NORTH DAKOTA GEOLOGICAL SURVEY

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CROSS-SECTION OF PALEOZOIC ROCKS OF WESTERN NORTH DAKOTA

BY

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Grand Forks, North Dakota, 1967

NORTH DAKOTA[1]

(Section E-F, Plate 5)

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Grand Forks, North Dakota

INTRODUCTION

The North Dakota segment of the cross section was constructed with the base of the Spearfish Formation as the datum. However, the Permian-Triassic boundary now is thought to be within redbeds of the Spearfish Formation (Dow, 1964). If this interpretation is correct, perhaps as much as 300 ft of Paleozoic rocks in well 3 and smaller thicknesses in wells 1, 2, and 4–12 are excluded from Plate 5.

Wells were selected which best illustrate the Paleozoic section and its facies changes in the deeper part of the Williston basin. They include the deepest well in North Dakota (well 8), but the scarcity of wells reaching the Precambrian in the area of the cross section necessitated the selection of two wells which reached total depth in Silurian rocks, seven which reached Ordovician rocks, and only four which reached the Precambrian.

Data and correlations are based on information from the North Dakota Geological Survey records in Grand Forks. The writer logged most of the wells, except where sample descriptions were available from North Dakota Geological Survey files. Logs for wells 1 and 15 were provided, respectively, by R. A. Schoon of the South Dakota Geological Survey and G. L. Hutch of the Saskatchewan Department of Mineral Resources. Terminology for these wells corresponds to that used on Plates 4 and 6 of the cross section.

STRATIGRAPHY

The Deadwood Formation is of Late Cambrian to Early Ordovician age in the central basin area. The precise position of the systemic boundary is uncertain. Only wells 4, 8, 10, and 11 penetrate the complete Deadwood section. In these wells it consists of interbedded white to light-gray sandstone, medium-gray and greenish-gray shale, and light-gray, fossiliferous, fragmental limestone. The anomalously thin Deadwood section in well 10 is the result of deposition over a monadnock of Precambrian rocks.

The Winnipeg Group of Middle Ordovician age has been divided into three formations in North Dakota which, in ascending order, are the Black Island, Icebox, and Roughlock. The Black Island generally consists of clean quartzose sandstone, the Icebox of greenish-gray, noncalcareous shale, and the Roughlock of greenish-gray to brownish-gray, calcareous shale or siltstone.

The Black Island and Icebox Formations can be traced northward to Saskatchewan, but they have not been recognized as formations there and are included in an undivided Winnipeg Formation. The Black Island pinches out southwestward because of nondeposition along the Cedar Creek anticline, but the Icebox and Roughlock Formations, although not present on the cross section because they were not penetrated by the selected wells, extend southward into South Dakota, where they are recognized as members of the Winnipeg Formation.

The Bighorn Group, of Middle Ordovician to Early Silurian(?) age, includes the Red River, Stony Mountain, and Stonewall Formations. The Red River is predominantly brownish-gray limestone with some dolomite and thin anhydrite beds in the upper part. The subdivisions of the Red River recognized in South Dakota (units A, B, and C) can be traced into North Dakota, but they have not been recognized formally. The Stony Mountain Formation is divided into two members. The lower, or Stoughton Member, consists of medium-gray, argillaceous limestone and calcareous shale. The upper, or Gunton Member, is yellowish-brown dolomite. The Stonewall Formation is light-gray and light-brownