurface studies of the writer and previously published surface studies.

Paleontological evidence for the exact age of pre-Winnipeg sedimentary rocks of the subsurface is sparse. Seager, and others (1942, p. 1423) and Ross (1957, p. 450) have stated that much of the Deadwood formation of eastern Montana is Early Ordovician in age. This conclusion is in agreement with the physical evidence which shows the upper beds of the

Deadwood formation being truncated by pre-Winnipeg erosion towards the Black Hills outcrop area.

The study of the Deadwood formation in North Dakota did not reveal any widespread unconformity which might represent the Cambro-Ordovician systemic boundary. Rather, the study indicates that deposition was probably continuous from Late Cambrian through Early Ordovician, and the only major break in sedimentation in the studied interval was between the Deadwood formation and the overlying Winnipeg formation of Middle Ordovician age. The lack of evidence of a break in sedimentation in the pre-Winnipeg rocks makes it nearly impossible to attempt to restrict the Deadwood formation of either the surface or subsurface sections to rocks of Late Cambrian age.

The conodont fauna of the Deadwood formation has such a limited known geographic distribution and it is so different from any previously described fauna that definite conclusions cannot be made from this fauna. However, it does have some significance as to the age of the upper part of the Deadwood formation in the Nesson anticline area and seems to reinforce the conclusions of Ross (1957) that much of the Deadwood formation in the subsurface of the Williston Basin is of Early Ordovician age.

Conodonts have commonly been thought to begin in Early Ordovician, but recently Müller (1956, p. 1335) reported 53 specimens associated with Late Cambrian trilobites in limestone of the Deadwood formation in the northern Black Hills, South Dakota. He also reported conodonts from the <u>Conaspis</u> zone in the Dugway Mountains, Utah. He did not give systematic descriptions of these specimens, but he stated that they were all simple cone types, were characterized by large basal cavities, and many of the specimens were of a different preservation, having been altered to a "sericite-like" material.

The conodonts from the Deadwood formation of North Dakota appear to be of an "altered" type and resemble Müller's Upper Cambrian specimens in that respect; but the presence of compound forms in the collections from the Deadwood formation in North Dakota, indicated that this fauna is probably younger than Müller's Upper Cambrian faunas.

This Deadwood fauna does not closely resemble any previously described fauna. The collections from the Deadwood formation are composed mostly of representatives of the Distacodidae, or simple cone-type conodonts, which account for about 75 per cent of the specimens. This predominance of the Distacodidae is characteristic of Early Ordovician conodont faunas and suggests an Early Ordovician age for the Deadwood fauna.

Three genera of blade and bar type conodonts which are present in the Deadwood fauna, namely Coleodus, Neocoleodus, and Leptochirognathus, have not previously been reported from rocks older than the Harding formation (Middle Ordovician, Colorado). However, these genera represent only a very minor, though conspicuous part, of the Deadwood fauna and most of the forms common to the Harding formation (Branson and Mehl, 1933a; Sweet, 1955), such as Chirognathus, Cordylodus, Ozarkodina, and Trichonodella are absent in the Deadwood fauna. Therefore, the Deadwood fauna is probably older than the Harding fauna. Until more study of the ranges of Lower and Middle Ordovician conodonts have been made, the exact position of the Deadwood fauna is uncertain, however, the predominance of representatives of the Distacodidae suggests that this fauna should probably be considered to be of Early Ordovician age.

WINNIPEG FORMATION

Name and Definition

Dowling (1895, p. 66) first applied the term Winnipeg sandstone to the predominantly sandstone section overlying the Precambrian rocks and underlying the "mottled limestone" (Red River formation of later writers) in the Lake Winnipeg area of Manitoba. In the subsurface of southwestern Manitoba and eastern North Dakota the term Winnipeg formation has been applied to the section composed predominantly of greenish gray shale with a thin basal sandstone which overlies the Precambrian and underlies the Red River formation. This unit has been traced through the subsurface of North Dakota and parts of South Dakota, so that although there are some facies changes within the Winnipeg formation, this unit can now be traced from the Manitoba area through the subsurface of the Williston Basin to the outcrop sections in the northern Black Hills, South Dakota.

Thickness

The isopach map of the Winnipeg formation (Fig. 12) shows an area of marked thickening in northwestern North Dakota and one of slight thickening in south-central North Dakota. The area of thickening in northwestern North Dakota is near the center of the Williston Basin and coincides with the greatest thickness of the lower part of the Winnipeg formation, suggesting that the Williston Basin began to form with the beginning of Winnipeg deposition. The isopach map of the Deadwood formation might suggest that the Williston Basin began to form during the time of deposition of the Deadwood formation. However, the present thickness of the Deadwood formation reflects an interval of pre-Winnipeg erosion and not the original depositional thickness, hence the increased thickness in the central part of the Basin is possibly due to a protective cover of Winnipeg sediments in that area while the margins of the Basin were still being eroded. Studies have shown (e. g., Laird, 1953, p. 27; Porter and Fuller, 1959, p. 176) that the areas of greatest accummulation of sediments in the Williston Basin have shifted during Early Paleozoic time. It is noteworthy that the area of thickening in the south-central part of the state is due mainly to a thickening of the upper part of the Winnipeg formation, and this is near the area of greatest thickness of the overlying Red River formation.

The limit of the Winnipeg formation towards the southeast and east is an erosional limit since the Winnipeg formation maintains a relatively uniform thickness until the erosional edge of the overlying Red River formation is reached, and then the Winnipeg formation thins rapidly. The Winnipeg formation thins toward the southwest by non-deposition or possibly erosion of the lower beds and thins slightly toward the northeast by depositional thinning and possibly some erosion of the shale lithofacies.

Lithology

Manitoba:

Surface sections of the Winnipeg formation were examined on Black, Punk, and Deer Islands in July, 1959. Glacial drift extends to the beaches along the north shore of Black Island except for one locality, where a few feet of firmly cemented, arkosic, conglomeratic sandstone is present just above lake level. Although the contact with the

Precambrian rocks was not exposed, it is noteworthy that further east along the north shore the bays lack sandy beaches, whereas to the west, broad, sandy beaches are numerous and are probably composed, at least in part, of sand from the basal sandstone of the Winnipeg formation. Thus, the arkosic sandstone is probably from the basal part of the Winnipeg formation.

The writer checked one of Baillie's measured sections (Baillie, 1952, Section 4, p. 43), noted an exposure of sandstone of the upper unit of the Winnipeg formation and some other exposures of the lower unit of the Winnipeg formation, but did not reach the Precambrian-Winnipeg contact along the south shore of Black Island. The outcrops of the Winnipeg formation on Black Island are incomplete sections of the Winnipeg formation and do not clearly show the stratigraphic relationships of Baillie's units within the Winnipeg formation or the contact with the overlying Red River formation.

The complete Winnipeg formation is not exposed at any one locality in the Lake Winnipeg area, but the lower and upper contacts may be seen on the north side of Punk Island during periods of low lake levels. Precambrian greenstone was exposed at lake level in July, 1959, near the northeastern corner of the island. Here the basal sandstone of the Winnipeg formation is a clean, rounded, very fine- to medium-grained, friable, quartzose sandstone. This sandstone is so poorly consolidated that it is difficult to differentiate between sandstone in place and reworked beach sand. Thus, the exact contact between the sandstone and the greenstone is difficult to determine. However, there are at least two localities where a few feet of bedded sandstone are present only a few hundred feet laterally from exposed greenstone; and since the slope is low, this sandstone cannot be very much above the base of the formation.

The complete thickness of the basal sandstone unit could not be determined, but 21 feet of sandstone was exposed above lake level at one locality along the north shore of Punk Island. The silicified, arkosic sandstone which is present at lake level at this locality is very similar to the sandstone bed exposed on the north side of Black Island and is probably very near the base of the Winnipeg formation. A few hundred yards farther west along the north shore, the Red River formation was exposed about 43 feet above lake level. The bank was covered with slump, so complete details of the section were not determined because of lack of time; however, the contact between the basal sandstone unit and the overlying shale was about 19 feet above lake level.

The upper part of the Winnipeg formation is much better exposed on the northeast corner of Deer Island, where Baillie's "upper unit" of the Winnipeg formation is well exposed in one nearly vertical section. The basal sandstone is exposed at lake level and along the shore to the southeast of this locality. It consists of yellowish gray, rounded, frosted, very fine- to medium-grained, firmly cemented, quartzose sandstone. The sandstone is overlain by 13 feet 7 inches of greenish gray shale and sandy shale with interbedded thin lenses of sandstone. The upper 9 feet 6 inches of the Winnipeg formation is composed of very fine- to medium-grained, poorly consolidated, yellowish gray, quartzose sandstone, the lower four feet of which contain thin greenish gray shale lenses; the contact with the overlying Red River formation is sharp.

Baillie (1952, p. 9) has estimated the thickness of the Winnipeg formation at ± 80 feet in the Lake Winnipeg area. Measurements of incomplete sections lead the writer to believe that this estimate is too large, at least for the Punk Island area, where an estimate of about 50 feet is probably more nearly correct.

The physical equivalence of the units of the Winnipeg formation of the outcrop sections with the subsurface sections in Manitoba are still somewhat doubtful. This is due to relatively rapid facies changes near the outcrop area and a lack of wells for subsurface data near the outcrop area.

The closest well to the outcrop area for which sample descriptions are available is the Stony Mountain No. 1 well, located in sec. 29, T. 12, 2 EPM, about sixty miles southwest of the Victoria Beach outcrop area. This well has a section of the Winnipeg formation which is typical of the subsurface of northeastern North Dakota and much of southwestern Manitoba. Sample descriptions for this well are as follows (Kerr, 1949, p. 85):

Winnipeg formation	
610 - 650	Shale, green-grey
650 - 695	Shale, green
695 - 708	Sandstone, light-grey, coarse-grained, very many grains rounded and etched
Precambrian	
708 - 740	Igneous rock, light-grey, much biotite

This well shows the predominance of shale which is characteristic of the Winnipeg formation in much of the subsurface of southern Manitoba, although a thick sandstone section is present in the upper part of the Winnipeg formation in some areas (Andrichuk, 1959, p. 2349). However, even where the thick sandstone section is present in the upper part of the Winnipeg formation, the lower section is similar to the section in the Stony Mountain No. 1 well.

South Dakota:

The Winnipeg formation may be divided into three members in the subsurface of the north-central part of South Dakota, but as the formation thins towards the Black Hills, only the upper two members are present (see Fig. 9). The upper member of the Winnipeg formation is about 35 feet thick in the Weller, Bush - Weisman No. 1 well, located in SW 1/4 SE 1/4 sec. 13, T. 5 N., R. 3 E., Lawrence County, South Dakota, which is about eleven miles north of the Whitewood Canyon outcrop sections near Deadwood, South Dakota. In this well, the upper member of the Winnipeg formation consists of very light gray siltstone and very fine grained sandstone, becoming dolomitic in the upper part and containing minor amounts of shaly beds. The similarity of the surface section to the upper member of the Winnipeg formation in the Weller, Bush - Weisman No.1well, was recognized by Carlson (1958, p. 23) and therefore, the term Roughlock member was applied to the upper member of the Winnipeg formation in the subsurface of the Williston Basin.

If the terms Roughlock and Icebox are accepted as members of the Winnipeg formation, the Winnipeg formation then crops out in the northern Black Hills where it lies unconformably on the Deadwood formation and is overlain conformably by the Whitewood formation in some areas and unconformably by the Englewood formation (Mississippian) in other areas where the Whitewood formation is absent.

McCoy suggested that the Skolithos-bearing quartzitic sandstone (his Aladdin formation) was probably equivalent to the lower member of

the Winnipeg formation of the subsurface of the Williston Basin. This hypothesis is difficult either to prove or disprove, but the writer believes that the physical evidence of the surface and subsurface sections strongly suggests that McCoy's hypothesis is erroneous.

At the type section of the Deadwood the lower part of the Skolithos-bearing quartzitic sandstone contains a 14-inch bed of very fine-grained, calcareous sandstone, which is very similar to the sandstone beds underlying the quartzitic sandstone. Furnish, and others (1936, p. 1332) have also noted that the Skolithos-bearing quartzitic sandstone unit seems to grade into the underlying sandstone, whereas the contact between the quartzitic sandstone and the overlying green shale is sharp. This suggests that if there is a break in sedimentation in this area, it is between the quartzitic sandstone and the Icebox shale. It may be significant that the basal few feet of the Icebox shale contain sand lenses and "floating" sand grains; but the remainder of the shale contains few, if any, sand grains.

An outcrop south of the Englewood Station, located in the SW 1/4 NE 1/4 sec. 30, T. 4 N., R. 3 E., Lawrence County, South Dakota, adds further information about the nature of the Deadwood-Winnipeg contact in the Black Hills outcrop area. At this locality, green shale (Icebox member) lies on a reddish gray, glauconitic, dolomitic limestone of the Deadwood formation with just a few inches of reddish, fine-grained sandstone intervening. If the quartzitic sandstone were equivalent to the basal sandstone of the Winnipeg formation, its absence at this locality could not be readily explained, however, if it is a part of the Deadwood formation its absence can be readily explained as due to erosional thinning of the Deadwood formation, since this section is located about nine miles southwest of Deadwood, South Dakota, and the Deadwood formation thins from 400 to 500 feet in the northern Black Hills to 4 to 50 feet in the southern Black Hills.

In the subsurface, the Weller, Bush - Weisman No. 1 well has a sandstone unit of indeterminate thickness underlying the Icebox member of the Winnipeg formation. Although lithologic samples were available for only the upper ten feet, mechanical logs indicate that the sandstone unit is probably about 50 feet thick. These samples are composed of grayish orange to grayish pink, fine- to medium-grained, quartzose sandstone, which is probably a physical equivalent of the quartzitic sandstone of the Whitewood Canyon section. The thickening of the sandstone unit from 12 to 25 feet in the outcrop area to 50 feet in the Weller, Bush - Weisman No. 1 well is probably the result of including the calcareous sandstone of the surface sections with the quartzitic sandstone as one unit in the subsurface, although the thickening of the sandstone unit would also fit the regional pattern of northward thickening of the Deadwood formation.

Therefore the writer concludes that the Black Island member of the Winnipeg formation is absent in the Black Hills area, unless the lower few feet of sandy shale is considered to be the Black Island member and that the term Aladdin sandstone should be rejected because it is a relatively insignificant part of the Deadwood formation.

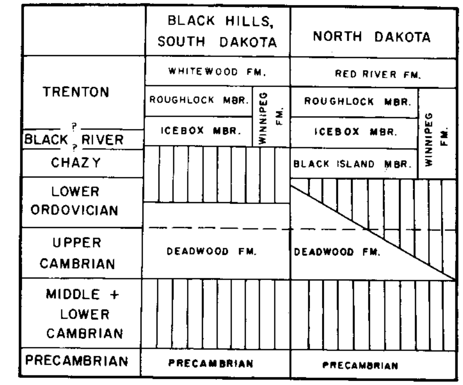


Figure 11 - Time Rock Correlation chart.

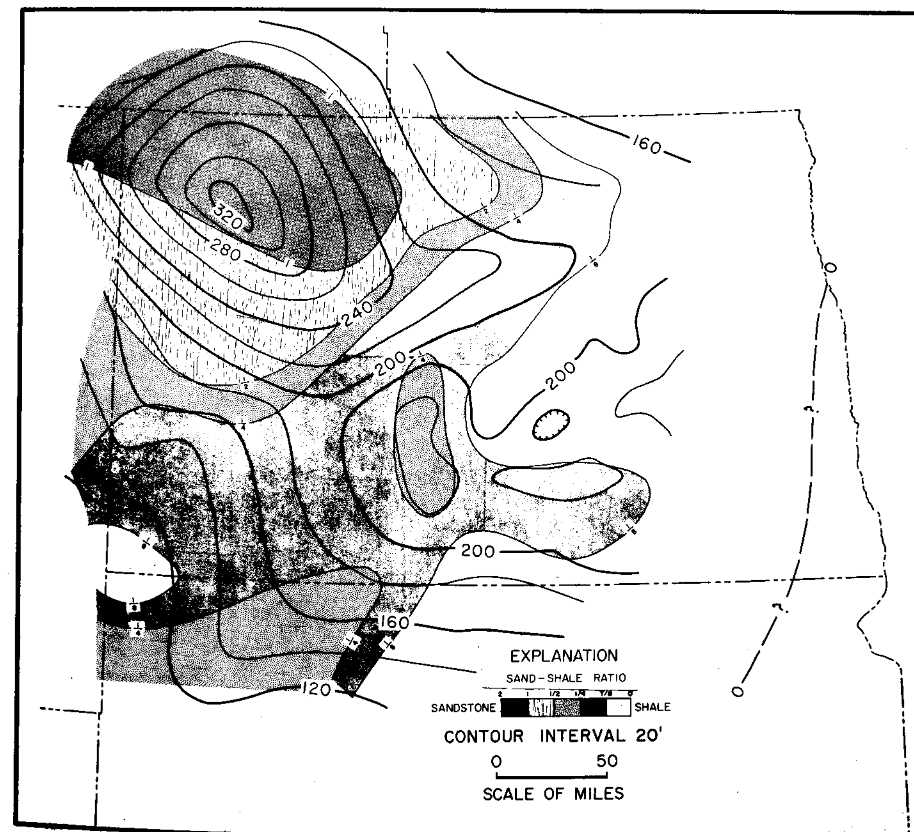


Figure 12 - Isopach and sand-shale ratio map of the Winnipeg formation.

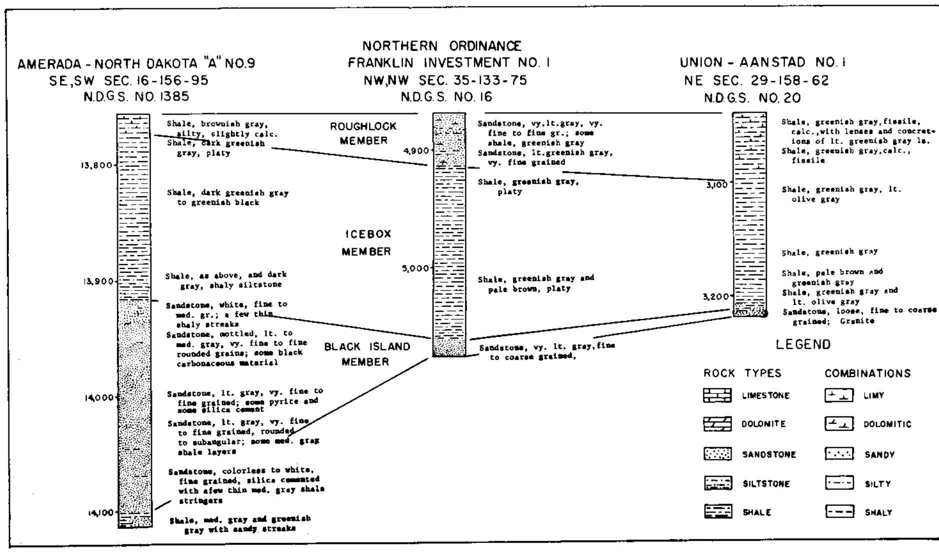


Figure 13 - Columnar sections of the Winnipeg formation.

North Dakota:

The Winnipeg formation is composed of sandstone, shale, and siltstone which range in thickness from 0 to 357 feet in North Dakota and which may be divided into three members. This three member subdivision is useful throughout most of North Dakota and can be recognized in adjacent states and provinces, although the upper member is difficult to trace on the north and northeastern flank of the Williston Basin. The isopach map of the Winnipeg formation (Fig. 12) represents the depositional thickness of the Winnipeg formation for the most part, but the limit toward the southeast is due to post-Red River erosion.

In North Dakota, the Winnipeg formation is composed of a clean, quartzose, basal sandstone member overlain by a greenish gray, silty to clayey shale member and an upper calcareous shale member except in the southeastern part of the state where the upper part of the Winnipeg formation consists of a calcareous siltstone or very fine grained, calcareous sandstone. The lithology and thickness of these members varies, so three wells were chosen to show some of these variations in three areas of the state. The wells chosen for the columnar sections (Fig. 13) were the Union Oil Company - Aanstad No. 1 well (NDGS 20), northeastern North Dakota; the Northern Ordinance, Franklin Investment No. 1 well, (NDGS 16), Emmons County, south-central North Dakota; and the Amerada Petroleum Corporation - North Dakota "A" No. 9 well, (NDGS 1385), northwestern North Dakota.

Members of the Winnipeg Formation

Black Island Member:

Name and Definition

Genik (1951) proposed the term Black Island member for the basal sandstone member of the Winnipeg formation. This was an unfortunate choice of terms, because neither the upper nor lower contacts of the basal sandstone unit are exposed on Black Island, although these contacts are exposed on nearby islands. Nevertheless Kupsch (1953, p. 11), working in the east-central Saskatchewan outcrop area used the term Black Island member for the basal sandstone member of the Winnipeg formation of that area. Later Genik (1954, p. 1) applied the term Black Island member to the basal sandstone unit of the Winnipeg formation in the surface and subsurface of Manitoba and throughout the subsurface of the Williston Basin.

Some geologists (*e. g.*, Andrichuk, 1959, p. 2349) doubt that the basal sandstone of the surface sections in the Lake Winnipeg area is equivalent to the basal sandstone of the subsurface because of (a) the greater thickness of the basal sandstone and the lesser thickness of the shale in the surface sections and (b) the lesser total thickness of the Winnipeg formation in the surface sections. However, it seems reasonable that the increased thickness of the coarser clastics in the surface sections may be due to deposition of this part of the column nearer the strandline. By this interpretation the basal sandstone of the surface section is continuous with the basal sandstone of the subsurface section. Since the term Black Island has previously been applied to the basal sandstone in the subsurface, and the basal sandstone of the subsurface is probably equivalent to the basal sandstone of the surface section on

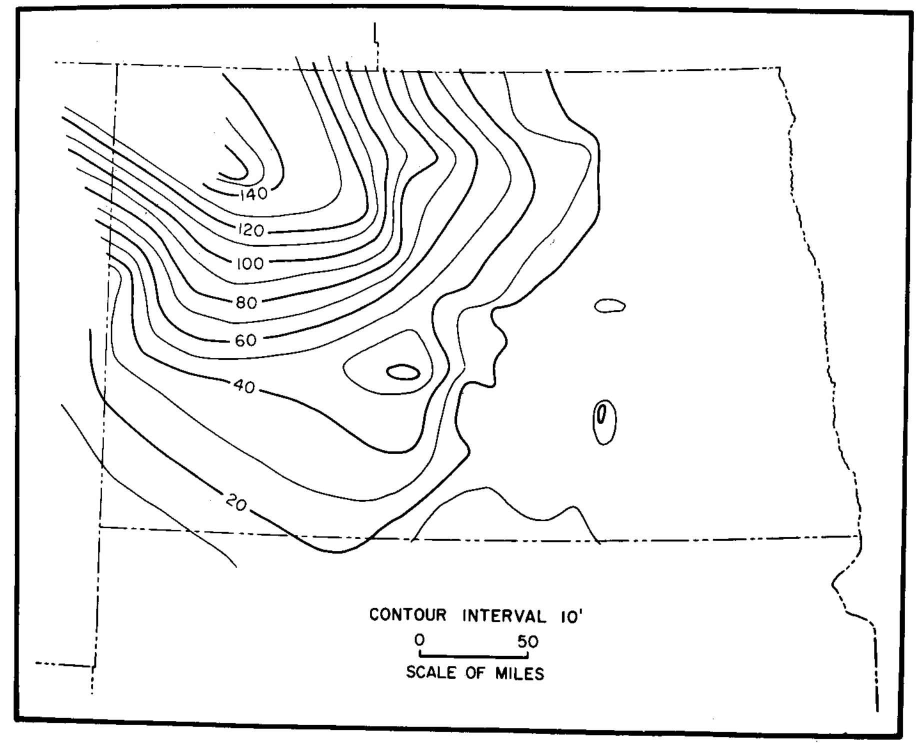


Figure 14 - Isopach map of the Black Island member of the Winnipeg formation.

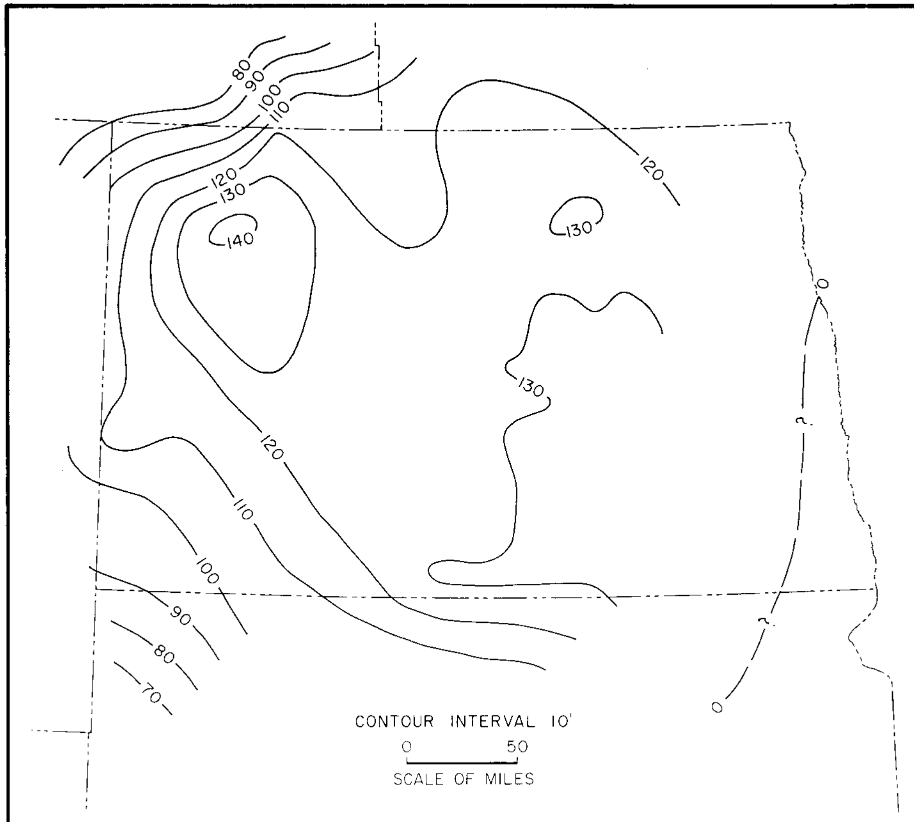


Figure 15 - Isopach map of the Icebox member of the Winnipeg formation.

Black Island, the term Black Island member is herein accepted for the lower member of the Winnipeg formation in the subsurface of the Williston Basin.

Thickness and Lithology

In the eastern part of North Dakota where the Black Island member is generally less than 30 feet thick it is composed of well rounded, usually frosted, very fine- to medium-grained, very friable, quartzose sandstone. As this member thickens toward the north and northwest, where it attains a maximum thickness of 170 feet in the Amerada Petroleum Corporation - North Dakota "A" No. 9 well, it becomes less well sorted and the sand grains show less evidence of mechanical action. The Black Island member is composed of mottled light gray, very fine- to medium-grained, rounded to subangular, poorly sorted, silty and argillaceous sandstone in northwestern North Dakota. The clay content is small, but it accounts for a mottled appearance of the sandstone. In this area, the sandstone is firmly cemented either with silica or, in some cases, with pyrite.

<u>Icebox Member:</u>

Name and Definition

The term Icebox formation was introduced by McCoy (1952, p. 45) for some olive-green shales which overlie the <u>Skolithos</u>-bearing quartzitic sandstone and underlie light colored siltstone in the northern Black Hills outcrop area. These shales, previously considered to be a part of the Whitewood formation, were given formational rank by McCoy. This shale unit can be traced by means of sample and mechanical logs into the subsurface of both South Dakota and North Dakota (see Fig. 10) where it is equivalent to the middle member of the Winnipeg formation. Therefore the writer considers the Icebox to be a member of the Winnipeg formation.

Thickness and Lithology

The Icebox member of the Winnipeg formation consists of 90 to 145 feet of greenish gray to dark greenish gray, splintery to fissile, waxy, non-calcareous shale. Locally in the eastern part of North Dakota, however, the shale may be pale brown or grayish red. The Icebox member contains some "floating" sand grains, sand lenses, and is silty in the lower part. Black phosphatic nodules, which have been cited as evidence of diastems within the Winnipeg formation (Baillie, 1952, Genik, 1954), are relatively common in the shale of the outcrop sections in Manitoba and South Dakota as well as in the subsurface of the Williston Basin. However they do not seem to be useful as horizon markers; rather they seem to have an erratic distribution within the shale. The thinning of the Icebox member on the southwest flank of the Williston Basin is probably due to non-deposition of the lower beds but might be due, at least in part to erosion. The contact with the underlying Black Island and overlying Roughlock members are gradational.

<u>Roughlock Member:</u>

Name and Definition

The term Roughlock formation was introduced by McCoy (1952, p. 44) for the light colored siltstone which overlies the Icebox shale and underlies the Whitewood limestone in the northern Black Hills. This unit can be traced into the subsurface of northern South Dakota and southern North Dakota on the basis of lithology and mechanical logs, where it is equivalent to the upper member of the Winnipeg formation. Therefore, the term Roughlock member has been applied to the upper member of the Winnipeg formation in the subsurface of the Williston Basin.

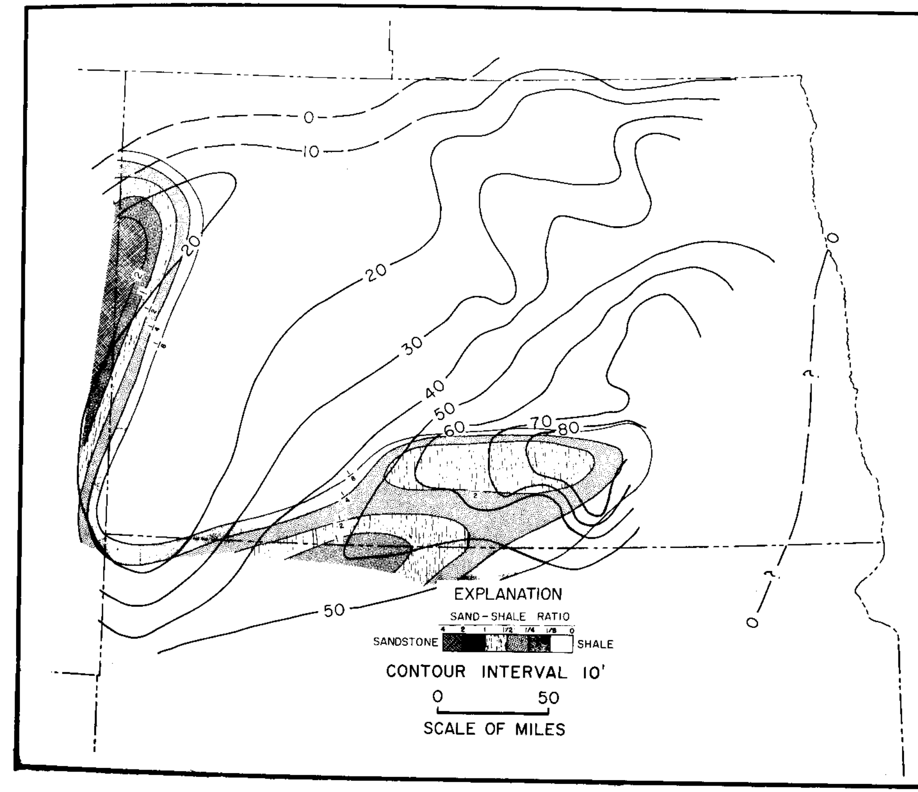


Figure 16 - Isopach and sand-shale ratio map of the Roughlock member of the Winnipeg formation.

Thickness and Lithology

The Roughlock member ranges in thickness from 0 to 90 feet. It consists of very light gray, very fine grained, calcareous sandstone and siltstone in the south-central part of the state. The siltstone grades laterally into a greenish gray, calcareous, silty shale and then into a greenish gray, calcareous shale to the north and northeast. Toward the north, the Roughlock member gradually becomes very difficult to trace as the transition from the green shale of the Icebox member into the overlying argillaceous limestone of the Red River formation is less gradual. In northwestern North Dakota, near the limit of recognition of the Roughlock member, the interval referred to as the "Winnipeg transition zone" by some petroleum geologists (Petroleum Information, drilling reports) is herein included in the Roughlock member. The area of greatest thickness of the Roughlock member coincides quite closely to the areas of increased coarser clastics towards the southern margin of the Basin.

Facies Relationships

Winnipeg deposition began with very fine- to medium-grained clastics which were generally well sorted before they were deposited; although in northwestern North Dakota, the Black Island member is much thicker than in other areas of the state, and is not as well sorted. The greater thickness of the formation in northwestern North Dakota may indicate more rapid subsidence in that area and/or that clastics were being supplied to that area, while much of eastern North Dakota was still being eroded. The greater thickness of the basal sandstone accounts for most of the increased thickness of the Winnipeg formation in northwestern

North Dakota (Fig. 12) and accounts for the higher sand-shale ratios in that area.

Deposition was apparently continuous from the beginning of deposition of the Winnipeg formation at least through deposition of the overlying Red River formation in the central part of the Williston Basin. The sequence was one of gradually finer grained clastics upward, beginning with very fine- to medium-grained sandstone, then silty shale, shale, calcareous shale and as the supply of clastics diminished, carbonates became the dominant lithofacies. This was probably due to the seas becoming more widespread, so this area was further from the source of clastic material. The boundary between the Winnipeg and Red River formations has been drawn at the position in the section between predominantly clastic rocks below and predominantly carbonate rocks of the Red River above.

The sequence of Winnipeg deposition on the margins of the Basin differs from that in the central part of the Basin and is yet different on various flanks of the Basin. Thus, on the northeastern flank of the Williston Basin, in the Lake Winnipeg area the Winnipeg formation is composed of a basal sandstone, a middle shale, and an upper sandstone and the contact between the sandstone and the overlying limestone of the Red River formation is sharp. In contrast, along the southwestern flank of the Basin, the basal sandstone is absent and the shale member is overlain by siltstone which grades into the overlying limestone of the Whitewood formation.

Some geologists (e. g., McCoy, 1952; Butler, and others, 1955) do not agree with the interpretation that the Skolithos-bearing, quartzitic sandstone is part of the Deadwood formation rather than an equivalent of the basal sandstone of the Winnipeg formation. However, the writer believes that the absence of a basal sandstone in the Winnipeg formation in several wells in southwestern North Dakota, southeastern Montana and northwestern South Dakota, the thinning of the Icebox member from 100 feet in southwestern North Dakota to 30 to 70 feet in the surface sections in the northern Black Hills, and the relatively uniform thickness or slight thickening of the Roughlock member of the Winnipeg formation from southwestern North Dakota to the surface sections in the northern Black Hills show that the Winnipeg formation thins toward the Black Hills by non-deposition of the lower beds of the Winnipeg formation.

Although the surface section in the Lake Winnipeg area is mostly sandstone, the presence of the shale beds makes a sequence of a basal sandstone, middle shale and upper sandstone very similar to the sequence in the Carmen, Manitoba, area. In the subsurface of the Carmen area the basal sandstone unit is much thinner, and the shale and the upper sandstone unit are much thicker. The greater thickness of the basal sandstone unit and the thinness of shale in the Lake Winnipeg area might be explained by proximity to the strandline. Hence, the basal sandstone of the surface section may be interpreted as representing a lateral equivalent of the basal sandstone of the subsurface plus a partial equivalent of the shale unit of the subsurface.

In contrast, the difference in thickness of the upper sandstone unit in the two areas may be due to different modes of deposition. Andrichuk (1959, p. 2354) suggested that the Carmen sand body is a bar type deposit, based on its shape and areal extent. The upper sandstone of the surface sections, however, probably represent nearshore deposits of the "Winnipeg sea". Thus, the Carmen sand body is interpreted as having been deposited as an offshore bar while the upper sandstone of the Lake Winnipeg area was

being deposited near the strandline, rather than an equivalent of the entire surface section as was suggested by Andrichuk.

This conclusion is based partially on the similar lithologic sequence in these two local areas and partially on paleontological evidence which is discussed elsewhere in this paper. The age of the Winnipeg formation in the Carmen area can only be determined by indirect evidence, but if the entire surface section were equivalent to the Carmen sand body, it should be expected that the surface section would be younger than the lower part of the Winnipeg formation in the Carmen area. However, the lower part of the section of the Winnipeg formation of the Carmen area is nearly the same thickness as the Winnipeg formation in northeastern North Dakota and the lower section of the Winnipeg formation in the remainder of southern Manitoba; hence the lower section of the Winnipeg formation of the Carmen area is approximately equivalent to the Icebox and Black Island members of the Winnipeg formation of North Dakota. Since the shale lithofacies of the surface section in Manitoba contains a fauna similar to the upper part of the Icebox member of the surface section in South Dakota and the subsurface section in North Dakota, it is probably equivalent to the upper part of the shale of Andrichuk's lower section of the Winnipeg formation of the Carmen area. The lower part of the shale lithofacies of the lower section of the Winnipeg formation of the Carmen area may have been replaced by the sandstone lithofacies of the nearer shore environment in the Manitoba outcrop area. This would account for some of the thinning of the shale in the outcrop area. Both Baillie (1952) and Genik (1954) noted oolitic pyrite zones in the uppermost beds of the basal sandstone unit and zones of phosphatic nodules in the shale of the surface sections, and they suggested that these zones might represent diastems within the Winnipeg formation. These diastems might also account for some of the thinning of the Winnipeg formation in the Lake Winnipeg area.

Relations to Adjacent Strata

The Winnipeg formation lies unconformably on the Deadwood formation throughout most of North Dakota and in South Dakota and eastern Montana. Exceptions to this are in northeastern North Dakota and southern Manitoba, where the Winnipeg formation lies nonconformably on Precambrian rocks and in northwestern North Dakota where it may be conformable with the underlying Deadwood formation. Throughout the subsurface and in the surface sections in South Dakota, the Winnipeg formation is gradational into the overlying limestones. However, in Manitoba the contact with the overlying Red River formation is sharp in the outcrop areas, indicating a possible break in sedimentation in that area.

Paleontology

General

Macauley reported several macrofossils from cores of the Union Oil Company - Aanstad No. 1 well (NDGS 20), but they are rare in cuttings and cores of the Winnipeg formation. The writer found only two identifiable specimens in cuttings of the Winnipeg formation and no identifiable specimens in the few available cores. The two specimens were obtained from a depth of 6,090 to 6,100 feet in the Caroline Hunt Trust Estate- University Lands No. 1 well, (NDGS 701) Burleigh County, North Dakota. These specimens were free from the matrix, but they are greenish gray in color and are probably from the Winnipeg formation. They have been identified as Paucicrura rogata (Sardeson) and Hesperorthis tricenaria

(Conrad). Both of these species are listed as Middle Ordovician fossils (Cooper, 1944). One specimen of Flexicalymene sp. in a core from the Roughlock member of the Winnipeg formation in the Union Oil Company - Aanstad No. 1 well is in the collections of the Department of Geology, University of North Dakota.

However, the Winnipeg formation contains a varied microfauna. Although the shale is not uniformly fossiliferous, most of the samples contain at least a few specimens of conodonts and some samples contained a few ostracodes. The ostracodes have not been studied, but two specimens of Aechmina sp. were readily identified from collections from a depth of 5,787 feet in the Continental Oil Company - Leuth No. 1 well (NDGS 207). The conodonts are the most useful fossils, however, because of their relative abundance, widespread occurrence, and the variety of forms present. The collections in the present study were obtained from two localities in South Dakota, two localities in Manitoba and three wells in North Dakota. The stratigraphic position of the samples from the subsurface of North Dakota and the surface sections in South Dakota with respect to the three member subdivision is quite definite. However, the relationship of the samples from Manitoba with respect to this three fold subdivision is not clear.

The conodonts of the Winnipeg formation are amber in color and are readily identifiable following either the classification of Branson and Mehl (1944, p. 237) or that of Hass (1959, p. 377); hence to be consistent with the earlier treatment of the Deadwood fauna, the writer has followed Hass in the classification of conodonts from the Winnipeg formation also. A number of studies of Middle and Upper Ordovician conodonts have been published, including studies of most of the formations from the Glenwood through the Maquoketa formations in the Upper Mississippi Valley (Stauffer, 1935a, 1935b, Glenister, 1957, Ethington, 1959). Therefore, most of the specimens of the Winnipeg fauna can be referred to previously described species, and comparisons with Middle and Upper Ordovician faunas from a nearby geographic area can be readily made. The number of specimens of each species which were obtained from each sample is shown in Table II (in pocket). Some striking differences may be noted within the Winnipeg formation by comparing faunas from different localities and different horizons from the same locality.

<u>Conodont Faunas:</u>

Deer Island, Manitoba: Baillie's upper unit of the Winnipeg formation is exposed on the northeast corner of Deer Island (Fig. 17). Eight samples were collected from this locality, seven of which were from the measured section.

Sample F-1 was from the uppermost part of the basal sandstone unit and was unfossiliferous. Samples F-6 and F-7 were from sandstone of the upper unit of the Winnipeg formation and were also unfossiliferous. Sample F-5 was mostly sandstone and contained only a few specimens. Sample F-2, from the basal foot of the sandy shale, contained only a few specimens. Sample F-8 was from an outcrop a few hundred feet northwest of the measured section and from the same stratigraphic position as sample F-2. Samples F-3 and F-4 were from the sandy shale and contained a representative number of specimens. These samples were characterized by the presence of <u>Cordylodus</u> <u>plattinensis</u> Branson and Mehl, <u>Drepanodus</u>

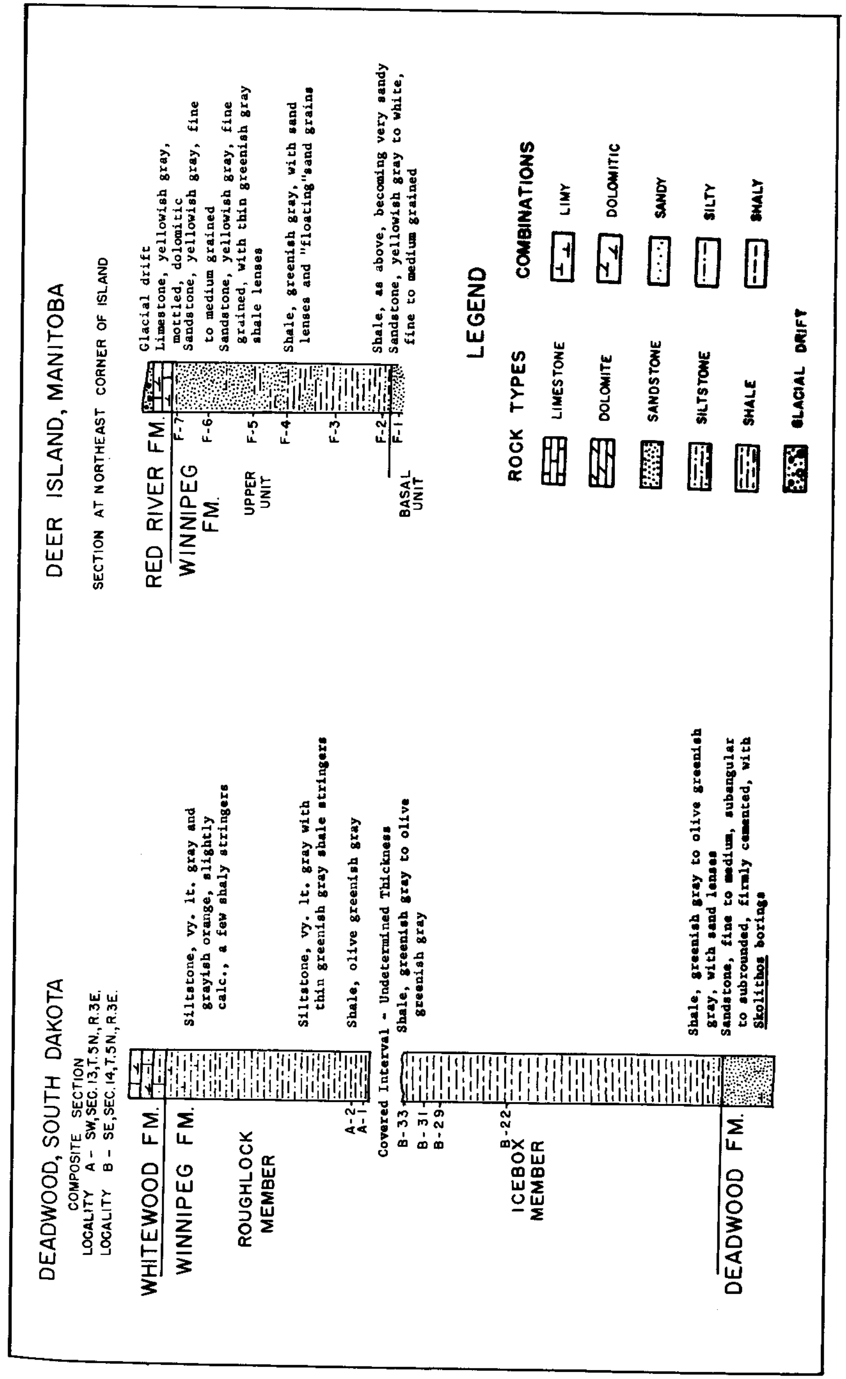


Figure 17 - Columnar sections of the Winnipeg formation of the fossil localities in Manitoba and South Dakota.

homocurvatus Lindstrom, Panderodus arcuatus (Stauffer) and Trichonodella recurva (Branson and Mehl).

Victoria Beach, Manitoba: The Winnipeg formation was exposed at lake level at this locality in May, 1959, because Lake Winnipeg was at a low water level. Samples of the Winnipeg formation were collected along the shore for a distance of about 270 yards. The samples are composed of greenish gray shale with sand lenses and "floating" sand grains throughout. Although some samples were more fossiliferous than others, no noticeable differences in the faunules were observed. The stratigraphic position of these samples with respect to Baillie's basal and upper units of the Winnipeg formation could not be determined because of the poor exposures. However, these samples are probably from near the base of Baillie's upper unit of the Winnipeg formation, since lithologically and faunally they are very similar to sample F-3 from the Deer Island section.

Cordylodus plattinensis Branson and Mehl, Drepanodus homocurvatus Lindström, Panderodus arcuatus (Stauffer) and Trichonodella sp. are the most abundant species from these samples also, although Ozarkodina concinna Stauffer and Oistodus sp. are also important constituents of these faunules.

Deadwood, South Dakota: The complete Winnipeg formation is not exposed at one locality, but most of the Winnipeg formation is exposed at two localities near Deadwood, South Dakota. The roadcut on the north side of U. S. Highway No. 14A (Locality B), just north of Deadwood and southwest of the junction of U. S. Highways No. 14A and 85 exposes the lower 33 feet of the Icebox member of the Winnipeg formation. Another

section, near the junkyard just east of Deadwood and south of U. S. Highway No. 14A (Locality A), exposes the upper 22 feet 3 inches of the Winnipeg formation underlying the Whitewood formation. This section includes 19 feet 9 inches of siltstone and argillaceous siltstone of the Roughlock member and 2 feet 6 inches of the Icebox member. These sections were sampled at one foot intervals. Samples were processed from throughout these sections, but the only samples in the writer's collections which yielded specimens were from the interval beginning 22 feet above the base of the Icebox member to the uppermost beds of the Icebox member.

The fauna from locality A, from the upper two feet of the Icebox member shows a remarkable similarity to the fauna of the Deer Island and Victoria Beach localities in Manitoba. Comparisons of these collections show that the only conspicuous addition to the Manitoba fauna is the species Eoligonodina prima (Branson and Mehl). It should be noted, moreover, that Eoligonodina prima is very close to Cordylodus plattinensis Branson and Mehl (see Pl. 2, Figs. 1 and 2).

The samples from locality B, which are from 22 to 33 feet above the base of the Icebox member contain a different fauna than the samples from locality A., although some elements of the fauna such as Cordylodus plattinensis Branson and Mehl and Drepanodus homocurvatus Lindström, are the same. The additions of Phragmodus undatus Branson and Mehl, Lonchodus spinuliferus Stauffer, and Dichognathus sp. and the absence of Panderodus in the samples from locality B are important differences.

North Dakota: In the Union Oil Company - Aanstad No. 1 well (NDGS 20) the lower two-thirds of the Roughlock member and the uppermost part of the Icebox member of the Winnipeg formation was cored. Four samples numbered 30-2, 30-5, 30-7 and 30-9 were processed and each sample yielded some conodonts. The exact depth of each sample could not be determined because they recovered only 50 feet of core from a cored interval of 56 feet. However, the upper three samples are from the Roughlock member and sample 30-9 is probably from the uppermost part of the Icebox member. The conodonts from the upper three samples were grouped on the chart (Table II) because these samples are so similar, but sample 30-9 was kept separate because of differences in abundance of some of the species.

In this well, the Roughlock member contained a distinctive fauna, characterized by the presence of Belodina compressa (Branson and Mehl), Distacodus insculptus (Branson and Mehl), several species of Panderodus and Falodus predentatus (Graves and Ellison). It was also characterized by an absence of most of the species common to the Icebox member.

In the Union Oil Company - Skjervheim No. 1 well (NDGS 27) a 28 foot interval of the lower part of the Icebox member of the Winnipeg formation was cored. Samples of this core were not uniformly fossiliferous, but three of the samples yielded a sufficient number of specimens for an apparently representative sample of the fauna.

The samples from the upper part of the cored interval contained a fauna quite similar to the fauna of the Icebox member of the South Dakota outcrop sections. However, the lower samples contained a distinctly different fauna characterized by an abundance of Chirognathus spp. and Bryantodina compacta Stauffer, although a few specimens of most of the species common to the upper part of the Icebox member are also present.

In the Continental Oil Company - Leuth No. 1 well (NDGS 207) the lower 60 feet of the Icebox member of the Winnipeg formation was cored. These samples did not break down as readily as the other samples from the subsurface, but some conodonts were obtained from each of six samples. The fauna from these samples is very similar to the upper samples from the Skjervheim well and to the Icebox member of South Dakota.

Age and Correlation

The age of the Winnipeg formation is partially involved in the controversy as to the age of the overlying Red River formation. In the Ordovician Correlation Chart (Twenhofel, and others, 1954), Twenhofel (p. 281-282) summarized the evidence for a Richmondian age for the Red River formation and Kay (p. 282) summarized the evidence for a Trentonian age for the Red River formation. The Red River formation was then placed in the Richmondian stage in the Correlation chart.

Baillie (1952, p. 41) considered the Winnipeg formation to be "Trentonian (?)" in age and a probable lateral equivalent of the Decorah-Platteville interval in Iowa and Illinois. This conclusion was based partially on regional depositional considerations and partially on faunal lists.

The Winnipeg formation of the outcrop area of Manitoba is poorly fossiliferous. Genik (1951) reported that he found no identifiable fossils in the lower unit of the Winnipeg formation and fossils were not abundant in the upper unit. Baillie's (1952, p. 25) faunal list for the Winnipeg formation is entirely from the upper unit. Macauley (1955, p. 51) states that:

The best specimens are from the shalier sandstone and the pure sandstone of the upper part of the outcrop section, and from the subsurface shale.

The age of the Winnipeg formation in Manitoba has previously been based on comparisons of the Winnipeg macrofauna to the macrofauna of the overlying Red River and Stony Mountain formations. Macauley and Leith (1951, p. 1462) state that the Winnipeg fauna is very similar to the fauna of the Red River and Stony Mountain formations, and they further state that the Winnipeg formation is therefore probably of Late Ordovician age in Manitoba. The Winnipeg formation was placed in the Richmondian stage in the correlation chart based on the evidence cited above.

Ross (1957, p. 461) noted the Middle Ordovician affinities of the faunal lists of the Winnipeg formation, but he did not consider the evidence to be conclusive for either a Middle or Late Ordovician age assignment.

The present study indicates, that on the basis of comparisons of the conodont fauna of the Winnipeg formation with the conodont faunas of the Middle Ordovician rocks of the Upper Mississippi Valley, the Winnipeg formation is Middle Ordovician in age. The lower part of the Icebox member contains a fauna similar to the Glenwood formation of Minnesota and the middle to upper part of the Icebox member contains a fauna similar to the Decorah formation. Hence the Icebox member is probably Blackriveran to Trentonian in age. No fossils were obtained from the Black Island member in the present studies, but previously Holland and Waldren (1955, p. 1574) suggested on the basis of conodonts that this part of the Winnipeg is probably Chazyan or Blackriveran. Based on

stratigraphic position it would appear that the Black Island must be at least as old as Blackriveran, so the writer is in agreement with their conclusion.

The Roughlock member contains some forms which have not previously been reported from the Decorah formation; however, the overall aspect of the Roughlock fauna is one of closer affinity to the Decorah fauna than to the fauna of the Galena formation. Hence the Roughlock is probably correlative with the upper part of the Decorah formation and is probably Trentonian in age.

PLATE I

All figures are unretouched photographs of whitened specimens. All photographs X 34. Sample localities are designated by North Dakota Geological Survey well file numbers. N. D. G. S. No. 1385

Fig. 1 - Coleodus simplex Branson and Mehl, inner lateral view, N. D. G. S. No. 105; Locality - N. D. G. S. well No. 1385.

2 - Neocoleodus sp., inner lateral view, N. D. G. S. No. 109; Locality - N. D. G. S. well No. 1385.

3 - Leptochirognathus sp., inner lateral view, N. D. G. S. No. 108; Locality - N. D. G. S. well No. 1385.

4 - Unidentified specimen; Acodus (?) sp., N. D. G. S. No. 112, Locality - N. D. G. S. well No. 1636.

5, 6 - Unidentified specimens, lateral view, posterior view, N. D. G. S. No. 113; Locality - N. D. G. S. well No. 1636.

7, 8 - Drepanodus arcuatus Pander, outer lateral view, inner lateral view, N. D. G. S. No. 106; Locality - N. D. G. S. well No. 1636.

9, 11 - Oistodus sp., outer lateral view, inner lateral view, N. D. G. S. No. 111; Locality - N. D. G. S. well No. 1636.

10 - Acontiodus sp., (?), posterior view, N. D. G. S. No. 104; Locality - N. D. G. S. well No. 1636.

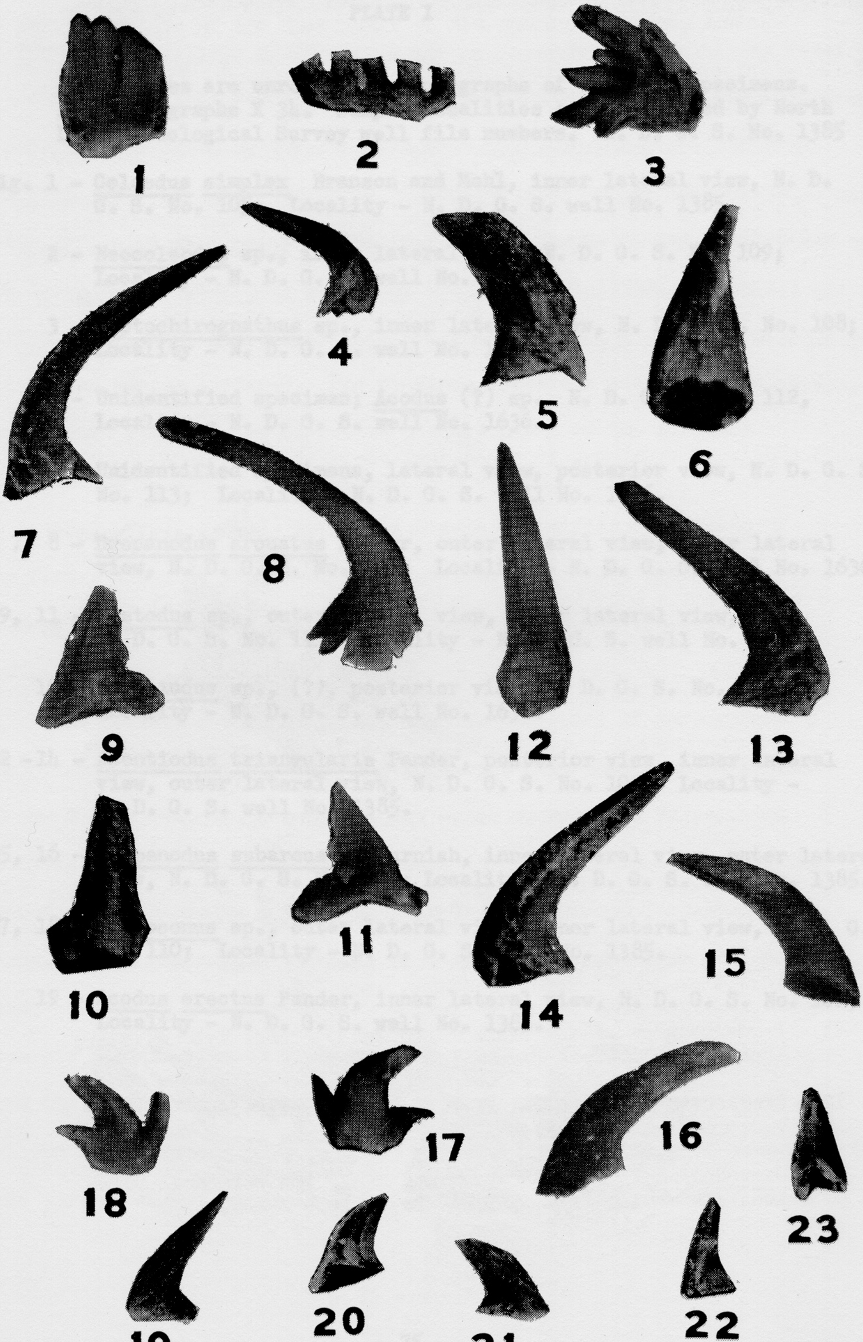
12 -14 - Acontiodus triangularis Pander, posterior view, inner lateral view, outer lateral view, N. D. G. S. No. 103; Locality - N. D. G. S. well No. 1385.

15, 16 - Drepanodus subarcuatus Furnish, inner lateral view, outer lateral view, N. D. G. S. No. 107; Locality - N. D. G. S. well No. 1385.

17, 18 - Ptiloconus sp., outer lateral view, inner lateral view, N. D. G. S. No. 110; Locality - N. D. G. S. well No. 1385.

19 - Acodus erectus Pander, inner lateral view, N. D. G. S. No. 102; Locality - N. D. G. S. well No. 1385.

PLATE I



20, 21 - Acodus brevis Branson and Mehl, inner lateral view, outer lateral view; Locality - N. D. G. S. well No. 1636.

22, 23 - Unidentified specimens, N . D. G. S. Nos. 114, 115; Locality - N. D. G. S. well No. 1636.

PLATE II

All figures are unretouched photographs of whitened specimens. All photographs X34. Sample localities are keyed to Table II (in pocket).

Fig. 1 - Cordylodus plattinensis Branson and Mehl, inner lateral view; Locality - N. D. G. S. well No. 27, sample from 3,373 feet.

2 - Eoligonodina prima (Branson and Mehl), inner lateral view; Locality - N. D. G. S. well No. 207, sample from 5,761 feet.

3 - Chirognathus sp., inner lateral view; Locality - N. D. G. S. well No. 27, sample from 3,373 feet.

4 - Panderodus gracilis (Branson and Mehl), inner lateral view; Locality - N. D. G. S. well No. 27, sample from 3,361 feet.

5 - Phragmodus undatus (Branson and Mehl), outer lateral view; Locality - N. D. G. S. well No. 27, sample from 3,373 feet.

6 - B ryantodina compacta Stauffer, inner lateral view; Locality - N. D. G. S. well No. 27, sample from 3,373 feet.

7 - Ozarkodina concinna Stauffer, inner lateral view; Locality - N. D. G. S. well No. 27, sample from 3,373 feet.

8 - Panderodus arcuatus (Stauffer), inner lateral view; Locality - Victoria Beach, Manitoba.

9 - Cordylodus plattinensis Branson and Mehl, outer lateral view; Locality - Deer Island, Manitoba, sample F - 3.

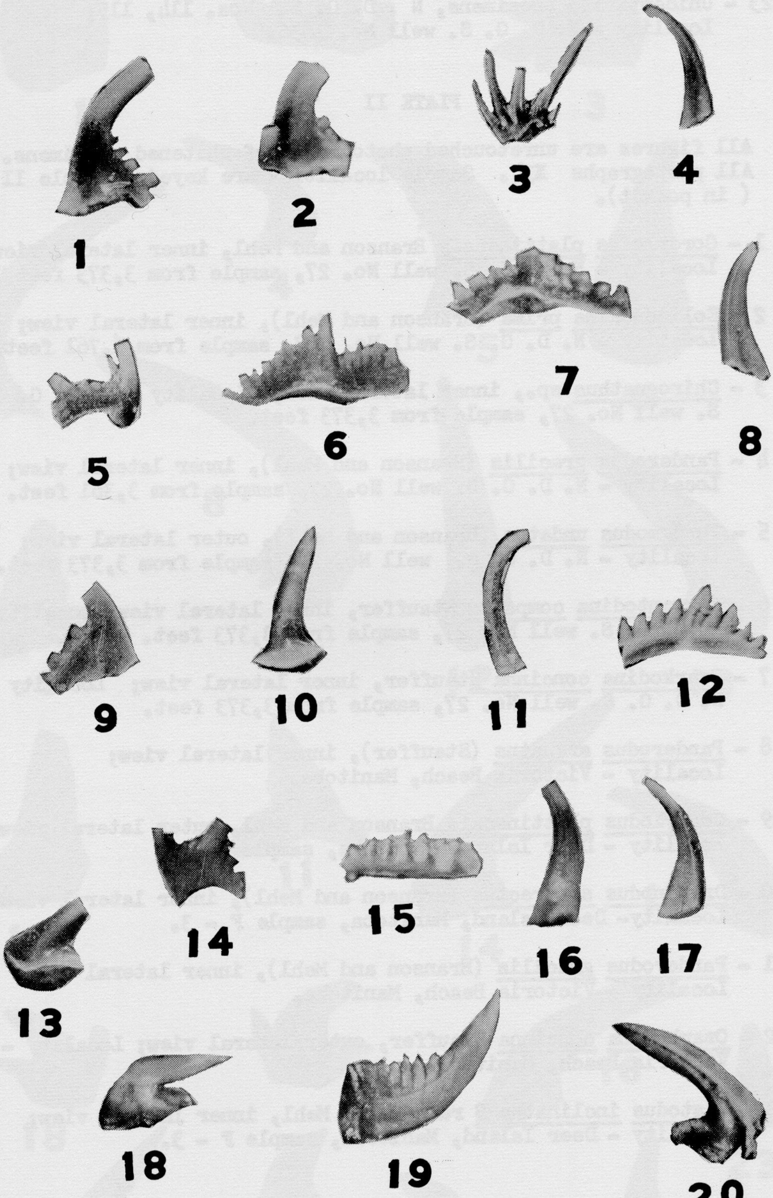
10 - Drepanodus suberectus (Branson and Mehl), inner lateral view; Locality- Deer Island, Manitoba, sample F - 3.

11 - Panderodus gracilis (Branson and Mehl), inner lateral view; Locality - Victoria Beach, Manitoba.

12 - Ozarkodina concinna Stauffer, outer lateral view; Locality - Victoria Beach, Manitoba.

13 - Oistodus inclinatus B ranson and Mehl, inner lateral view; Locality - Deer Island, Manitoba, sample F - 3.

PLATE 2



14 - Phragmodus undatus (Branson and Mehl), inner lateral view; Locality - Deadwood, South Dakota, sample B - 22.

15 - Scyphiodus primus Stauffer, supero-lateral view; Locality - Deadwood, South Dakota, sample B - 22.

16 - Panderodus intermedius (Branson and Mehl), inner lateral view; Locality - Deadwood, South Dakota, sample A - 2.

17 - Panderodus arcuatus (Stauffer), inner lateral view; Locality - Deadwood, South Dakota, sample A - 2.

18 - Oistodus fornicalis Stauffer, outer lateral view; Locality - N. D. G. S. well No. 20, sample 30 - 2 to 30 - 7.

19 - Belodina compressa (Branson and Mehl), inner lateral view; Locality - N. D. G. S. well No. 20, sample 30 - 2 to 30 - 7.

20 - Distacodus insculptus (Branson and Mehl), inner lateral view; Locality - N. D. G. S. well No. 20, sample 30 - 2 to 30 - 7.

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APPENDIX A - LIST OF WELL LOCATIONS

North Dakota Locations

North Dakota Geological Survey Well Number	Well Name and Location
5	Glenfield Oil Company - No. 1 SE 1/4 sec. 18, T. 146 N., R. 62 W., Foster County
15	Carter Oil Company - E. L. Semling No. 1 SE 1/4 SE 1/4 sec. 18, T. 141 N., R. 81 W., Oliver County
16	Northern Ordinance - Franklin Investment No. 1 NW 1/4 NW 1/4 sec. 35., T. 133 N., R. 75 W., Emmons County
19	Continental Oil Company, Pure Oil Company - Davidson No. 1 SW 1/4 SW 1/4 sec. 6, T. 140 N., R. 77 W., Burleigh County
20	Union Oil Company - Aanstad No. 1 NE 1/4 sec. 29, T. 158 N., R. 62 W., Ramsey County
21	F. F. Kelly, Plymouth Oil Company - Fritz Leutz No. 1 NW 1/4 NE 1/4 sec. 28, T. 142 N., R. 89 W., Mercer County
22	Samedan Oil Corporation - Vaughn Hanson No. 1 NE 1/4 sec. 10, T. 146 N., R. 81 W., McLean County
23	Roeser & Pendleton Incorporated - J. J. Weber No. 1 SE 1/4 sec. 35, T. 133 N., R. 76 W., Emmons County
24	Magnolia Petroleum Company - Dakota A No. 1 NE 1/4 sec. 36, T. 141 N., R. 73 W., Kidder County
26	Phillips Petroleum Company, Carter Oil Company - Dakota No. 1 NW 1/4 sec. 29, T. 136 N., R. 81 W., Morton County
27	Union Oil Company - Chris Skjervheim No. 1 C NW 1/4 NE 1/4 sec. 28, T. 159 N., R. 63 W., Cavalier County
29	Red River Development and Oil Company - Edgar Berg No. 1 SW 1/4 sec. 35, T. 152 N., R. 51 W., Grand Forks County
32	Amerada Petroleum Corporation - H. O. Bakken No. 1 SW 1/4 NW 1/4 sec. 12, T. 157 N., R. 95 W., Williams County
38	The California Company - Blanche Thompson No. 1 SW 1/4 SE 1/4 sec. 31, T. 160 N., R. 81 W., Bottineau County

39 Hunt Oil Company - W. B. Shoemaker No. 1
NE 1/4 SW 1/4 sec. 3, T. 157 N., R. 78 W., McHenry County

40 Barnett Drilling Incorporated - John Gaier No. 1
NW 1/4 NW 1/4 sec. 11, T. 141 N., R. 67 W., Stutsman County

43 Peak Drilling Company - Olhauser No. 1
NE 1/4 SE 1/4 sec. 8, T. 132 N., R. 78 W., Emmons County

47 Williams Herbert Hunt Estate - Joe & Anna Wald No. 1
SE 1/4 SW 1/4 sec. 23, T. 155 N., R. 81 W., Ward County

49 Stanolind Oil & Gas Company - McLean County No. 1
SW 1/4 SW 1/4 sec. 28, T. 150 N., R. 80 W., McLean County

52 Wanete Oil Company - M. O. Lee, et al No. 1
C NE 1/4 NE 1/4 sec. 24, T. 156 N., R. 85 W., Ward County

61 Hunt Oil Company - Peter Lennertz No. 1
NW 1/4 SE 1/4 sec. 17, T. 153 N., R. 77 W., McHenry County

64 Hunt Oil Company - Oliver Olson No. 1
SW 1/4 NW 1/4 sec. 18, T. 163 N., R. 77 W., Bottineau County

83 Lion Oil Company - Peder and Lillie Sebelius No. 1
SW 1/4 NW 1/4 sec. 23, T. 161 N., R. 73 W., Rolette County

89 General Atlas Carbon Company - A. Ketterling No. 1
NE 1/4 NE 1/4 sec. 15, T. 131 N., R. 73 W., McIntosh County

94 Champlin Refining Company - Elmer Heim No. 1
NE 1/4 NW 1/4 sec. 12, T. 133 N., R. 65 W., LaMoure County

100 Union Oil of California - Arne and Helmi Saari No. 1
C SW 1/4 sec. 35, T. 161 N., R. 68 W., Towner County

105 Stanolind Oil & Gas Company - W. and I. Waswick No. 1
SW 1/4 NE 1/4 sec. 2, T. 153 N., R. 85 W., Ward County

110 Lion Oil Company - G. Huss No. 1
NW 1/4 NW 1/4 sec. 23, T. 163 N., R. 75 W., Bottineau County

120 General Atlas Carbon Company - A. Peplinski No. 1
SE 1/4 NW 1/4 sec. 21, T. 142 N., R. 63 W., Stutsman County

134 General Atlas Carbon Company - F. Barthel No. 1
SW 1/4 NE 1/4 sec. 15, T. 142 N., R. 65 W., Stutsman County

145 Continental Oil Company - Paul H. McCay No. 1
NW 1/4 NW 1/4 sec. 32, T. 137 N., R. 76 W., Burleigh County

149 Pollard and Davis - Dwane Guscette No. 1
NW 1/4 NW 1/4 sec. 20, T. 142 N., R. 61 W., Barnes County

151 Hunt Oil Company - Emma Kleven No. 1
SW 1/4 SW 1/4 sec. 18, T. 140 N., R. 80 W., Burleigh County

155 Continental Oil Company - Nels Dronen No. 1
NE 1/4 NE 1/4 sec. 9, T. 140 N., R. 75 W., Burleigh County

171 F. H. Rhodes - Harold Murphy No. 1
NW 1/4 NE 1/4 sec. 18, T. 163 N., R. 65 W., Towner County

174 Continental Oil Company - G. A. Duemeland No. 1
NW 1/4 NW 1/4 sec. 3, T. 140 N., R. 77 W., Burleigh County

194 F. H. Rhodes - R. R. Gibbons No. 1
SW 1/4 SE 1/4 sec. 17, T. 157 N., R. 65 W., Towner County

196 Carter Oil Company - Allyn MacDiarmid No. 1
NE 1/4 NE 1/4 sec. 16, T. 154 N., R. 65 W., Ramsey County

207 Continental Oil Company - John Leuth No. 1
NE 1/4 NE 1/4 sec. 27, T. 146 N., R. 73 W., Wells County

227 National Bulk Carriers, Inc. - E. L. Hild, No. 1
SE 1/4 SW 1/4 sec. 31, T. 158 N., R. 66 W., Towner County

230 Carter Oil Company - North Dakota State No. 1
NE 1/4 SE 1/4 sec. 16, T. 143 N., R. 71 W., Kidder County

246 Northern Natural Gas - R. and B. Lee No. 1
C NE 1/4 NE 1/4 sec. 36, T. 154 N., R. 63 W., Ramsey County

254 Amerada Petroleum Corporation - Lars Kvam T. 1, No. 2
C SW 1/4 NE 1/4 sec. 19, T. 156 N., R. 95 W., Williams County

287 Frazier and Conroy Drilling Company - Sarah Dunbar No. 1
NW 1/4 NW 1/4 sec. 13, T. 146 N., R. 63 W., Foster County

291 Amerada Petroleum Corporation - Herman May Unit No. 1
NW 1/4 NE 1/4 sec. 9, T. 139 N., R. 100 W., Billings County

295 T. M. Evans - F. L. Bailey No. 1
SW 1/4 NE 1/4 sec. 26, T. 145 N., R. 62 W., Foster County

316 T. M. Evans Production Corporation - A. L. Johnson No. 1
NW 1/4 SW 1/4 sec. 23, T. 160 N., R. 70 W., Rolette County

334 T. M. Evans - Christian Erickson No. 1
NE 1/4 SE 1/4 sec. 24, T. 145 N., R. 64 W., Foster County

370 Herman Hanson Oil Syndicate - Reg. Ogilvie No. 1
NW 1/4 NW 1/4 sec. 21, T. 140 N., R. 65 W., Stutsman County

383 S. D. Johnson - M. D. Wolf No. 1
NW 1/4 NW 1/4 sec. 17, T. 158 N., R. 62 W., Ramsey County

390 Midwest Exploration Corporation - Union Central Life Insurance and H. Amann No. 1
SE 1/4 SE 1/4 sec. 24, T. 160 N., R. 67 W., Towner County

403 Pure Oil Company - J. M. Carr No. 1
NE 1/4 NE 1/4 sec. 15, T. 146 N., R. 66 W., Foster County

406 Herman Hanson Oil Syndicate - M. M. Mueller No. 1
NE 1/4 NE 1/4 sec. 20, T. 140 N., R. 65 W., Stutsman County

407 Calvert Exploration Company - C. and O. Jack No. 1
NE 1/4 SW 1/4 sec. 13, T. 153 N., R. 63 W., Ramsey County

408 Calvert Exploration Company - Wendell Haley No. 1
SW 1/4 SW 1/4 sec. 1, T. 153 N., R. 63 W., Ramsey County

410 Gulf Oil Corporation - Dorough Federal No. 1
NE 1/4 SW 1/4 sec. 24, T. 143 N., R. 103 W., Golden Valley County

411 S. D. Johnson Company - Edwin Werner No. 1
SW 1/4 SE 1/4 sec. 11, T. 158 N., R. 63 W., Ramsey County

422 McLaughlin Incorporated - L. D. Wolfe No. 1
NE 1/4 SW 1/4 sec. 33, T. 158 N., R. 62 W., Ramsey County

434 Midwest Exploration Company - H. P. Juntenen No. 1
NW 1/4 NW 1/4 sec. 27, T. 163 N., R. 68 W., Towner County

435 Midwest Exploration Company - Heckman No. 1
SW 1/4 NE 1/4 sec. 12, T. 158 N., R. 69 W., Pierce County

437 Calvert Exploration Company - North Dakota State No. 1
NW 1/4 NW 1/4 sec. 16, T. 150 N., R. 67 W., Eddy County

469 Turner Oil Company - Dwight Holmes No. 1
SE 1/4 NE 1/4 sec. 8, T. 163 N., R. 55 W., Pembina County

470 Blackwood and Nichols Company - Gilman and Lang No. 1
NE 1/4 SE 1/4 sec. 15, T. 140 N., R. 105 W., Golden Valley County

485 W. H. Hunt, Zack Brooks - State No. 1
NW 1/4 NW 1/4 sec. 16, T. 129 N., R. 104 W., Bowman County

515 Herman Hanson Oil Syndicate - Harold Billey No. 1
SE 1/4 NW 1/4 sec. 11, T. 129 N., R. 63 W., Dickey County

555 Stanolind Oil and Gas Company - N. W. Improvement Company No. 1
SE 1/4 SE 1/4 sec. 17, T. 143 N., R. 100 W., Billings County

572 Herman Hanson Oil Syndicate - John Bell No. 1
NE 1/4 NW 1/4 sec. 14, T. 129 N., R. 63 W., Dickey County

580 A. J. Scott - A. J. Scott No. 1
NE 1/4 NE 1/4 sec. 15, T. 151 N., R. 53 W., Grand Forks County

590 Caroline Hunt Trust Estate - F. M. Fuller No. 1
SW 1/4 SE 1/4 sec. 6, T. 136 N., R. 73 W., Logan County

609 Caroline Hunt Trust Estate - George Leitner No. 1
SW 1/4 SE 1/4 sec. 14, T. 148 N., R. 71 W., Wells County

620 Calvert Exploration Company - C. C. Nitschke No. 1
NE 1/4 SE 1/4 sec. 13, T. 130 N., R. 69 W., McIntosh County

621 Calvert Exploration Company - John Bender No. 1
NW 1/4 NW 1/4 sec. 19, T. 130 N., R. 69 W., McIntosh County

622 Calvert Exploration Company - Karl Schock No. 1
SW 1/4 NW 1/4 sec. 17, T. 131 N., R. 69 W., McIntosh County

631 Ohio Oil Company - Standing Rock Sioux Tribal No. 1
NE 1/4 SW 1/4 sec. 29, T. 131 N., R. 80 W., Sioux County

632 Calvert Exploration Company - Arthur J. and Ida John and Gina Stadum No. 1
NW 1/4 SE 1/4 sec. 31, T. 154 N., R. 70 W., Benson County

642 Caroline Hunt Trust Estate - Obed Larson No. 1
NW 1/4 NE 1/4 sec. 32, T. 150 N., R. 70 W., Wells County

644 Gordon B. Butterfield - Rudolph Trautman No. 1
SE 1/4 SE 1/4 sec. 5, T. 139 N., R. 68 W., Stutsman County

665 Caroline Hunt Trust Estate - John Waltz, Jr. No. 1
NE 1/4 NE 1/4 sec. 15, T. 148 N., R. 76 W., Sheridan County

668 Calvert Exploration Company - Margaret Meyers No. 1
SE 1/4 SW 1/4 sec. 25, T. 137 N., R. 67 W., Stutsman County

669 Calvert Exploration Company - Christ Rau No. 1
SE 1/4 SW 1/4 sec. 35, T. 139 N., R. 68 W., Stutsman County

670 Calvert Exploration Company - D. C. Wood No. 1
SE 1/4 SW 1/4 sec. 24, T. 139 N., R. 67 W., Stutsman County

671 Calvert Exploration Company - George Ganser No. 1
NW 1/4 SW 1/4 sec. 12, T. 140 N., R. 67 W., Stutsman County

672 Calvert Exploration Company - Vincent Wanzek No. 1
NW 1/4 NW 1/4 sec. 12, T. 139 N., R. 67 W., Stutsman County

673 Calvert Exploration Company - F. L. Robertson No. 1
NE 1/4 NE 1/4 sec. 26, T. 138 N., R. 67 W., Stutsman County

682 James H. Snowden - Chester L. Gibson No. 1
SE 1/4 SE 1/4 sec. 34, T. 130 N., R. 63 W., Dickey County

684 Caroline Hunt Trust Estate - J. R. Matz No. 1
NE 1/4 NE 1/4 sec. 1, T. 147 N., R. 75 W., Sheridan County

689 Caroline Hunt Trust Estate - N. Thormodsgard No. 1
NE 1/4 NE 1/4 sec. 31, T. 147 N., R. 71 W., Wells County

693 Caroline Hunt Trust Estate - Walter E. Bauer No. 1
SW 1/4 SW 1/4 sec. 19, T. 146 N., R. 76 W., Sheridan County

700 Turner Oil Company - Theodore Belanus No. 1
NE 1/4 SE 1/4 sec. 28, T. 164 N., R. 56 W., Pembina County

701 Caroline Hunt Trust Estate - Board of University and
School Lands No. 1
NE 1/4 NE 1/4 sec. 36, T. 144 N., R. 75 W., Burleigh County

706 Shell Oil Company - Gifford Marchus No. 1
SE 1/4 SE 1/4 sec. 23, T. 157 N., R. 70 W., Pierce County

723 Caroline Hunt Trust Estate - R. P. Schlabach No. 1
NE 1/4 NE 1/4 sec. 36, T. 139 N., R. 76 W., Burleigh County

725 James H. Snowden, et al - E. Trautman No. 1
SW 1/4 NW 1/4 sec. 36, T. 130 N., R. 63 W., Dickey County

735 Caroline Hunt Trust Estate - C. A. Pfeiffel No. 1
SW 1/4 SW 1/4 sec. 16, T. 146 N., R. 74 W., Sheridan County

748 Caroline Hunt Trust Estate - E. B. Sauter No. 1
NW 1/4 NE 1/4 sec. 32, T. 142N., R. 74 W., Kidder County

756 Caroline Hunt Trust Estate - R. A. Nicholson No. 1
SE 1/4 SE 1/4 sec. 32, T. 137 N., R. 77 W., Burleigh County

763 Caroline Hunt Trust Estate - Anton Novy No. 1
SE 1/4 SE 1/4 sec. 14, T. 144 N., R. 77 W., Burleigh County

765 Caroline Hunt Trust Estate - Soder Investment Company No. 1
SW 1/4 SW 1/4 sec. 31, T. 142 N., R. 76 W., Burleigh County

768 Calvert Exploration Company - State No. 1
NE 1/4 NE 1/4 sec. 8, T. 150 N., R. 65 W., Eddy County

871 F. B. Downing, Sr. - James Link No. 1
NW 1/4 NW 1/4 sec. 16, T. 132 N., R. 49 W., Richland County

956 Gulf Oil Corporation - Federal Unit No. 1
NW 1/4 SW 1/4 sec. 28, T. 148 N., R. 104 W., McKenzie County

1105 Cardinal Drilling Company, et al - J. S. Smith No. 1
SE 1/4 SW 1/4 sec. 8, T. 146 N., R. 65 W., Foster County

1112 Cardinal Drilling Company, et al - N. A. Graves and
Federal Land Bank No. 1
NE 1/4 NE 1/4 sec. 23, T. 146 N., R. 66 W., Foster County

1126 Cardinal Drilling Company, et al - J. M. Anderson No. 1
NW 1/4 NW 1/4 sec. 10, T. 146 N., R. 67 W., Foster County

1174 Powers Lake and G. A. Vincent - Wild No. 1
SW 1/4 SW 1/4 sec. 21, T. 159 N., R. 57 W., Cavalier County

1211 Calvert Drilling Incorporated - Francis Zwinger No. 1
NE 1/4 NE 1/4 sec. 8, T. 146 N., R. 68 W., Wells County

1227 Mike Wetch - H. F. Spickler No. 1 - A
NE 1/4 NE 1/4 sec. 25, T. 147 N., R. 64 W., Foster County

1231 Amerada Petroleum Corporation - Iverson Nelson Unit No. 1
NE 1/4 sec. 2, T. 155 N., R. 96 W., Williams County

1274 Wetch, Zachmeier and Disney Drilling Company
C. E. Blasky No. 1
SE 1/4 SE 1/4 sec. 9, T. 148 N., R. 62 W., Eddy County

1347 Calvert Drilling Incorporated - Ray Craig No. 1
NW 1/4 NW 1/4 sec. 25, T. 136 N., R. 71 W., Logan County

1356 North Plains Petroleum Incorporated - F. F. Danner No. 1
SW 1/4 SE 1/4 sec. 24, T. 152 N., R. 54 W., Grand Forks County

1385 Amerada Petroleum Corporation - N. D. "A" Unit No. 9
SE 1/4 SW 1/4 sec. 16, T. 156 N., R. 95 W., Williams County

1394 Calvert Drilling Incorporated - Marvin Kamm No. 1
NW 1/4 NW 1/4 sec. 22, T. 129 N., R. 66 W., Dickey County

1403 Amerada Petroleum Corporation - Boe, Olson Unit No. 1
NE 1/4 sec. 15, T. 155 N., R. 96 W., McKenzie County

1409 Leach Oil Corporation and Calvert Drilling Incorporated
Patterson Land Company No. 1
NW 1/4 SE 1/4 sec. 11, T. 140 N., R. 77 W., Burleigh County

1415 North Plains Petroleum Incorporated - C. O. Haugen No. 1
SE 1/4 SE 1/4 sec. 22, T. 152 N., R. 54 W., Grand Forks County

1443 Dakamont Exploration Corporation - Harold E. Jacobson No. 1
SW 1/4 NE 1/4 sec. 6, T. 162 N., R. 96 W., Divide County

1514 Amerada Petroleum Corporation - Ulven Unit No. 1
C NE 1/4 sec. 34, T. 156 N., R. 96 W., Williams County

1546 Kerr, McGee Oil Ind., Incorporated - Arlot Johnson No. 1
NE 1/4 NW 1/4 sec. 34, T. 162 N., R. 101 W., Divide County

1575 Carter Oil Company - Lewis L. and Ellen Johnson No. 1
NW 1/4 SW 1/4 sec. 9, T. 129 N., R. 106 W., Bowman County

1620 Pan American Petroleum Corporation - Raymond Vetter N o. 1
NE 1/4 SW 1/4 sec. 27, T. 139 N., R. 90 W., Morton County

1636 Amerada Petroleum Corporation - Peterson, Davidson Unit No. 1
C SW 1/4 sec. 17, T. 156 N., R. 95 W., Williams County

1694 Johnson Oil - Earl Moore No. 1
NW 1/4 N W 1/4 sec. 10, T. 162 N., R. 63 W., Cavalier County

1934 Reelfoot Development Company Incorporated - Louis and
Alvina B ryl No. 1
SE 1/4 SE 1/4 sec. 5, T. 152 N., R. 60 W., Nelson County

2001 Oil Exploration Company - Walter Fowler No. 1
SW 1/4 SE 1/4 sec. 18, T. 152 N., R. 58 W., Nelson County

2010 Carter Oil Company - Dallas D. Moore No. 1
NW 1/4 NE 1/4 sec. 7, T. 163 N., R. 102 W., Divide County

2219 The California Company - Bert Henry No. 4
SE 1/4 SW 1/4 sec. 6, T. 161 N., R. 79 W., Bottineau County

2342 Fred Traugott - Grimsi, Goodman Estate No. 1
NW 1/4 SW 1/4 sec. 3, T. 160 N., R. 57 W., Cavalier County

2373 Amerada Petroleum Corporation - Antelope Unit "A" No. 1
NE 1/4 SE 1/4 sec. 1, T. 152 N., R. 95 W., McKenzie County

Other Locations

Arbitrary Letter Symbol	Well Name and Location
A	California Standard - Hartney No. 16-33 lsd. 16, section 33, 5N., 24 W1, Manitoba
B	Canadian Gulf - Neuman No. 12 lsd. 12, section 29, 2N., 2W2, Saskatchewan
C	Tidewater Oil - Imperial South Kisbey Crown No. 1 lsd. 16, section 34, 7N., 6 W2, Saskatchewan
D	Imperial Oil, Ltd. - Halkett No. 15-7 lsd. 15, section 7, 3N., 8 W2, Saskatchewan
E	Amerada Petroleum Corporation - Loucks No. 1 SW$\frac{1}{4}$ section 35, T. 36N., R. 52E., Sheridan County, Montana
F	Sun Oil Company, et al. - Beagle Land and Livestock Company No. 1 SW$\frac{1}{4}$ section 17, T. 23N., R. 59E., Richland County, Montana
G	Shell Oil Company - No. 43-22A Unit SE$\frac{1}{4}$ section 22, T. 11N., R. 57E., Wibeaux County, Montana
H	Carter Oil Company - Northern Pacific No. 1 SE$\frac{1}{4}$ section 19, T. 4N., R. 62W., Fallon County, Montana
J	Amerada Petroleum Corporation - State No. 1 NW$\frac{1}{4}$ section 4, T. 14N., R. 4E., Butte County, South Dakota
K	Weller, Bush - Weisman No. 1 SW$\frac{1}{4}$ SE$\frac{1}{4}$ section 30, T. 7N., R. 4E., Lawrence County, South Dakota
L	Shell Oil Company - Homme No. 1 SE$\frac{1}{4}$ section 13, T. 20N., R. 12E., Perkins County, South Dakota
M	Shell Oil Company - Veal No. 1 SE$\frac{1}{4}$ section 7, T. 17N., R. 15E., Perkins County, South Dakota
N	J. P. Evans, J. R. Querbes Trust - H. Capp No. 1 NW$\frac{1}{4}$ section 9, T. 13N., R. 16E., Perkins County, South Dakota
P	Shell Oil Company - J. K. Winters No. 1 SW$\frac{1}{4}$ section 11, T. 22N., R. 19E., Corson County, South Dakota

Q Kerr, McGee - W. Cook No. 1
SW$\frac{1}{4}$ section 32, T. 13N., R. 22E., Dewey County, South Dakota

R Max Pray - Krangler No. 1
NW$\frac{1}{4}$ section 14, T. 121 N., R. 77W., Walworth County, South Dakota

APPENDIX B - LITHOLOGIC DESCRIPTIONS

Subsurface Sample Descriptions

Circular numbers refer to North Dakota Geological Survey circulars which are obtainable from the North Dakota Geological Survey, Grand Forks, North Dakota. These circulars contain sample descriptions for these wells by various members of the subsurface geology division of the North Dakota Geological Survey.

Carter Oil Company - E. L. Semling No. 1
SE 1/4 SE 1/4 sec. 18, T. 141 N., R. 81 W., Oliver County
North Dakota Geological Survey Well No. 15; Circular 98

Depth	Lithology
8250 - 8310	Limestone, light gray, very finely crystalline
8310 - 8330	Shale, medium dark gray, platy, calcareous; a little greenish gray, calcareous; much limestone, as above
8330 - 8350	Shale, greenish gray, 5 GY 6/1, and medium gray, splintery to platy, calcareous
8350 - 8360	Shale, dark greenish gray, 5 GY 4/1, splintery, calcareous
8360 - 8420	Shale, dark greenish gray to greenish gray and brownish gray, 5 YR 4/1, splintery
8420 - 8450	Shale, as above; with brownish gray increasing to about 50%
8450 - 8470	Shale, as above; mostly greenish gray
8470 - 8480	Samples, as above; a few pieces of sandstone, very light gray, fine to very fine grained
8480 - 8500	Sandstone, fine to medium grained, rounded, colorless, quartz; much shale in samples, as above
8500 - 8510	Sandstone, fine grained, colorless quartz, firmly cemented; some loose medium, subrounded, colorless quartz; much shale cave in samples
8510 - 8520	Sandstone, very light gray, fine to coarse grained, rounded, colorless quartz, firmly cemented
8520 - 8530	Sandstone, coarse to very coarse, rounded to subrounded, weakly cemented quartz
8530 - 8540	Samples, as above; mostly shale

8540 - 8550	Sample, mostly shale, dark greenish gray
8550 - 8570	Sandstone, very light gray, fine to medium grained, slightly calcareous, firmly cemented; a little dolomite, very light brownish gray, fine to medium crystalline grading into sandy dolomite
8570 - 8580	Limestone, light gray, very finely crystalline, dolomitic; much shale in samples, dark greenish gray and brownish gray
8580 - 8590	Limestone, very light gray, finely crystalline, fragmentel; samples contain much shale, as above
8590 - 8600	Samples nearly all shale, as above; traces of limestone, as above
8600 - 8610	Limestone, as above; shale, dark greenish gray and brownish gray, splintery
8610 - 8630	Limestone, as above with traces of glauconite; shale, dark greenish gray
8630 - 8640	Limestone, very light gray, finely crystalline, fragmental, glauconitic
8640 - 8660	Limestone, very light gray, finely crystalline, fragmental; with some sand grains becoming calcareous sandstone in part, medium to fine grained, rounded, quartz grains
8660 - 8670	Sandstone, very light gray, fine to medium grained, calcareous
8670 - 8730	Sandstone, as above; samples mostly dark greenish gray shale
8730 - 8740	Shale, brownish gray and dark greenish gray, splintery; some sandstone, as above
8740 - 8760	Limestone, very light gray, finely crystalline, sandy; shales, as above
8760 - 8780	Shale, brownish gray and dark greenish gray, splintery
8780 - 8800	Shale, as above; a little limestone, very light gray, finely crystalline, glauconitic, arenaceous
8800 - 8830	Sandstone, very light gray, fine grained, calcareous, glauconitic, some limestone, as above; much shale, as above
8830 - 8840	Sandstone, as above and pieces of igneous rock
8845 -	Dark igneous rock - gabbro

Northern Ordinance, Franklin Investment Company No. 1
NW 1/4 NW 1/4 sec. 35, T. 133 N., R. 75 W., Emmons County
North Dakota Geological Survey Well No. 16

Depth	Lithology
4870 - 4880	Limestone, light gray to light yellowish gray, fine grained to finely crystalline; a little sandstone, very light gray, very fine grained, slightly calcareous
4880 - 4895	Sandstone, very light gray, very fine to fine grained, slightly calcareous
4895 - 4903	Sandstone, as above; a little shale, greenish gray, flaky to platy, slightly calcareous
4903 -	Circulation - Sandstone, as above; some shale, as above
4903 - 4913	Cores - Shale, greenish gray, sandy
4913 - 4930	Shale, greenish gray, platy; some sandstone, light greenish gray, very fine grained
4930 - 4940	Poor sample - shale, greenish gray and medium light gray
4940 - 4960	Shale, greenish gray, platy
4960 - 4995	Shale, greenish gray, splintery
4995 - 5000	Shale, greenish gray and pale brown, splintery
5000 - 5020	Shale, greenish gray, splintery
5020 - 5060	Shale, greenish gray and pale brown, splintery
5062 -	Circulation - Sandstone, very light gray to reddish stained, fine to coarse grained
5060 - 5075	Sandstone, as above, some pyrite cement
5075 - 5105	Sandstone, grayish orange, fine to coarse grained
5105 - 5110	Sandstone, as above; and loose medium to coarse, rounded, frosted quartz grains
5110 - 5155	Sandstone, loose, very coarse to coarse, rounded, frosted quartz grains
5155 - 5165	Sandstone, very light gray, fine grained; much loose sand, as above
5165 - 5190	Sandstone, very light gray, fine to medium grained, with some coarse grained, calcareous, glauconitic
5190 - 5200	Sandstone, as above; some dolomite, very light gray, finely crystalline to fine grained

5200 - 5225 Sandstone, very light gray to very pale orange, fine grained, slightly calcareous, glauconitic

5225 - 5245 Sandstone, very light gray, fine to medium grained, glauconitic, calcareous; a little dolomite, very light gray, finely crystalline, glauconitic. (5225-30) and (5240-5245)

5245 - 5270 Dolomite, very light gray, finely crystalline to fine grained, granular, slightly glauconitic; sandstone, as above

5270 - 5275 A little sandstone and dolomite, as above; mostly loose, coarse to very coarse, rounded quartz

5275 - 5280 Dolomite and sandstone, as above

5280 - 5320 Sandstone, very light gray, fine to coarse grained, calcareous, glauconitic; some limestone, very light gray, finely crystalline, fragmental (5285-5295) and (5305-5320)

5320 - 5350 Sandstone, very light gray, fine to medium grained, calcareous, glauconitic

5350 - 5353 Pink granite

Continental Oil Company, Pure Oil Company - Davidson No. 1
SW 1/4 SW 1/4 sec. 6, T. 140 N., R. 77 W., Burleigh County
North Dakota Geological Survey Well No. 19

Depth	Lithology
6440 - 6480	Limestone, very light gray to yellowish gray, finely crystalline, fragmental in part, slightly dolomitic
6480 - 6510	Limestone, as above; a little dolomite, light brownish gray, microsucrosic; a few pieces of white chert
6510 - 6520	Shale, light greenish gray, calcareous, lumpy
6520 - 6530	Shale, medium gray, splintery, calcareous and light greenish gray, splintery calcareous
6530 - 6540	Shale, medium gray and greenish gray, splintery, calcareous
6540 - 6550	Shale, dark greenish gray, splintery
6550 - 6570	Shale, dark greenish gray, 5 GY 4/1, and dark yellowish brown, 10 YR 4/2, splintery
6570 - 6600	Shale, dark greenish gray, splintery
6600 - 6640	Shale, dark greenish gray, dark yellowish brown, splintery
6640 - 6660	Shale, dark greenish gray, splintery
6660 - 6680	Sandstone, very light gray, fine to medium grained, rounded to subrounded quartz, firmly cemented, some pyrite cement. Becoming medium to coarse grained (6670 - 6680)

6680 - 6690	Sandstone, very light gray, with orange tinge from iron stain, fine to medium grained, slightly calcareous
6690 - 6700	Sandstone, very light gray, very fine to fine grained, calcareous; some sandstone, as above; shale, dark greenish gray, splintery
6700 - circulation	Sandstone, very light gray, fine to coarse grained, quartzose, slightly calcareous; shale, dark greenish gray, splintery; traces of glauconite in the sandstone
6700 - 6710	Sandstone, very light gray to light greenish gray, very fine to fine grained, slightly calcareous, argillaceous; shale, dark greenish gray and olive gray, splintery
6710 - 6720	Sandstone, as above; a little dolomite; very light gray, fine grained, granular
6720 - 6730	Dolomite, very light gray, fine grained, granular; some medium grained, slightly glauconitic
6730 - 6740	Dolomite, as above; some sandstone; very light gray, fine to medium grained, calcareous
6740 - 6830	Sandstone, very light gray, fine to medium grained, rounded, calcareous, slightly glauconitic in part
6830 - 6840	Sandstone, as above; shale, dark greenish gray to greenish gray and olive gray, splintery; a little very light gray, fragmental limestone.
6840 - 6850	Sandstone, very light greenish gray, very fine grained, calcareous; shale, greenish gray, splintery to platy
6850 - 6870	Limestone, very light gray, fine grained, fragmental, glauconitic; shale, greenish gray, flaky to platy
6870 - 6880	Limestone, as above, becoming very glauconitic; a little shale, greenish gray
6880 - 6890	Limestone, as above, sandstone, very light gray, very fine to fine grained, calcareous, glauconitic
6890 - 6900	Sandstone, as above; some limestone, as above
6900 - 6930	Sandstone, very light gray, fine grained, glauconitic
6930 - 6935	Sandstone, as above; a few pieces of pink granite
6930 - 6950	Sandstone, as above
6950	Circulation 1 hr. - pink granite

Union Oil Company - Aanstad No. 1
NE 1/4 sec. 29, T. 158 N., R. 62 W., Ramsey County
North Dakota Geological Survey Well No. 20

Depth	Lithology
2990 - 3000	Limestone, very light gray to pinkish gray, fine grained.
3000 - 3050	Limestone, pinkish gray, fine grained, argillaceous
3050 - 3059	Limestone, as above; some shale, light gray with greenish tinge, calcareous
Cores 3059 - 3114; recovered 50 feet; (1-4, refers to boxes 1 to 4)	
30 - (1-4)	Shale, greenish gray, blocky, calcareous, with lens and conertion of limestone, light greenish gray, argill.
30 - (5-8)	Shale, greenish gray, blocky and fissile, calcareous
30 - (9-10)	Shale, greenish gray, fissile, calcareous; some fossil fragments
3114 - 3130	Shale, greenish gray and light olive gray, platy, compact
3130 - 3160	Shale, greenish gray, platy
3160 - 3170	Shale, pale brown, platy to splintery compact; shale, as above
3170 - 3190	Shale, greenish gray, platy to splintery
3190 - 3200	Shale, light olive gray and greenish gray, platy to splintery
3200 - 3210	Shale, as above; a few loose, fine to medium, rounded, quartz grains
3210 - 3218	Sand, loose, fine to coarse, rounded, frosted quartz grains, mostly fine to medium grained.

Kelly, Plymouth - F. Leutz No. 1
NW 1/4 NE 1/4 sec. 28, T. 142N., R. 89 W., Mercer County
North Dakota Geological Survey Well No. 21   Circular No. 13

Depth	Lithology
11,820 - 860	Limestone, light brownish gray, very finely crystalline
11,860 - 900	Shale, greenish gray, platy, calcareous
11,900 - 920	Shale, dark greenish gray, platy, very slightly calcareous

11,920 - 12,010	Shale, dark greenish gray, platy to splintery
12,010 - 020	Sample, as above
12,020 - 050	Sandstone, white, fine grain, firmly cemented; mostly cavings
12,050 - 060	Sandstone, very light gray, fine grained, glauconitic; sample mostly dark greenish gray shale
12,060 - 080	Sandstone, white, fine to medium grained, cemented and sandstone, light greenish gray, fine grained with interbedded greenish gray shale; sample mostly dark greenish gray shale
12,080 - 130	Sandstone, white, fine to medium grained, subangular, quartzoses friable
12,130 - 150	Dolomite, light yellowish gray, fine grained, with fine to medium sand grains; some sandstone, white, fine grained, slightly dolomitic
12,150 - 160	Very poor sample; nearly all cavings
12,160 - 170	Dolomite, very pale orange, very finely crystalline, some fine grained, arenaceous dolomite
12,170 - 200	Dolomite, light brownish gray, fine to medium crystalline, fragmental
12,200 - 230	Dolomite, as above; with some sand grains
12,230 - 290	Sandstone, very light gray, fine to medium grained, calcareous
12,290 - 340	Sandstone, very light gray, fine to medium grained, subangular to rounded, friable, very slightly calcareous, mostly medium grained; scattered small amounts of greenish gray shale
12,340 - 370	Limestone, very light gray, fine grained, silty and some sandstone, as above
12,370 - 400	Limestone, very light gray to light brownish gray, very finely crystalline, slightly arenaceous in part (12,370 - 12,380)
12,400 - 420	Limestone, very light gray to light brownish gray, very fine to medium crystalline, traces of glauconite
12,420 - 440	Limestone, as above; some shale, greenish gray, platy, slightly calcareous

12,440 - 500 Limestone, very light gray, fine to medium crystalline, glauconitic; some shale, as above; more shale, as above from (12,490 - 12,500)

12,500 - 520 Sandstone, very light gray to white, fine to medium grained, calcareous, traces of glauconite; shale, greenish gray; some limestone as above

12,524 - circulation - Sandstone, as above, and loose, medium grained, rounded quartz

Magnolia Petroleum Company - Dakota "A" No. 1
NE 1/4 sec. 36, T. 141 N., R. 73W., Kidder County
North Dakota Geological Survey Well No. 24

Depth	Lithology
5000 - 5050	Limestone, light gray to light yellowish gray, finely crystalline to microsuerosic, slightly dolomitic; a little chert, light gray
5050 - 5140	Limestone, yellowish gray, finely crystalline, fragmental in part
5140 - 5160	Limestone, as above; limestone, light brownish gray, very finely crystalline, dense, dolomitic
5164 - 5180	Samples, as above
5180 - 5220	Limestone, very light gray, fine grained to finely crystalline, fragmental (ditch samples)
5220 - 5230	Shale, platy to flaky, soft, greenish gray, 6GY 6/1
5260 - 5340	Shale, greenish gray, 5G 6/1, splintery, brittle
5340 - 5370	Shale, greenish gray and light olive gray, splintery, brittle (traces of sandstone (5360-5370))
5371 - circulation	- Sandstone, very pale orange, very fine to medium and coarse grained; loose quartz, fine to very coarse, rounded, colorless
5370 - 5380	Mostly loose quarta grains, as above; some very pale orange sandstone, as above
5380 - 5390	Sandstone, grayish orange, fine to medium grained, firmly cemented
5390 - 5400	Sandstone, grayish orange, fine to coarse grained, firmly cemented

5400 - 5420	Sandstone, fine to very coarse, very pale orange
5420 - 5430	Sandstone, as above; loose, coarse to very coarse, rounded, quartz grain
5430 - 5450	Sand, loose, medium to very coarse, rounded, frosted, quartz grains
5450 - 5460	Dolomite, very light gray, very fine to fine grained, glauconitic, sandy; some sandstone, as above, with interbedded green shale
5460 - 5500	Dolomite, very pale orange, fine grained, granular; much loose sand, as above in samples (5460-5470)
5510 - 5580	Dolomite, pale red to grayish orange pink, medium grained, glauconitic
5580 - 5600	Dolomite, as above; some loose, coarse to very coarse, rounded, frosted, quartz grained
5600 -	Granite, orange; much sand, loose, coarse to very coarse, rounded, frosted, quartz grains

Phillips Petroleum, Carter Oil - Dakota No. 1
NW 1/4 sec. 29, T. 136N., R. 81 W., Morton County
North Dakota Geological Survey Well No. 26

Depth	Lithology
7050 - 7090	Limestone, light yellowish gray to light gray, finely crystalline to fine grained, granular; a little chert, light gray to white
7090 - 7110	Very poor samples
7110 - 7130	Limestone, light gray, fine grained, granular, slight greenish tinge, slightly argill.
7130 - 7140	Sandstone, very light gray, very fine grained; some limestone, as above
7140 - 7180	Sandstone, as above
7180 - 7210	Shale, medium dark gray, platy, compact; some light gray to light greenish gray lumpy, compact shale
7210 - 7310	Shale, greenish gray, 5G 6/1, platy to splintery brittle
7310 - 7320	Shale, as above; a little sandstone, very light gray, fine grained

7320 - 7340	Sandstone, very light gray, medium to fine grained, calcareous
7340 - 7370	Sandstone, very light gray, fine to coarse grained, calcareous
7370 - 7380	Sandstone, as above, a little glauconite
7380 - 7400	Sandstone, very light gray, very fine to fine grained, calcareous; shales, greenish gray to dark greenish gray and brownish gray, splintery, brittle
7400 - 7440	Sandstone, very light gray, fine to medium grained, calcareous, some shale, greenish gray, splintery
7440 - 7460	Sandstone, as above; shale, greenish gray and olive gray, 5Y 4/1
7460 - 7500	Sandstone, very light gray, very fine to medium grained, calcareous
7500 - 7530	Sandstone, as above with loose, medium to coarse grained, rounded quartz
7530 - 7550	Sandstone, very light gray, fine grained, glauconitic, calcareous; some limestone, yellowish gray, fine grained to finely crystalline, fragmental, glauconitic
7550 - 7560	Limestone, as above; some sandstone, as above
7560 - 7580	Sandstone, very light gray, fine to medium grained; shale, greenish gray, platy, some olive gray and medium dark gray
7580 - 7600	Shale, as above
7600 - 7610	Dolomite, very pale orange, miscrosucrosie, slightly glauconitic; much shale, as above
7610 - 7630	Sandstone, very light gray, fine grained, glauconitic, calcareous and limestone, very light gray, fine to medium grained, fragmental, glauconitic
7660 - 7670	Limestone, very pale orange, medium grained, granular, slightly dolomitic, glauconitic, some limestone, very light gray, as above
7670 - 7690	Sandstone, very light gray, fine grained, calcareous, glauconitic, limestone, as above
7690 - 7710	Sandstone, as above; some interbedded shale, medium gray and limestone, very light gray, fine to medium grained, glauconitic

7710 - 7720	Sandstone, very light gray, fine to medium grained, calcareous, glauconitic, some limestone, as above
7720 - 7740	Limestone, very light gray, very finely crystalline, fragmental in part; some sandstone, as above
7740 - 7750	Sample nearly all shale, greenish gray
7750 - 7760	Sandstone, very light gray, medium to coarse grained, slightly calcareous
7760 - 7770	Sandstone, loose coarse, rounded, quartz grains, some sandstone, as above
7770 - 7780	Sand, as above; some green chips of schistose rock

Union Oil Company - C. Skjervheim No. 1
NW 1/4 NE 1/4 sec. 28, T. 159 N., R. 63 W., Cavalier County
North Dakota Geological Survey Well No. 27; Circular No. 106

Depth	Lithology
3200 - 3210	Limestone, very light gray with a reddish tinge in part, fine grained to finely crystalline, fragmental
3220 - 3235	Limestone, as above
3235 - 3245	Limestone, very light gray, fine grained to finely crystalline, some shell fragments
3245 - 3250	Limestone, very light gray to light gray, fine grained to finely crystalline
3250 - 3260	Limestone, as above and some shale, greenish gray, 5G 6/1, splintery
3260 - 3270	Limestone, very light gray to light gray, fine grained to finely crystalline, fragmental
3270 - 3275	Limestone, as above; a little shale, medium light gray with a greenish tinge, calcareous
3275 - 3290	Shale, greenish gray, 5G 6/1, calcareous, platy to lumpy
3300 - 3315	Shale, greenish gray, platy
3315 - 3350 cores	Shale, greenish gray, pale olive and pale yellowish brown, splintery
3352 - 3378	Shale, greenish gray, lumpy, soapy
3378 - 3390	Shale, greenish gray, platy to lumpy

3390 - 3395 cores	Shale, greenish gray and pale olive, splintery to platy
3395 - core 1, 2	Sandstone, very light gray, fine to medium, rounded, colorless, quartz grains, friable
3395 - 3408	
core 3	Sandstone, light gray, fine to medium grained, firmly cemented, silty, some pyrite cement
core 4	Sandstone, very light gray, fine to medium, rounded quartz grains, silica cemented; and pink, coarsely crystalline granite; one piece of weathered gray granite
core 5	Quartz diorite

Red River Development Company - E. Berg No. 1
SW 1/4 sec. 35, T. 152 N., R. 51 W., Grand Forks County
North Dakota Geological Survey Well No. 29

Depth	Lithology
350 - 370	Shale, grayish red, slightly calcareous
370 - 390	Sandstone, loose, very fine to medium grained, rounded, slightly frosted, quartz grains
390 - 400	Sandstone, loose, as above and a few chips of white and reddish gray, cemented sandstone
400 - 430	Unconsolidated sandstone, very fine to fine, rounded, slightly frosted grains
430 - 440	Poorer sample - sandstone, as above; shale, brownish gray, flaky, calcareous
440 -	Granite, light colored, quartz, horneblende mica, feldspar

Amerada Petroleum Corporation - H. O. Bakken No. 1
SW 1/4 NW 1/4 sec. 12, T. 157 N., R. 95 W., Williams County
North Dakota Geological Survey Well No. 32; Circular No. 16

Depth	Lithology
13,370 - 410	Limestone, brownish gray, finely crystalline
13,410 - 415	Poor samples
13,415 - 425	Limestone, as above

13,425 - 560	Shale, dark greenish gray, 5G 4/1, to greenish black, 5GY 2/1, platy, compact
13,560 - 570	Sandstone, fine to medium grained, firmly cemented with silica cement
13,570 - 629	Sandstone, fine to medium grained, firmly cemented, some pyrite cement, dark carbonaccous streaks
13,629 - 638	Sandstone, fine to coarse, subangular grained quartzose, friable
13,638 - 643	Sandstone, fine to coarse grained, poorly cemented with clay
13,643 - 656	Sandstone, very fine to medium grained, friable with dark carbonaccous streaks
13,656 - 658	Sandstone, fine to medium grained, firmly cemented with silica
13,658 - 664	Sandstone, quartzitic, medium grained, a few pyrite nodules
13,664 - 669	Sandstone, medium to coarse grained, colorless, subangular quartz, slightly friable
13,669 -	(1st section) Sandstone, white, very fine to medium grained, friable
13,709 -	(2nd - 4th section) Sandstone, white, fine to medium grained, friable

California Company - B. Thompson No. 1
SW 1/4 SE 1/4 sec. 31, T. 160 N., R. 81 W., Bottineau County
North Dakota Geological Survey Well No. 38; Circular No. 7

Depth	Lithology
7800 - 7820	Limestone, very light gray to light gray, very fine to finely crystalline, fragmental
7836 - 7866	Limestone, light gray, very finely crystalline
7866 - 7870	Limestone, as above; a little shale, greenish gray, 5GY 6/1, calcareous
7870 - 7980	Shale, dark greenish gray, 5GY 4/1, splintery
7980 - 7990 cores	Sandstone, very light gray, fine grained, subrounded quartz, firmly cemented
7990 - 8010	Sandstone, very light gray, fine to medium, rounded to subrounded, quartz grains with thin shale stringers, firmly cemented

8010 - 8030	Sandstone, very light gray, medium grained, subrounded to rounded quartz, with some shale stringers, quite friable
8030 - 8040	Sandstone, very light gray, fine to medium grained, subrounded to rounded, colorless quartz grains, quite friable
8040 - 8060	Poor samples, few pieces of sandstone, as above, much shale caving
8060 - 8076	Sandstone, very light gray, very fine grained, calcareous, silty; some sandstone, as above
8076 - 8080	Sandstone, very light gray, fine to very fine grained, very slightly calcareous
8080 - 8126	Sandstone, as above, fine to medium grained
8126 - 8130	Sandstone, very light gray, very fine to fine grained, slightly calcareous, and glauconitic; much sandstone, as above
8130 - 8136	Sandstone, glauconitic, as above; some shale, medium gray to dark greenish gray, splintery with some glauconitic nodules
8226 - 8236	Sandstone, as above; some shale, as above
8236 - 8240	Shale, dark greenish gray, splintery and sandstone, as above
8240 - 8246	Sandstone, loose, medium to coarse, rounded to subrounded quartz; much sandstone and shale in samples
8246 - 8250	Sandstone, as above and a few pieces of granite
8250 - 8270	Granite

Barnett Drilling Incorporated - J. Gaier No. 1
NW 1/4 NW 1/4 sec. 11, T. 141 N., R. 67 W., Stutsman County
North Dakota Geological Survey Well No. 40; Circular No. 11

Depth	Lithology
3750 - 3760	Limestone, light gray, finely crystalline
3770 - 3790	Limestone, light gray, finely crystalline
3800 - 3810	Sandstone, very light gray, very fine grained, calcareous
3810 - 3860	Siltstone, very light gray, calcareous; a little sandstone, as above

3860 - 3870	Shale, greenish gray, 5GY 6/12 flaky to platy, calcareous
3870 - 3880	Shale, greenish gray, platy to splintery, brittle
3880 - 3970	Shale, greenish gray and light olive gray, splintery, brittle
3970 - 3980	Shale, pale red, 10R 4/2, flaky; a little sandstone, fine grained, friable, quartzose
3980 - 3990	Sandstone, pinkish gray, fine grained, dolomitic
3990 - 4010	Sandstone, pinkish gray, varying from very fine grained to medium grained, some pyrite cemented, some loose medium quartz grains
4010 - 4020	Sandstone, light gray to pinkish gray, very fine to fine grained, glauconitic, and pinkish gray, fine to medium grained, friable
4020 - 4040	Sandstone, moderate red, very fine grained, dolomitic, glauconitic grading to pale red, fine to medium crystalline dolomite
4040 - 4070	Sandstone, mod. orange pink, fine grained, friable, slightly calcareous and glauconitic
4070 - 4090	Dolomite, pale red, 5R 6/2, medium crystalline, good intergranular porosity, arenaceous, grading into sandstone, pale red, fine grained, dolomitic
4090 - 4120	Sandstone, pale red to grayish red, 10R 4/2 fine to medium grained, dolomitic
4120 - 4130	Sandstone, as above, becoming medium to coarse grained
4130 - 4140	Sandstone, medium to very coarse, rounded frosted loose quartz grains
4143 -	Orange pink granite

Peak Drilling Company - Olhauser No. 1
NE 1/4 SE 1/4 sec. 8, T. 132N., R. 78 W., Emmons County
North Dakota Geological Survey Well No. 43; Circular No. 83

Depth	Lithology
5362 - circulation -	Siltstone, very light gray, calcareous grading to very fine grained sandstone
5360 - 5380	Siltstone, as above; sample mostly Red River cave

5380 - 5410	Shale, greenish gray, soft, platy, sample mostly cave
5410 - 5540	Shale, greenish gray, 5G 6/1, platy to splintery, compact
5550 - circulation -	Sandstone, fine to medium grained, subangular to rounded, colorless quartz, weakly cemented
5560 - circulation -	Dolomite, very light gray, fine to medium crystalline, arenaceous, slightly glauconitic grading to dolomitic, very fine to medium grained sandstone
5560 - 5620	Dolomite, as above
5620 - 5630	Dolomite, as above; some sandstone, fine to medium grained, rounded, colorless quartz
5630 - 5710	Samples, as above; with some medium to coarse grained, rounded, quartz grains
5710 - 5730	Dolomite, fine to medium crystalline, granular, traces of glauconite
5730 - 5790	Dolomite, light gray, fine to coarsely crystalline, glauconitic, arenaceous
5790 - 5800	Dolomite, as above; some loose, medium to coarse, rounded quartz grains
5800 - 5880	Dolomite, light gray to light yellowish gray, fine to medium crystalline granular, slightly glauconitic becoming very glauconitic 5830 - 5880 grading to dolomitic sandstone
5880 -	Granite, orange pink

W. H. Hunt Estate - J. A. Wald No. 1
SE 1/4 SW 1/4 sec. 23, T. 155 N., R. 81 W., Ward County
North Dakota Geological Survey Well No. 47; Circular No. 12

Depth	Lithology
	Very poor samples
8150 -	Limestone, very light gray, sublithographic to finely crystalline, fragmental
- samples same to 8230	
8230 - 8328	Shale, greenish gray, splintery
8328 -	Sandstone
8330 - 8350	Samples, as above
8350 - 8410	Sandstone, medium to very coarse, rounded, quartz, very friable; much cave in samples
8410 - 8420	Sandstone, fine to medium grained, cemented
8420 - 8440	Sandstone, fine to coarse grained, firmly cemented, some pyrite cement
8440 - 8480	Sandstone, as above; a few pieces of dolomite, very light gray, finely crystalline, slightly glauconitic
8480 - 8510	Sandstone, very light gray, calcareous, slightly glauconitic, fine to medium grained
8510 - 8570	Sandstone, very light gray, fine to coarse grained, silica cemented, weakly cemented, slightly calcareous; scattered glauconite and greenish gray shale
8570 - 8652	Sandstone, very light gray, fine to medium grained, glauconitic, firmly cemented, slightly calcareous

Hunt Oil Company - P. Lennertz No. 1
NW 1/4 SE 1/4 sec. 17, T. 153N., R. 77 W., McHenry County
North Dakota Geological Survey Well No. 61; Circular No. 24

Depth	Lithology
6900 - 6940	Limestone, very light gray, finely crystalline, fine grained
6940 - 6960	Limestone, very light gray, fine grained, silty
6960 - 6980	Shale, dark greenish gray, 5GY 4/1, platy, calcareous
6980 - 7030	Shale, dark greenish gray, 5GY 4/1, splintery, brittle
7030 - 7060	Shale, dark greenish gray and light olive gray, platy, splintery, brittle, compact
7060 - 7100	Shale, dark greenish gray, splintery to platy, brittle
7100 - 7110	Samples poor - mostly limestone and shale cavings - some loose sand, fine to medium, rounded to subangular grains
7110 - 7130	Sandstone, very light gray, very fine to medium grained, rounded to subangular, quartzose, quite friable
7130 - 7140	Mostly fine to coarse, loose, rounded to subrounded quartz; some cemented sandstone, as above

7140 - 7190	Sandstone, very light gray, very fine to medium grained, firmly cemented for the most part
7190 - 7210	Sandstone, very light gray, very fine to fine grained, somewhat friable, well sorted

Hunt Oil Company - O. Olson No. 1
SW 1/4 NW 1/4 sec. 18, T. 163 N., R. 77 W., Bottineau County
North Dakota Geological Survey Well No. 64; Circular No. 9

Depth	Lithology
6130 - 6160	Limestone, very light gray, fine grained, fragmental
6160 - 6300	Shale, greenish gray, splintery
6300 - 6310	Sand, loose, fine to coarse, rounded quartz and some cemented, fine grained quartz
6310 - 6330	Sandstone, fine grained, subangular to rounded, cemented quartz
6330 - 6340	Sandstone, very light gray, fine grained, glauconitic, calcareous; shale, greenish gray
6340 - 6350	Poor sample
6350 - 6360	Sandstone, very light gray, fine grained, calcareous, glauconitic and greenish gray shale
6360 - 6390	Dolomite, very light gray, fine to medium crystalline, glauconitic; sandstone, as above
6390 - 6410	Sandstone, as above; some loose, medium, rounded quartz
6410 -	Granite, light gray

Lion Oil Company - Huss No. 1
NW 1/4 NW 1/4 sec. 23, T. 163 N., R. 75 W., Bottineau County
North Dakota Geological Survey Well No. 110; Circular 38

Depth	Lithology
6160 - 6190	Limestone, very light gray, fine grained to finely crystalline, fragmental
6190 - 6200	Shale, light greenish gray, very calcareous, silty; much limestone, as above
6200 - 6220	Shale, as above
6220 - 6230	Shale, as above and greenish gray, splintery

6230 - 6350	Shale, greenish gray, brittle, splintery
6350 - 6370	Sandstone, loose, fine to coarse grained, rounded, frosted quartzose; some poorly cemented (6360-6370)
6370 - 6380	Sandstone, loose, as above; some fine to medium grained partly cemented with pyrite
6380 - 6390	Sandstone, very light gray, very fine to fine grained, glauconitic, slightly calcareous
6400 - 6410	Sandstone, as above; dolomite, very light gray, medium crystalline, glauconitic, silty
6410 - 6420	Sandstone, loose, fine to very coarse grained, rounded, frosted quartzose
6420 - 6430	Sand, as above; some orange pink granite

General Atlas Carbon Company - A. Peplinski No. 1
SE 1/4 NW 1/4 sec.21, T. 142 N., R. 63 W., Stutsman County
North Dakota Geological Survey Well No. 120; Circular 15

Depth	Lithology
2600 - 2650	Limestone, very light gray, finely crystalline
2650 - 2670	Samples, as above with medium to coarse loose, quartz grains
2670 - 2730	Limestone, light gray, fine grained, silty; (very poor samples 2690-2730) shale, greenish gray, platy, calcareous (2690-2730)
2730 - 2810	Shale, greenish gray, platy to splintery, brittle
2810 - 2850	Shale, grayish red, platy to flaky
2850 - 2890	Sandstone, loose, fine to coarse grained, rounded to subangular quartz
2890 - 2910	Sandstone, grayish red to pale red, fine to medium grained, dolomitic, traces of glauconitic
2910 - 2918	Sandstone, loose, fine to coarse grained, rounded to subangular, quartz grains
2918 -	Granite - no samples

Continental Oil Company - P. McCay No. 1
NW 1/4 NW 1/4 sec. 32, T. 137 N., R. 76 W., Burleigh County
North Dakota Geological Survey Well No. 145; Circular 21

Depth	Lithology
5760 - 5790	Shale, greenish gray, splintery, brittle
Cores	
5790 - 5812½	Shale, greenish gray, blocky, compact
5812½ - 5815	Sandstone, very fine to medium grained, subangular to rounded colorless quartz, very friable, some brownish staining
5815 - 5819	Sandstone, very fine to medium grained, firmly cemented and shale, greenish gray, platy
5819 - 5822½	Sandstone, very fine to medium grained, subangular to rounded, very friable, some brownish staining, no fluorescence
5828 - 5830	Shale, greenish gray, blocky, compact with a few "floating" sand grains
5830 - 5831½	Shale, as above, with floating sand and glauconite grains
5831½ - 5834	Dolomite, very light gray, finely crystalline, granular
Samples	
5830 - 5870	Dolomite, as above
5870 - 5895	Dolomite, light gray, fine to coarsely crystalline, arenaceous, traces of glauconite; some sandstone, as below
5895 - 5920	Sandstone, very fine to medium grained, dolomitic; some dolomite, as above; much loose fine to medium grains
5920 - 5965	Sandstone, fine to coarse grained, slightly dolomitic, some loose grains
5965 - 5985	Sandstone, fine to medium grained, dolomitic, grading to a sandy dolomite
5985 - 6080	Dolomite, very light gray, fine to medium crystalline, sandy, glauconitic; poor samples
6080 - 6110	Loose sand, fine to medium grained, rounded, quartz; some dolomite, as above

6110 - 6115	Dolomite, very light gray, fine to medium crystalline, sandy, slightly glauconitic
6115 - 6125	Dolomite, as above; loose sand, as from 6080-6110
6125 - 6145	Sandstone, fine to medium grained, rounded, slightly glauconitic and dolomitic; some loose sand, as above; some dolomite, as above
6180 - circulation	Light gray to dark gray granite goreiss

Continental Oil Company - Duemeland No. 1
NW 1/4 NW 1/4 sec. 3, T. 140 N., R. 77 W., Burleigh County
North Dakota Geological Survey Well No. 174

Depth	Lithology
6400 - 6415	Limestone, light gray, finely crystalline
6415 - 6425	Shale, greenish gray, platy, calcareous
6425 - 6430	Shale, as above; siltstone, very light gray, calcareous
6430 - 6435	Shale, as above
6435 - 6460	Shale, as above; siltstone, greenish gray, calcareous
6460 - 6510	Shale, greenish gray, splintery, brittle
6510 - 6570	Shale, greenish gray and olive gray, splintery, brittle
Core -	Folio descriptions
6570 - 6575	Shale, brownish gray, streaked with fine to coarse sand at 6571
6575 - 6576	Sandstone, fine to medium, quartzose, well rounded, well sorted, friable; light gravity oil stain
6576 - 6580	Sandstone, as above; oil stain and cut
6580 - 6582	Shale, brownish gray, waxy
6582 - 6584	Sandstone, fine to medium grained, quartzose, well rounded
6584 - 6592	Sandstone, medium grained, quartzose, very friable, subangular to rounded, poor to fair sorting, spotty stain and cut
6592 - 6594	Sandstone, fine grained, quartzose, subangular to well rounded, imbedded shale pellets

6594 - 6595	Shale, grayish brown, sandy streaked
6595 - 6629	Dolomite, brownish gray to grayish brown, micro to finely crystalline, slightly argillaceous and laminated with shale pyritic, locally, very slightly sandy, glauconitic in part
6629 - 6638	Dolomite, as above
6638 - 6647	Limestone, brown, coarsely crystalline, sandy, slightly argillaceous to laminated with shale grades into calcareous sandstone - 47
6647 - 6653	Sandstone, brown to tan, mottled, very calcareous, poorly sorted, argillaceous; very fine to fine grained, well rounded and frosted in the last foot.

Samples

6655 - 6660	Sandstone, very light gray, very fine to fine grained, calcareous glauconitic (samples mostly cave)
6660 - 6680	Sandstone, fine to very fine grained, quartzose, (very slightly calcareous) subangular to rounded (samples poor)
6680 - 6690	Sandstone, fine to medium grained, subangular to rounded, very slightly calcareous
6690 - 6730	Sandstone, as above; some coarse, rounded quartz grains, becoming coarser 6720-6730; traces of glauconite (6725-6730)
6730 -	Shale, brownish gray and greenish gray
6730 - 6760	Splintery, brittle, slightly calcareous
6760 - 6765	Dolomite, very light gray, fine grained, granular, traces of glauconite and sand
6765 - 6775	Limestone, very light gray, fine grained, glauconitic; some dolomite, as above
6775 - 6780	Limestone and dolomite, as above; some shale, greenish gray
6780 - 6790	Limestone, very light gray, fine grained, glauconitic
6790 - 6825	Samples mostly greenish gray shale
6825 - 6835	Sandstone, very fine to fine grained, glauconitic; well sorted, quite friable (sample poor)
6835 - 6860	Sample mostly shale, greenish gray

Continental Oil Company - Leuth No. 1
NE 1/4 NE 1/4 sec. 27, T. 146 N., R. 73 W., Wells County
North Dakota Geological Survey Well No. 207; Circular 20

Depth	Lithology
5605 - 5655	Limestone, yellowish gray, finely crystalline to fine grained; some light gray chert; bottom 10 feet, very poor sample
5675 - 5685	Shale, greenish gray, splintery to flaky
5685 - 5715	Shale, greenish gray, 5G 6/1 splintery, some olive gray, splintery
5735 - 5750	Shale, greenish gray, splintery
5825 - 5855	Cavings
5855 - 5875	Sandstone, loose, medium to very coarse, rounded, frosted quartz grains
5875 - 5890	Sandstone, very light gray, fine to coarse grained, slightly calcareous
5890 - 5965	Sandstone, pinkish gray, fine to medium grained, fairly well cemented; much medium to coarse, loose, rounded, frosted quartz
5915 - 5920	Sandstone, cemented, as above; a few chips of very light gray, fine grained, glauconitic limestone
5920 - 5925	Sandstone, light brownish gray, very fine grained, limey, glauconitic; some sandstone, pinkish gray, as above
5925 - 5935	Sandstone, pinkish gray, very fine to coarse grained, well cemented, slightly calcareous
5935 - 5965	Sandstone, pinkish gray to yellowish gray, very fine to medium grained, calcareous, glauconitic
5990 - 6005	Sandstone, very light gray, fine grained, calcareous, glauconitic; some limestone, very light gray, fine grained, glauconitic
6005 -	Granite, pink

Carter Oil Company - North Dakota State No. 1
NE 1/4 SE 1/4 sec. 16, T. 143 N., R. 71 W., Kidder County
North Dakota Geological Survey Well No. 230; Circular 32

Depth	Lithology
4750 - 4770	Poor samples, Cretaceous shale cavings
4770 - 4810	Limestone, white to very light gray, fine grained, chalky; a little chert, very light gray
4810 - 4830	Sample mostly Cretaceous shale cave
4840 - 4850	Samples, same as above
4860 - 4870	Limestone, white, as in 4770-4810
4870 - 4940	Sample mostly Cretaceous shale cave; some shale, greenish gray, platy to splintery
4940 - 4980	Shale, greenish gray, splintery
4980 - 4995	Shale, greenish gray and grayish red, 5R 4/2, splintery
Core -	Unavailable, file description
5010 - 5065	Rec. 42' sand, broken with occasional red dolomitic shale

Amerada Petroleum Corporation - H. May Unit No. 1
NW 1/4 NE 1/4 sec. 9, T. 139 N., R. 100 W., Billings County
North Dakota Geological Survey Well No. 291; Circular 50

Depth	Lithology
12,929 - 934	Sandstone, very light gray, fine to very fine grained with scattered medium grains and greenish gray shale stringers, slightly friable
12,934 - 935	Sandstone, as above and shale, medium dark gray, platy
12,935 - 936	Sandstone, as above and white, sedimentary quartzite
12,946 - 951	Shale, medium to medium dark gray, platy, velvety
12,951 - 956	Limestone, medium light gray, micro-crystalline, dense
12,956 - 966	Limestone, medium light gray, finely crystalline with scattered medium crystalline, scattered pyrite (961-966)
12,966 - 976	Limestone, medium light gray, fine to medium crystalline fragmental; a couple of thin, dark gray shale stringers

Depth	Lithology
12,976 - 996	Limestone, medium gray to light brownish gray, very finely crystalline, scattered medium crystalline, and thin dark gray shale stringers
12,996 - 13,000	Sandstone, light gray, fine to medium grained, shaly, calcareous
13,000 - 004	Sandstone, white, medium grained, quartzitic cement with greenish gray shale stringers
13,004 - 014	Sandstone, white to light brownish gray, medium grained, calcareous
13,014 - 019	Sandstone, as above and medium to coarse grained with shale stringers
13,019 - 020	Sandstone, white, fine to medium grained; shale stringers, slightly calcareous
13,020 - 033	Sandstone, white and light brownish gray, medium to coarse grained, calcareous; some thin medium gray shale stringers
13,033 - 038½	Sandstone, white to light brownish gray, fine to coarse grained, some shale stringers, calcareous
13,045 - 070	Sandstone, as above, white from (13,053-13,070)
13,073 - 078	Sandstone, white, medium to coarse grained, angular to subangular, quartzose
13,078 - 112	Sandstone, white, fine to coarse grained, quartzose
13,112 - 115	Sandstone, white, fine to medium grained, quartzose
13,115 - 120	Sandstone, white, fine to coarse grained; some shaly stringers
13,120 - 127	Sandstone, light gray, fine to medium grained, slightly argillaceous and shale, medium dark gray
13,127 - 154	Sandstone, white to light gray, fine to medium grained, slightly calcareous; some thin beds of shale, medium dark gray (13,136-13,142 and 13,150-13,154)
13,154 - 155	Limestone, medium light gray to light brownish gray, fine to coarsely crystalline, fragmental, glauconitic
13,155 - 157	Sandstone, light gray, fine grained, calcareous; some shale, medium dark gray
13,157 - 158	Sandstone, green, fine to medium grained, glauconitic, calcareous, pyritic

13,158 - 162	Sandstone, light gray, very fine grained, slightly calcareous, looks like quartzite with medium dark gray, shale stringers
13,165 - 167	Sandstone, as above, with thin shale stringers
13,167 - 169	Limestone, light brownish gray, fine to medium crystalline, fragmental
13,169 - 179	Limestone, light gray, fine grained, silty with some shale, medium dark gray, stringers slightly glauconitic (13,175-13,179)
13,179 - 182	Limestone, light gray, medium to coarsely crystalline, fragmental, glauconitic, with thin shale lenses
13,182 - 221	Limestone, light gray, fine to medium crystalline, with thin shale stringers
13,221 - 236	Interbedded limestone and shale, as above; glauconitic (13,231-13,236)
13,236 - 242	Limestone, light gray, medium to coarsely crystalline, fragmental, glauconitic with some shale layers
13,242 - 252	Limestone, light gray, fine to medium crystalline, with some shale layers, medium gray
13,252 - 259	Limestone, light gray, very finely crystalline, some fine to medium crystalline
13,259 - 274	Limestone, light gray, very fine to medium crystalline, interbedded with medium to coarsely crystalline limestone
13,274 - 276	Shale, medium gray, calcareous
13,276 - 285	Limestone, light gray, fine to medium crystalline, interbedded with shale, medium gray, calcareous
13,285 - 287	Limestone, light gray, very finely crystalline
13,287 - 288	Limestone and shale, as from (276-285)
13,288 - 295	Limestone, light gray, medium to coarsely crystalline
13,295 - 297	Limestone, as above, interbedded with finely crystalline limestone; shale stringers
13,297 - 301	Limestone, light gray, medium to coarsely crystalline, glauconitic

13,301 - 307	Sandstone, light gray, fine to medium grained, calcareous, glauconitic with argillaceous layers
13,307 - 325	Limestone and shale, as from 13,295-13,297)

Pure Oil Company - J. Carr No. 1
NE 1/4 NE 1/4 sec. 15, T. 146 N., R. 66 W., Foster County
North Dakota Geological Survey Well No. 403; Circular 43

Depth	Lithology
3310 - 3325	Limestone, pinkish gray, fine grained, some limestone, light yellowish gray, finely crystalline
3325 - 3350	Limestone, as above, a little white chert
3350 - 3400	Samples poor - some limestone, as above; a few chips of light greenish gray, calcareous siltstone 3380-3385
3400 - 3405	Poor samples
3405 - 3425	Shale, greenish gray, 5G 6/1, platy, slightly calcareous
3425 - 3430	Shale, greenish gray and olive gray, platy to splintery, slightly calcareous
3430 - 3495	Shale, greenish gray, 5G 6/1, splintery, brittle
3495 - 3535	Shale, greenish gray and olive gray, splintery, brittle
3535 - 3540	Shale, as above; some limestone cave and a few loose, medium quartz grains
3540 - 3545	Sandstone, loose, fine to medium grained, subangular to rounded quartz
3545 -	Weathered, gray igneous rock

Herman Hanson Oil Syndicate - M. Mueller No. 1
NE 1/4 NE 1/4 sec. 20, T. 140N., R. 65 W., Stutsman County
North Dakota Geological Survey Well No. 406; Circular 51

Depth	Lithology
2980 - 3010	Limestone, very light gray, fine grained to finely crystalline, fragmental
3010 - 3030	Sandstone, very light gray, very fine to fine grained, calcareous, limestone, light gray, fine grained, arenaceous

3030 - 3050	Shale, light greenish gray, lumpy to flaky, calcareous, slightly silty (poor samples)
3050 - 3100	Shale, as above; sandstone, very light gray to light greenish gray, very fine grained, silty, calcareous
3100 - 3160	Shale, greenish gray, platy to splintery, brittle
3160 - 3200	Shale, grayish red, flaky; shale, greenish gray as above
3200 - 3216	Shale, grayish red and light olive gray, 5Y 5/2, flaky
3216 - 3230	Samples, same as above; a few loose quartz grains, fine to medium grained, rounded
3230 - 3250	Sandstone, grayish orange pink, fine grained, friable, traces of glauconite and shale, greenish gray and grayish red
3250 - 3270	Sandstone, as above, and grayish pink, fine to medium grained, subangular to subrounded
3270 - 3277	Sandstone, grayish red to grayish pink, fine to medium grained, dolomitic, traces of gluaconite
core	
3277 - 3280	Sandstone, very light gray, very fine to fine grained, friable, with thin shale, greenish gray, streaks
3280 - 3285	Sandstone, very light gray to pinkish gray, very fine to fine grained with scattered medium grains
3285 - 3290	Sandstone, pale red, very fine to fine grained, slightly dolomitic
3290 - 3295	Sandstone, very light gray, very fine to fine grained, friable, quartzose
3295 - 3300	Sandstone, very light gray, very fine to fine grained, some medium grains, rounded, quartzose, very friable
3300 - 3305	Sandstone, as above with a few medium to coarse, subangular quartz grains
3305 -	Weathered pink granite

Gulf Oil Corporation - Dorough, Federal No. 1
NE 1/4 SW 1/4 sec. 24, T. 143 N., R. 103 W., Golden Valley County
North Dakota Geological Survey Well No. 410

Depth	Lithology
13000 - 3010	Limestone, light brownish gray, very finely crystalline, dense, slightly argillaceous; some shale, black, platy, brittle, calcareous
13010 - 015	Shale, dark greenish gray, platy to splintery, non-calcareous
13015 - 025	Shale, dark greenish gray and brownish gray, splintery, brittle
13025 - 035	Sandstone, very light gray, very fine grained, calcareous, firmly cemented; shale, as above
13035 - 080	Shale, brownish gray and dark greenish gray, splintery; mostly dark greenish gray (055-080)
13080 - 114	Shale, brownish black, splintery
13114 - 120	Sandstone, very light gray, fine grained, shaly, calcareous; sample, mostly shale
13120 - 133	Sandstone, white, fine to medium grained, slightly calcareous
cores	
13133 - 135	Sandstone, light greenish gray, very fine to fine grained, with scattered medium, rounded grains, firmly cemented; thin shaly streaks
13135 - 139	Sandstone, very light gray to white, fine grained, friable
13139 - 145	Sandstone, very light gray, fine grained, with scattered medium grains, friable, shaly (greenish gray) some pyrite
13145 - 149	Sandstone, light greenish gray and white, fine to very fine grained, silica cemented; some scattered medium grains
13149 - 151	Sandstone, very light gray, fine to medium, rounded grains; shale, greenish gray, blocky
13151 - 157	Shale, greenish gray, platy with arenaceous streaks
13157 - 159	Sandstone, very light gray, very fine grained, slightly argillaceous, some iron oxide staining
13159 - 164	Shale, medium gray, platy with arenaceous lens; sandstone greenish gray, very fine grained, argill, approaching quartzite texture

13,164 - 167	Shale, brownish black, platy; a lens of medium to fine grained, rounded sandstone, pyrite cemented and orthoquartzite, very light gray
13,167 - 169	Shale, brownish black, platy
13,169 - 183	Limestone, light gray, fine to medium crystalline, a few shell fragments, a little pyrite; with thin layers of greenish gray
13,183 - 204	Limestone, light gray, fine to coarsely crystalline, a little pyrite and glauconite; thin layers of greenish gray shale
13,204 - 206	Dolomite, light brownish gray, fine to medium crystalline and limestone, as above
13,206 - 208	Limestone, light brownish gray, medium to coarsely crystalline fragmental, traces of pyrite and glauconite
13,208 - 226	Limestone, light brownish gray, fine to medium crystalline scattered thin layers of medium gray shale
13,226 - 228	Shale, medium dark gray, platy to flaky, calcareous
13,228 - 230	Shale, as above; interbedded with limestone, light brownish gray, fine to medium crystalline
13,230 - 238	Limestone, light brownish gray, fine to medium crystalline slightly fragmental, traces of shale and glauconite
13,238 - 253	Interbedded limestone, light brownish gray, fine to medium crystalline, and shale, medium dark gray
13,253 - 255	Limestone, light gray, very finely crystalline
13,257 - 329	Limestone, light gray, finely to medium crystalline; with shale interbeds; traces of glauconite
13,329 - 348	Limestone, as above; with shale layers, glauconitic and shell fragments
13,348 - 352	Limestone, as above; with brachiopod fragments
13,352 -	Limestone, light gray, very finely crystalline and medium crystalline, fragmental; some interbedded shale

Calvert Exploration Company - North Dakota State No. 1
NW 1/4 NW 1/4 sec. 16, T. 150 N., R. 67 W., Eddy County
North Dakota Geological Survey Well No. 437; Circular 45

Depth	Lithology
3850 - 3975	Very poor samples
3975 - 4070	Shale, greenish gray, splintery to platy, brittle

4070 - 4100	Shale, greenish gray and grayish red, platy and splintery, brittle
4100 - 4110	Sandstone, pinkish gray to very light gray, very fine to medium and coarse grained, slightly calcareous, subangular to rounded grains
4110 - 4120	Sandstone, pinkish gray, fine to coarse grained, rounded and subangular, mostly loose quartz grains
4120 - 4130	Sand, loose, medium to coarse, rounded quartz grains; some sandstone, as above
4130 - 4150	Sandstone, grayish orange pink, very fine to fine grained, friable, very slightly calcareous
4150 - 4160	Sandstone, pinkish gray to very light gray, very fine to fine grained, very slightly calcareous, friable
4160 - 4180	Dolomite, pale red, fine to medium crystalline, sandy, traces of glauconite; some sandstone, as above
4180 - 4210	Sandstone, pinkish gray to light gray, very fine to fine grained, slightly dolomitic, traces of glauconite
4210 - 4220	Sand, loose, fine to very coarse, subangular to rounded, quartz grains; a few chips of orange-pink granite
4220 - 4235	Orange-pink granite

Calvert Exploration Company - J. Bender No. 1
NW 1/4 NW 1/4 sec. 19, T. 130 N., R. 69 W., McIntosh County
North Dakota Geological Survey Well No. 621

Depth	Lithology
3430 - 3467	Limestone, yellowish gray, very finely crystalline
3467 - circulation - 1 hr.	Sample mostly limestone, as above; some loose, subangular quartz; some shale, various shades of gray; a few pieces of siltstone, light greenish gray, calcareous
3467 - 3490	Shale, greenish gray, 5 GY 6/1, platy, silty
3490 - 3500	Siltstone, very light gray, calcareous
3500 - 3520	Shale, greenish gray and medium gray, platy to flaky
3520 - 3640	Shale, greenish gray, splintery
3640 - 3650	Sandstone, very light gray, fine to medium grained, shale as above

3653 - circulation - Sandstone, very light gray, fine grained, glauconitic, calcareous; some sandstone, as above; shale, greenish gray

3650 - 3670	Sandstone, glauconitic, as above
3670 - 3700	Dolomite, very light gray, fine grained, silty, glauconitic; yellow stained (3690-3700)
3700 - 3760	Dolomite, very light gray, fine to medium grained, glauconitic; a little sandstone, very light gray, fine grained, glauconitic
3760 - 3780	Sand, fine to coarse, loose, rounded, frosted, quartz grains; dolomite, as above (3760-70)
3780 - 3790	Sand, loose as above; some chips of chalky white, weathered granite?
3790 - 3820	Samples, as above with some chips of fresh pink granite
3820 - 3830	Pink granite

Ohio Oil Company - Sioux Tribal No. 1
NE 1/4 SW 1/4 sec. 29, T. 131 N., R. 80 W., Sioux County
North Dakota Geological Survey Well No. 631; Circular 91

Depth	Lithology
5590 - 5620	Limestone, yellowish gray, finely crystalline
5620 - 5650	Limestone, as above; some chert, white
5650 - 5690	Sandstone, very light gray, very fine to fine grained
5720 - 5730	Shale, greenish gray, 5 G 6/1, splintery
5730 - 5740	Shale, pale brown, 5 YR 5/2, splintery
5740 - 5780	Shale, greenish gray, 5 G 6/1, splintery
5800 - 5820	Shale, as above
5820 - 5830	Sandstone, fine to medium grained, pyrite cemented
5840 - 5850	Sandstone, fine to medium grained, rounded, friable (sample mostly green shale)
5860 - 5870	A few chips of fine grained, white sandstone, slightly calcareous
5870 - 5880	Some loose, fine to medium, rounded, frosted, quartz grains

5890 - 5907	Some loose grains, as above

Calvert Exploration Company - M. Meyers No. 1
SE 1/4 SW 1/4 sec. 25, T. 137 N., R. 67 W., Stutsman County
North Dakota Geological Survey Well No. 668

Depth	Lithology
3500 - 3550	Shale, greenish gray, splintery
3550 - 3590	Samples poor; some grayish red shale from 3580-90
3591 - circulation 1 hr.	Sandstone, mostly loose, fine to medium, rounded to subrounded, quartz grains
3590 - 3600	Sandstone, as above
3600 - 3620	Dolomite, very pale orange, very finely crystalline; some sandstone, as above
3630 - 3670	Sandstone, pale red, fine grained, dolomitic
3670 - 3680	Sandstone, pinkish gray to pale red, fine to medium grained, dolomitic, traces of glauconite
3680 - 3690	Sandstone, as above and loose, fine to coarse, rounded to subrounded grains
3690 - 3700	Sandstone, as above and dark igneous rock (metamorphic?)
3700 - circulation	dark gray, igneous rock

Calvert Exploration Company - V. Wanzek No. 1
NW 1/4 NW 1/4 sec. 12, T. 139 N., R. 67 W., Stutsman County
North Dakota Geological Survey Well No. 672

Depth	Lithology
3540 - 3570	Limestone, very light gray, fine grained; a little chert, white and pinkish gray, finely crystalline, dolomite
3570 - 3610	Sandstone, very light gray, fine grained, calcareous
3610 - 3640	Shale, greenish gray, silty, calcareous, platy, some sandstone, as above; much limestone cave
3640 - 3730	Shale, greenish gray, platy to splintery, brittle
3730 - 3740	Shale, grayish red and greenish gray, platy to flaky and splintery
3740 - 3760	Shale, pale brown and greenish gray, splintery, brittle

3760 - 3770	Sandstone, loose, fine to medium, rounded, quartz; shale, as above
3770 - 3790	Sandstone, pale red, fine to medium grained, slightly dolomitic; some coarse grains, rounded
3790 - 3810	Sandstone, pale red as above, mostly medium to coarse grained and sandstone, pinkish gray to very pale orange, very fine to fine grained, quite friable, traces of glauconite
3810 - 3880	Dolomite, pale red, medium crystalline, sandy, glauconitic grading to pale red, dolomitic sandstone
3880 - 3890	Sandstone, pale red, dolomitic, fine to medium rounded grains, loose
3890 - 3899	Loose, fine to coarse grained, subangular to rounded quartz grains and orange pink granite

Calvert Exploration Company - F. L. Robertson No. 1
NE 1/4 NE 1/4 sec. 26, T. 138 N., R. 67 W., Stutsman County
North Dakota Geological Survey Well No. 673

Depth	Lithology
3420 - 3450	Limestone, very light gray, finely crystalline to very finely crystalline, a little white chert
3450 - 3480	Limestone, very light gray, fine grained, earthy
3480 - 3500	Sandstone, light gray, fine grained, calcareous
3500 - 3530	Shale, greenish gray, flaky, calcareous, silty
3530 - 3540	Poor sample
3540 - 3550	Shale, greenish gray, platy, calcareous
3550 - 3670	Shale, greenish gray, splintery, brittle
3670 - 3680	Shale, as above; a few chips of granite

Caroline Hunt Trust Estate - Board of University and School Lands No. 1
NE 1/4 NE 1/4 sec. 36, T. 144 N., R. 75 W., Burleigh County
North Dakota Geological Survey Well No. 701

Depth	Lithology
6000 - 6070	Limestone, very light gray, finely crystalline to fine grained
6070 - 6090	Shale, dark greenish gray to medium dark gray, splintery, slightly calcareous

6090 - 6130	Shale, greenish gray, and olive gray, splintery, slightly calcareous; 2 Brachiopod specimens (90-00)
6130 - 6170	Shale, greenish gray and brownish gray, splintery; greenish gray shale, slightly calcareous
6170 - 6200	Shale, greenish gray, splintery
6200 - 6250	Samples, same as above
6260 - 6270	Samples, mostly cavings as above; one chip of sandstone, very light gray, fine grained
6270 - 6280	A few pieces of sandstone, fine to medium, rounded quartz, silty
6280 - 6290	A few pieces of sandstone, very light gray, very fine to fine grained
6290 - 6300	A few loose, medium to coarse, rounded quartz grains

Cardinal Drilling Company - N. A. Graves, Federal Land Bank No. 1
NE 1/4 NE 1/4 sec. 23, T. 146 N., R. 66 W., Foster County
North Dakota Geological Survey Well No. 1112

Depth	Lithology
3450 - 3460	Limestone, very light gray, finely crystalline to sublithographic
3460 - 3470	Limestone, very light gray, fine grained to finely crystalline, some white chert
3470 - 3500	Limestone, as above; shale, light greenish gray, 5 G 8/1, very calcareous; (3480-3490) very poor sample
3500 - 3520	Poor samples
3520 - 3560	Siltstone, light greenish gray, calcareous; shale, light greenish gray to greenish gray, calcareous; mostly shale (3530-60)
3560 - 3570	Shale, greenish gray, splintery, very slightly calcareous; a little olive gray, shale, splintery
3570 - 3610	Shale, greenish gray, splintery
3610 - 3630	Shale, greenish gray and grayish red, splintery, brittle
3630 - 3640	Shale, pale brown, 5 YR 5/2

3640 - 3650	Shale, greenish gray and grayish red, splintery, brittle
3660 - 3700	Shale, as above
3700 - 3710	Sandstone, fine to medium grained, friable; much loose, medium to coarse, rounded quartz grains
3710 - 3720	Dolomite, grayish red, 5 R 4/2, fine to medium crystalline, glauconitic
3720 - 3740	Dolomite, grayish pink to grayish red, fine to medium crystalline, glauconitic, silty
3740 - 3760	Dolomite, grayish red, fine to medium crystalline, glauconitic, silty with scattered sand grains
3760 - 3770	Dolomite, grayish red, 5 R 4/2, fine to medium and coarsely crystalline, glauconitic, arenaceous
3770 - 3800	Sandstone, medium to very coarse, rounded to subangular, loose quartz; a little fine to medium grained, cemented sandstone
3800 - 3802	Pink granite

Wetch, Zachmeier and Disney Drilling Company - C. E. Blaskey No. 1
SE 1/4 SE 1/4 sec. 9, T. 148 N., R. 62 W., Eddy County
North Dakota Geological Survey Well No. 1274

The samples from 2,810 to 3,030 were not corrected for sample lag.

Depth	Lithology
2750 - 2770	Limestone, very pale orange, very fine grained to finely crystalline, with a few scattered shell fragments
2770 - 2800	Limestone, very light yellowish gray, very fine grained to finely crystalline, scattered shell fragments, scattered reddish mottling; and limestone, as above
2800 - 2810	Limestone, very light gray, finely crystalline to fine grained, scattered shell fragments; some chert, white and light gray
2810 - 2870	Limestone, very light gray to yellowish gray, finely crystalline to fine grained, a few scattered shell fragments, a few scattered pieces of chert
2870 - 2880	Limestone, as above; a little Dolomite, very pale orange, finely crystalline; some chert, white
2880 - 2900	Dolomite, grayish orange pink, finely crystalline; limestone, yellowish gray to grayish orange pink, finely crystalline to fine grained, scattered shell fragments, some white chert
2900 - 2910	Dolomite and limestone, as above; a little shale, medium light gray with a greenish tinge, platy, calcareous
2910 - 2920	Shale, medium light gray, platy, calcareous
2920 - 2960	Shale, pale red, 5 R 6/2, greenish gray, 5 G 6/1; platy, very slightly calcareous
2960 - 2990	Shale, as above, very calcareous in part
2990 - 3000	Shale, grayish red, splintery, compact
3000 - 3030	Shale, as above and greenish gray, splintery; poor samples, much cave from Red River
3036 - circulation	- Sandstone, fine to medium, rounded to subrounded, loose, colorless quartz grains
3045 - 3060	Sandstone, as above, with a few coarse grains
3060 - 3080	Sandstone, grayish red, very fine to fine grained, dolomitic, silty, color from iron staining; loose sand, as above
3080 - 3100	Sandstone, grayish red, very fine to medium grained, firmly cemented, silty in part
3100 - 3102	Samples as above, with a few pieces of weathered granite?

Calvert Drilling, Incorporated - R. Craig No. 1
NW 1/4 NW 1/4 sec. 25, T. 136 N., R. 71 W., Logan County
North Dakota Geological Survey Well No. 1347

Depth	Lithology
4100 - 4140	Limestone, very light gray, fine grained, fragmental
4140 - 4170	Sandstone, very fine grained, silty, calcareous
4170 - 4200	Samples porr; some sandstone, as above, some medium gray shale; some limestone cavings
4200 - 4210	A few pieces of shale, greenish gray, flaky
4210 - 4334	Shale, greenish gray, splintery, brittle
4330 - 4342	Sand, white, fine to medium grained, rounded, quartzose

4340 - 4350	Sandstone, very pale orange, very fine grained, friable
4350 - 4360	A couple of chips of sandstone, as above
4360 - 4370	Sandstone, very light gray and very pale orange, very fine to fine grained
4380 - 4390	Sandstone, very pale orange to grayish red, very fine to fine grained, friable, traces of glauconite
4390 - 4420	Sandstone, as above and mod. red, dolomite, sandstone grading to mod. red dolomite, medium crystalline, sandy, traces of glauconite
4420 - 4450	Sandstone, very pale orange to grayish pink, very fine to fine grained, friable, mod. glauconitic
4450 - 4470	Sandstone, pinkish gray to mod. red, fine to medium grained, dolomitic grading to sandy dolomite
4470 - 4540	Dolomite, pale red to grayish pink, fine to medium crystalline, arenaceous; some dolomitic sandstone, as above; traces of glauconite
4540 - 4560	Sample mostly shale cave; some dolomite, as above; some loose, medium to coarse grained, rounded quartz
4562 -	Granite, no samples

Amerada Petroleum Corporation - North Dakota "A" Unit No. 9
SE 1/4 SW 1/4 sec. 16, T. 156 N., R. 95 W., Williams County
North Dakota Geological Survey Well No. 1385

Depth	Lithology
13,933-943	Sandstone, white, fine to very fine, rounded, silica cemented, quartzose; (shale, greenish gray at (13,933) sandstone, some quite friable, some firmly cemented; a few thin shaly streaks and some black carbonaceous material beginning at 13,940
13,946-961	Sandstone, mottled light to medium gray, very fine to fine, rounded, quartz grains; black carbonaceous and shaly material gives the mottled appearance
13,961	Sandstone, light gray, very fine to fine, rounded quartz grains, very little carbonaceous material, some pyrite cement associated with the carbonaceous material
13,963-990	Sandstone, as from 13,946-961

13,990 - 14,008	Sandstone, light gray, very fine to fine, rounded quartz grains; little carbonaceous material and pyrite
14,013 - 021	Sandstone, white and medium gray, mottled, very fine to fine, rounded, slightly frosted; carbonaceous mottling and pyrite associated with the carbonaceous material
14,021	Sandstone, light gray, very fine to fine grained, colorless, rounded to subangular, quartz grains, small amounts of pyrite
14,022 - 027	Sandstone, as from 14,013-021
14,027	Sandstone, as above; with shale, medium gray, in thin layers
14,030½ - 061	Sandstone, light gray, very fine to fine, rounded to subangular quartz, some fine to medium
14,069 - 090	Sandstone, colorless to white, very fine to fine grained, silica cemented; with a little shale, medium gray, sandy, fine, rounded quartz
14,090 - 095	Sandstone, colorless to white, very fine to fine grained; with scattered shale grains and increased amount of medium gray shale and shale stringers
14,095 - 105	Shale, medium gray, sandy and shaly sandstone, very fine to fine grained, rounded
14,105 - 110	Sandstone, white to colorless, very fine to fine grained, quartz; light gray shale; some medium gray shale stringers
14,110 - 120	Shale, greenish gray and medium gray, platy, with some sandy streaks; some sandstone, as above
14,120 - 125	Shale, greenish gray and pale red, splintery; some sandstone, as above
Core	
14,129 - 134	Sandstone, pale red, very fine to medium, rounded, frosted quartz grains
14,134 - 139	Sandstone, white, very fine to medium, rounded, frosted quartz; a little white argillaceous cement
14,139 - 144	Sandstone, white, very fine to medium, rounded, frosted, quartz
14,144 - 154	Sandstone, very light gray, very fine to fine grained, rounded, argillaceous

14,154 - 162 Shale, grayish red, compact

14,162 - 167 Sandstone, white, very fine to medium grained, contains conodonts

14,167 - 174 Shale, greenish gray with interbedded thin sandstone streaks

14,184 - 189 Sandstone, very fine to fine, rounded, frosted grains

14,189 - 199 Quartzite, colorless, oil stained on fractures

14,199 - 224 Sandstone, colorless, very fine to fine grained, silica cemented

14,271 - 276 Sandstone, white, very fine grained, silica cemented

14,276 - 281 Sandstone, as above with shale stringers, medium gray

14,281 - 291 Shale, medium gray

Samples

14,293 - 295 Shale, as above

14,295 - 300 Dolomite, brownish gray, finely crystalline, dense, slightly limy

14,300 - 315 Limestone, brownish gray, finely crystalline, dense, shale, medium gray

14,315 - 320 Limestone, brownish gray, very finely crystalline, dense, fragmental

14,320 - 340 Limestone, medium gray, very fine to finely crystalline, fragmental, glauconitic

14,340 - 345 Limestone, as above; some shale, medium gray

14,345 - 350 Limestone, as above; sandstone, white, fine to medium, rounded grains, silica cemented

14,350 - 375 Sandstone, white, fine to medium, rounded grains, silica cemented

14,385 - 390 Sandstone, as above

14,390 - 395 Sandstone, as above; a little limestone, light gray, very finely crystalline

14,395 - 400 Dolomite, medium gray, finely crystalline, argillaceous

14,400 - 405 Dolomite, as above; some medium gray shale

14,405 - 415 Limestone, light gray, very finely crystalline, slightly argillaceous

14,415 - 420 Limestone, medium gray, finely crystalline, fragmental; shale, medium gray, platy, slightly calcareous

14,420 - 425 Shale, as above

14,425 - 427 Shale, medium gray and greenish gray, platy, slightly calcareous

14,427 - 435 Limestone, light gray, finely crystalline; shale, as above

14,435 - 460 Shale, medium dark gray, platy, compact, splintery, some limestone as above

14,460 - 465 Shale, as above; a little limestone, very finely crystalline, glauconitic

14,465 - 483 Limestone, very light gray, very finely crystalline, slightly glauconitic, fragmental; much shale, as above

14,485 - 505 Limestone, very light gray and light brownish gray, very finely crystalline, fragmental, slightly glauconitic; shale, greenish gray and medium dark gray, splintery, slightly calcareous

14,505 - 545 Limestone, light gray, very finely crystalline, fragmental, slightly glauconitic

14,545 - 560 Shale, medium dark gray, splintery, brittle; some limestone, as above

14,560 - 610 Limestone, light gray to medium gray, very finely crystalline; some shale, as above

14,610 - 620 Limestone, as above; a little sandstone, dirty gray, fine grained, argillaceous; shale, medium dark gray

14,620 - 625 Shale, medium dark gray, platy, with sandstone lenses and scattered sand grains; some sandstone, as above

14,625 - 685 Limestone, light gray, finely crystalline, glauconitic; a little sandstone, and shale, as above

14,685 - 695 Limestone, very light gray, finely crystalline, slightly argillaceous, glauconitic and sandy

14,695 - 705 Limestone, as above; some sandstone and shale, interbedded, greenish gray and red stained, sand, fine grained

14,705 - 720 Sandstone, very fine to fine grained, rounded, argillaceous with some sandy shale, medium gray; a little limestone, as above

14,720 - 735 Limestone, light gray, fine to medium crystalline, very glauconitic

14,735 - 770 Sandstone, white, very fine to medium, rounded, frosted, quartz, silica cemented

14,770 - 795 Weathered Precambrian, orange-pink Syenite; some rounded sand grains

14,795 - 800 Syenite, orange pink

14,800 - Syenite, light gray

Calvert Drilling, Incorporated - M. Kamm No. 1
NW 1/4 NW 1/4 sec. 22, T. 129 N., R. 66 W., Dickey County
North Dakota Geological Survey Well No. 1394

Depth	Lithology
2800 - 2920	Limestone, grayish orange pink, fine to medium crystalline, fragmental; some white chert a little more reddish colored and shaly 2890-2920
2920 - 2940	Sandstone, very light gray, very fine grained, silty, slightly calcareous; most of sample is limestone, as above
2940 - 2990	Very poor samples
2990 - 3100	Shale, greenish gray, splintery, waxy
3100 - 3110	Sandstone, loose, fine to medium, rounded quartz grains; shale, cave
3110 - 3130	Poor samples, traces of grayish red shale, with glauconite
3130 - 3165	Sandstone, pale red and yellowish gray, fine to medium grained, dolomitic, glauconitic
3165 -	Granite, light gray, weathered, gneissic texture

Amerada Petroleum Corporation - Boe, Olson Unit No. 1
NE 1/4 sec. 15, T. 155 N., R. 96 W., Williams County
North Dakota Geological Survey Well No. 1403

Depth	Lithology
13,456 - 468	Sandstone, light gray, fine grained, rounded to subangular, some staining, quartzose
13,480 - 502	Sandstone, very light gray, very fine to fine grained, subangular and rounded, quartzose; much carbonaceous material, some light oil stain at 481

13,506 - 508	Sandstone, white, very fine to medium, quartzose, rounded and subangular; scattered light oil stain
13,509 - 510	Sandstone, as 480-502; a few thin medium dark gray shale stringers at 13,510
13,514 - 520	Sandstone, white, very fine to medium, rounded, frosted, quartzose; scattered stain, pyrite cement and a little carbonaceous material
13,530 - 548	Sandstone, light gray, very fine to fine grained; with much carbonaceous material giving it a mottled appearance
13,548 - 592	Sandstone, medium light gray, very fine to fine grained, rounded to subangular, firmly cemented with silica, some pyrite cement, no carbonaceous material, some oil stain at 13,564; rest nearly white to 13,592
13,685 - 700	Sandstone, light gray, very fine to medium, rounded and subangular, quartzose, some silica cement, mostly medium rounded, oil stained; becomes finer grained at 13,693 and coarser again at 13,695
13,700 - 702	Shale, medium gray, blocky
13,702 - 709	Sandstone, light gray, fine to medium, rounded, colorless quartz; scattered carbonaceous streaks and shale streaks
13,709 - 713	Sandstone, light brownish gray, very fine to fine grained, dolomitic
13,713 - 723	Dolomite, light gray to light brownish gray, finely crystalline, with thin shale streaks
13,723 - 738	Limestone, light gray to light brownish gray, finely crystalline; some shale, medium gray in thin layers and bands
13,738 - 748	Limestone, brownish gray, fine to medium crystalline, recrystallized fragmental, with dark to medium dark gray shale layers and bands, shale layers nearly 50%
13,748 - 755	Limestone, medium gray, very finely crystalline, very argillaceous
13,755 - 760	Limestone, light brownish gray, fine to medium crystalline, fragmental
13,764 - 786	Limestone, light gray, very finely crystalline, argillaceous; with medium dark gray shale layers, nearly 50% shale

13,786 - 850	Limestone, light gray, fine to medium crystalline, fragmental (one foot of conglomerate), some shale layers
13,850 - 875	Limestone, light gray, finely crystalline, fragmental, sandy, argillaceous, traces of glauconite; some shale, greenish gray and medium dark gray
13,875 - 880	Shale, medium dark gray, platy
13,880 - 905	Shale, medium dark gray to dark greenish gray, platy, some arenaceous streaks; (sample generally poor)
13,905 - 915	Shale, as above; limestone, brownish gray, very finely crystalline
13,915 - 935	Limestone, medium light gray, finely crystalline, some with traces of glauconite; shale, as above
13,935 - 14,000	Limestone, very light gray, finely crystalline to finely granular, glauconitic, fossiliferous, fragmental
14,000 - 010	Limestone, very light gray to light gray, finely crystalline, sandy, shaly, glauconitic
14,010 - 015	Limestone, as above; shale. medium dark gray, platy
14,015 - 040	Limestone, as above
14,040 - 045	Limestone, very light gray to white, finely crystalline, granular
14,045 - 060	Sandstone, very light gray to light brownish gray, very fine to fine grained, argillaceous; some medium dark gray, shale with sandstone streaks; limestone, light gray, fine grained, granular, silty, some with glauconite
14,060 - 145	Limestone, very light gray to white, finely crystalline, fragmental, glauconitic, silty
14,145 - 154	Syenite wash; orange pink feldspar, some greenish weathered mafics?; a few pieces of limestone with inclusions of pink feldspar

Dakamont Exploration Corporation - H. E. Jacobson No. 1
SW 1/4 NE 1/4 sec. 6, T. 162 N., R. 96 W., Divide County
North Dakota Geological Survey Well No. 1443; Circular No. 212

Depth	Lithology
11,330 - 370	Red River cave
11,370 - 414	Shale, greenish gray, nearly fissile to splintery
11,414 - 434	Shale, greenish gray to dark greenish gray, splintery and flaky
11,434 - 440	Sandstone, very fine to fine grained, rounded to subangular, firmly cemented; much shale, as above
11,440 - 450	Sandstone and shale, as above
11,450 -	Shale, greenish gray to dark greenish gray
Core	
11,439 - 444	Sandstone, white, very fine to fine grained, subrounded to subangular, slightly friable, quartzose
11,444 -	Sandstone, very fine to medium grained, rounded to subangular, firmly cemented, argillaceous
11,445 - 446	Sandstone, white, very fine grained, silica cemented, some pyrite
11,479 -	Sandstone, medium dark gray, very fine grained, firmly cemented, argillaceous
11,481	Shale, dark gray to grayish black, splintery
11,483	Sandstone, mottled, colorless to medium gray, very fine to medium, subrounded to subangular, quartzose with some shaly mottling
11,485	Sandstone, medium dark gray, fine to medium, rounded, shaly
11,486	Sandstone, white, fine to medium, rounded to subangular, quartzose

Amerada Petroleum Corporation - Ulven Unit No. 1
NE 1/4 sec. 34, T. 156 N., R. 96 W., Williams County
North Dakota Geological Survey Well No. 1514

Depth	Lithology
13,540 - 550	Shale, greenish gray to dark greenish gray, fissile
13,730 - 735	Sandstone, white and pinkish gray, very fine to medium grained, silica cemented; mostly quartzose sandstone; some sandstone has light greenish gray shale lenses and a shaly matrix

13,750 - 760 Sandstone, white to very light gray, very fine to medium grained, silica cemented, rounded, frosted, clean quartzose sand.

13,855 - 860 Sandstone, as above

13,890 - 900 Sandstone, white, very fine to medium, rounded grains, cemented with silica to an orthoquartzite, a little greenish gray shale with sandy lenses

13,900 - 920 Sandstone, as above, some iron staining, increasingly reddish gray 905-915

13,920 Shale, grayish red, medium dark gray and greenish gray; some grayish red, argillaceous sandstone, quartzitic sandstone, as above

Core

13,930 - 935 Sandstone, very light gray, fine to medium grained, rounded to subangular, silica cemented, slight oil stain and interbedded grayish red to greenish gray, sandy shale and argillaceous sandstone

13,935 Sandstone, very light gray, as above

13,951 - 956 Sandstone, very light gray to light brownish gray, very fine to medium rounded to subangular grains, micaceous, arkosic

13,956 - 961 Sandstone, white, very fine to medium, rounded, frosted grains, firmly cemented with silica

13,961 - 967 Dolomite, brownish gray, fine to medium crystalline

14,010 - 016 Sandstone, white, very fine to medium, rounded, quartzose, silica cemented

14,055 - 070 Limestone, light gray to brownish gray, finer to medium crystalline, fragmental

14,070 - 100 Limestone, white to medium light gray, fine to medium crystalline, fragmental, traces of glauconite

14,100 - 115 Limestone, light gray, finely crystalline, dense

14,115 - 225 Limestone, light gray to medium gray, fine to medium crystalline, fragmental, glauconitic

14,225 - 235 Limestone, as above; one chip of limestone includes a large fragment of orange-pink feldspar

14,235 - 250 Samples, limestone light gray to medium gray, fine to medium crystalline, glauconitic; increased amounts of cavings

14,250 - 305 Limestone, as above, one chip of orange-pink feldspar

14,305 - 310 Limestone, light gray, fine to medium crystalline, glauconitic contains numerous fragments of syenite

14,310 Limestone, white to very light gray, fine to medium crystalline, minor amounts of syenite

Description of Surface Sections

Section 1 - Located at the northeastern extremity of Deer Island, Lake Winnipeg, Manitoba

Lithology	Thickness Feet	Inches
Red River Formation		
Limestone, yellowish gray, mottled, dolomitic; overlain by glacial drift; contact with underlying beds sharp		
Winnipeg Formation		
Sandstone, yellowish gray, very fine grained, grading into siltstone, well consolidated, slightly calcareous	0	2
Sandstone, yellowish gray to white, fine to medium grained, rounded, frosted, quartzose, poorly consolidated	4	5
Sandstone, greenish gray, fine grained with an argillaceous matrix interbedded with sandstone, yellowish gray, fine to medium grained, clean, quartzose, poorly consolidated. Beds are one to four inches thick; predominately yellowish gray in the upper part	5	4
Shale, greenish gray, with sandy lenses and "floating" sand grains throughout; some lenses of relatively pure sandstone	13	6
Thickness of Section	23 feet	3 inches

Sandstone, yellowish gray to white, fine to medium, rounded, frosted, well consolidated, quartzose sandstone exposed at lake level.

Section 2 - Located just east of a prominent point along the north shore of Punk Island, Lake Winnipeg, Manitoba and southeast of Grindstone Point

Lithology	Thickness Feet	Inches
Winnipeg Formation		
Covered Interval		
Sandstone, yellowish gray, fine to medium grained, poorly consolidated	5	4
Sandstone, yellowish gray, fine to medium grained, slightly argillaceous, poorly consolidated	5	4
Siltstone, medium gray to yellowish gray, pyritiferous, grading into a fine grained sandstone	1	6
Sandstone, yellowish gray, fine to medium grained, rounded, frosted, poorly consolidated	7	1
Sandstone, light gray to yellowish gray, very fine to medium grained, firmly cemented with ferruginous and silica cement - exposed near lake level		
Thickness of Section	21 feet 3 inches	

Section 3 - Located a few hundred yards west of section 2, along the north shore of Punk Island. This section is largely covered by slump, but the contact with the Red River formation is well exposed

Lithology	Thickness Feet Inches
Red River Formation	
Limestone, yellowish gray, dolomitic, mottled; overlain by glacial drift	undetermined
Winnipeg Formation	
Sandstone, yellowish gray to light gray, fine to medium grained, slightly calcareous	about 5 feet thick
Mostly covered interval; some samples of greenish gray shale were obtained from this interval	about 21 feet
Contact of basal sandstone unit and overlying shale was found at about 19 feet above lake level.	
Sandstone, yellowish gray, fine to medium grained, poorly consolidated, partially covered with slump	about 19 feet
Thickness of Section	about 45 feet

Section 4 - Locality A, SW 1/4 sec. 13, T. 5 N., R. 3 E., Lawrence County, South Dakota

Lithology	Thickness Feet	Inches
Whitewood Formation		
Limestone, yellowish gray, silty, dolomitic	Undetermined	
Winnipeg Formation, Roughlock Member		
Siltstone, very light gray and grayish orange; some thin shaly stringers	7	3
Siltstone, very light gray; some greenish gray shale stringers; more argillaceous than above	3	0
Siltstone, very light gray and grayish red	4	0
Siltstone, very light gray, with a few greenish gray shale stringers	5	6
Winnipeg Formation; Icebox Member		
Shale, olive greenish gray	2	6
Total Thickness	22 feet 3 inches	

Section 5 - Locality B - SE 1/4 sec. 14, T. 5 N., R. 3 E., Lawrence County, South Dakota

Lithology	Thickness Feet Inches
Winnipeg Formation, Icebox Member	
Shale, greenish gray to olive gray, contains scattered phosphatic nodules	15
Shale, greenish gray to olive gray	6
Shale, greenish gray, scattered reddish iron staining	10
Shale, greenish gray, olive gray and pale orange, with fine to medium, rounded, frosted, "floating" sand grains and sand lenses	2
Deadwood Formation	
Sandstone, fine to medium grained, quartzitic, contains <u>Skolithos</u>	Thickness not measured
Total thickness of Winnipeg formation	33 feet

APPENDIX C

LIST OF MEMBER AND FORMATION TOPS

Member and formation tops were determined from mechanical logs. Listed below are the depths in feet to the top of each member or formation for every well for which logs were available. A dash indicates that the well ended in the next higher formation and an asterisk (*) denotes that the formation or member is absent in that well. The location of each well is given in Appendix A.

MEMBER AND FORMATION TOPS

N. D. G. S. Well Number	Roughlock	Icebox	Black Island	Deadwood	Precambrian
15	8,310	8,355	8,475	8,530	8,825
16	4,873	4,933	5,063	5,078	5,350
19	6,498	6,537	6,664	6,684	6,946
20	3,040	3,094	3,213	*	3,215
21	11,866	11,886	12,010	12,054	--
22	8,749	8,778	8,896	8,932	--
23	5,045	5,104	5,240	5,254	5,548
24	5,174	5,233	5,362	5,370	5,604
26	7,124	7,190	7,315	7,352	7,778
27	3,224	3,272	3,396	*	3,404
32	13,400	13,415	13,552	--	--
38	7,845	7,862	7,976	8,046	8,230
39	6,873	6,898	7,022	7,096	7,198
40	3,790	3,856	3,987	4,040	4,132
43	5,347	5,402	5,532	5,545	5,873
47	8,195	8,205	8,327	8,397	8,622

Well Number	Roughlock	Icebox	Black Island	Deadwood	Precambrian
49	8,640	8,662	8,780	8,842	--
52	9,934	9,957	10,073	?	--
61	6,944	6,972	7,097	7,135	
64	6,163	6,172	6,295	6,337	6,407
83	5,324	5,347	5,470	*	5,503
89	4,374	4,423	4,560	4,573	4,772
100	4,312	4,354	4,482	*	4,496
105	10,736	10,754	10,875	?	--
110	6,200	6,225	6,346	6,380	6,434
120	2,644	2,723	2,853	2,867	2,917
134	3,106	3,184	3,314	3,330	3,426
145	5,608	5,683	5,811	5,828	6,163
151	7,557	7,600	7,728	7,773	8,088
155	5,686	5,744	5,873	5,886	6,144
171	3,618	3,642	3,766	*	3,788
174	6,398	6,449	6,577	6,594	6,861
194	3,590	3,621	3,747	*	3,760
196	3,521	3,559	3,687	3,705	3,743
207	5,633	5,677	5,810	5,826	6,020
227	3,835	3,863	3,996	*	4,034
230	4,824	4,884	5,013	5,025	5,140
246	3,043	3,084	3,195	*	3,208
287	2,840	2,912	3,043	3,058	3,109
291	12,806	12,824	12,917	12,951	--
295	2,583	2,654	2,790	2,803	2,863
316	4,746	4,770	4,898	4,921	4,940

Well Number	Roughlock	Icebox	Black Island	Deadwood		Precambrian
334	2,993	3,063	3,195	3,210	82	3,292
370	3,004	3,075	3,204	3,217		--
383	3,083	3,133	3,255	*		3,265
390	3,874	3,917	4,043	*		4,060
403	3,372	3,433	3,556	*		3,563
406	3,014	3,086	3,217	3,234	74	3,308
407	3,028	3,076	3,207	3,226	50	3,276
410	12,990	13,004	13,114	13,157		--
411	3,155	3,204	3,327	*		3,337
422	3,018?	3,058	3,178	*		3,194
434	4,245	4,278	4,404	*		4,428
435	4,383	4,422	4,553	*		4,533
437	3,925	3,967	4,098	4,114	99	4,213
470	12,277	12,307	12,378	12,404		--
485	9,700	9,713	9,803	9,812		--
580	670	729	735	760	133	893
590	4,875	4,962	5,088	5,095		--
609	4,813	4,871	5,005	5,022		--
620	3,254	3,306	3,448	3,458	129	3,587
621	3,455	3,513	3,643	3,653	217	3,870
622	3,560	3,641	3,764	3,774	147	3,921
631	5,647	5,703	5,827	5,840		--
632	4,874	4,914	5,043	5,056	78	5,134
642	4,800	4,843	4,975	5,003		--
644	3,945	4,021	4,153	4,167	130	4,297
665	6,560	6,606	6,734	6,760		--

Well Number	Roughlock	Icebox	Black Island	Deadwood		Precambrian
668	3,372	3,462	3,586	3,595	99	3,694
669	3,746	3,817	3,947	3,966	131	4,097
670	3,503	3,572	*	*		3,702
671	3,627	3,698	3,828	3,844	93	3,937
672	3,565	3,632	3,761	3,774	118	3,892
673	3,464	3,548	3,675	*		3,678
682	1,680	1,733	1,852	Not Logged		
684	6,164	6,196	6,325	6,345		--
689	5,013	5,055	5,187	5,204		--
693	6,923	6,957	7,086	7,117		--
700	1,423	1,434	1,543	*		1,546
701	6,022	6,071	6,198	6,220		--
706	4,774	4,802	4,932	4,966	29	4,995
723	5,623	5,687	5,818	5,833	17	5,850
735	6,115	6,165	6,286	6,304		--
748	5,623	5,677	Not Logged			--
756	5,904	5,974	6,104	6,120		--
763	6,704	6,745	6,873	6,848		--
765	6,514	6,562	6,686	6,717		--
768	3,576	3,622	3,756	3,777	80	3,857
956	13,315	13,353	13,464	13,485		--
1105	3,324	3,392	3,518	*		3,523
1112	3,523	3,566	3,700	3,710	81	3,791
1126	3,852	3,912	Not Logged	Not Logged		
1211	4,103	4,156	4,287	4,303	69	4,372
1227	2,993	3,053	3,186	3,204		N.L.

Well Number	Roughlock	Icebox	Black Island	Deadwood		Precambrian
1231	13,232	13,250	13,380	13,528	59	13,587
1274	2,834	2,900	3,032	3,045	40	3,085
1347	4,122	4,207	4,334	4,350	200	4,550
1356	840	883	901	964	92	1,056
1385	13,753	13,774	13,920	14,100	695	14,795
1394	2,881	2,922	3,067	3,080	67	3,147
1403	13,261	13,286	13,426	13,607		N.L.
1409	6,326	6,380	6,507	6,523		--
1443	11,340	11,350	11,430	--		--
1514	13,514	13,527	13,683	13,872	586	14,458?
1546	11,595	11,603	11,683	--		--
1575	8,732	8,746	8,840	8,856		--
1620	10,982	11,018	11,162	11,177		--
1636	13,595	13,618	13,760	13,937		--
1694	3,185	3,226	3,344	*		3,365
1934	2,542	2,594	2,724	*		2,735
2010	*	10,820	10,900	--		--
2342	2,142	2,184	2,297	*		2,306
2373	13,763	13,788	13,963	14,123	1000	15,123

	Roughlock	Icebox	Black Island	Deadwood	Precambrian
A	*	5,216	5,335	*	5,363
B	*	9,986	9,101	9,183	--
C	*	8,180	8,253	8,313	8,563
D	*	9,822	9,897	10,032	10,397?
E	10,102	10,140	10,173	10,306	
F	12,937	12,973	13,084	13,110	--
G	9,353	9,376	9,467	9,480	10,395
H	8,818	8,835	*	8,925	9,655
J	7,206	7,253	*	7,317	--
K	2,864	2,904	*	2,970	--
L	8,581	8,634	8,725	8,740	9,327
M	7,656	7,690	7,900	7,912	8,292
N	6,793	6,810	6,904	6,914	7,296
P	7,757	7,813	7,914	7,937	8,430
Q	*?	5,575	5,675	5,693	5,936
R	3,623	3,647	3,746	3,758	3,805

TABLE II - The occurrence and abundance of conodonts in the Winnipeg formation.

Numbers in vertical columns refer to number of specimens in each sample.

SAMPLE LOCALITY	Union Oil Company - Aanstad No.1 well NE 1/4 sec 29, T.158 N., R. 62 W., Ramsey County, North Dakota.		T. 20 N., 7 EPM. Victoria Beach, Lake Winnipeg, Manitoba.					Northeast corner, Deer Island, Lake Winnipeg, Manitoba.				SE 1/4 SW 1/4 sec 13, T. 5 N., R. 3 E., Lawrence County, South Dakota.		SW 1/4 sec 14, T. 5 N., R. 3 E., near Deadwood, Lawrence County, South Dakota.				Continental Oil Company - Leuth No.1 well, NW 1/4 NW 1/4 sec 27, T. 146 N., R. 73 W., Wells County, North Dakota.					Union Oil Company - Skjervheim No.1 well, NW 1/4 NE 1/4 sec 28, T. 159 N., R. 63 W., Cavalier County, North Dakota.				
Conodont Species / Sample Number	30-2 30-7	30- 9	6	5	3	2	1	F- 5	F- 4	F- 3	F- 8	A- 1	A- 2	B- 33	B- 31	B- 29	B- 22	5752	5761	5780	5783	5791	3360	3364	3367	3370	3373
Acontiodus latus (?) Pander																	1										
Acontiodus staufferi Furnish																			1								
Acontiodus triangularis Pander																	1										
Acontiodus sp.									1																		
Belodina compressa (Branson and Mehl)	24	3																	1		1						
Belodina grandis (Stauffer)		1																									
Belodina sp. indet.																	2										
Bryantodina compacta Stauffer																									1	5	37+
Bryantodina typicalis Stauffer																											6
Chirognathus alternata Branson and Mehl																										2	3
Chirognathus duodactyla Branson and Mehl																											1
Chirognathus monodactyla Branson and Mehl																										3	3
Chirognathus multidens Branson and Mehl																											6
Chirognathus plana Branson and Mehl																											2
Chirognathus spp.															4	2									3	12	17
Cordylodus flexuosus (Branson and Mehl)			1		5				2					1		5	7	1	1			2	1	8	6		4
Cordylodus plattinensis Branson and Mehl			2		10	3	7		21	19		2	4	3	1	24	24	20	4	4			12	1	6		10
Cordylodus sp. indet.																	36	7					6		3		
Dichognathus typica Branson and Mehl																1											11
Dichognathus sp. indet.										1				2			20				1						
Distacodus falcatus Stauffer							6			1							2		7		2						
Distacodus insculptus (Branson and Mehl)	26	21																					2				
Drepanodus homocurvatus Lindstrom	7	3	3	3	17	6	24		17	19		9	7	2			17		5	3	2	4	12				4
Drepanodus subarcuatus Furnish																									1		
Drepanodus suberectus (Branson and Mehl)					2	1	3		2	2		2	3			? 2	3			1							
Eoligonodina magna Ethington	? 1	5																									
Eoligonodina prima (Branson and Mehl)												10	2					8	2								
Erismodus ? sp.																											
Falodus prodentatus (Graves and Ellison)	2	19																									1
Lonchodus spinuliferus Stauffer			1		3	1	2	1																			
Microcoelodus asymmetricus Branson and Mehl										4		8	2	10	25	68	60		5	10	1		14	4	1	5	3
Microcoelodus sp.										2						1	1								1		
Oistodus abundans Branson and Mehl	2	3																									
Oistodus excelsus Stauffer	1	2																	3				2				
Oistodus fornicalis Stauffer	4																										
Oistodus inclinatus Branson and Mehl					3	1	4		1	2								3									3
Oistodus sp.																											
Oneotodus ovatus (Stauffer)									1																	2	11
Ozarkodina concinna Stauffer					8		11			3	1				2		7										5
Ozarkodina macrodentata Graves and Ellison					? 4					2																	
Ozarkodina pauperata Stauffer							2																				
Ozarkodina sp. indet.	1	1	2		2	1	10	1							9		4			1						3	3
Panderodus arcuatus (Stauffer)	14	7	3	5	11	7	22	2	12	16	1	14	4				2										
Panderodus belatus (Stauffer)					2		3			4																	
Panderodus compressus (Branson and Mehl)							2		1																		
Panderodus gracilis (Branson and Mehl)	11	11	3		8	5	9	2	4	3	1	6	7														
Panderodus intermedius (Branson and Mehl)					2		11																				
Panderodus sp. indet.	1			7	8		6						4				5										
Phragmodus undatus Branson and Mehl	14	1													1	1	20-50			1	1				1	4	21
Polycaulodus duodentata																											
Polycaulodus sp.																	6								5	7	
Ptiloconus robustus (Stauffer)																											? 3
Scolopodus quadraplicatus Branson and Mehl																											1
Scolopodus sp.															1												
Scyphiodus primus Stauffer																	24				3						
Subcordylodus delicatus (Branson)					2																		1			1	
Trichonodella pumila (Branson and Mehl)													1				1	1									
Trichonodella recurva (Branson and Mehl)					4	1	5		11	7		15	8	6			18	2	1	2			2	2	4	7	4
Trichonodella sp. indet.			1	1	3	1	4		2	2	1	1	3					5	2		2	3	4	2	2		9
Unidentified specimens					1	1	1					1		1	5	7		6	3				2	2	1	40	13
Total specimens in Sample	108	80	16	16	95	28	132	6	75	79	4	68	45	25	48	111	251	53	35	22	15	9	64	17	36	91	81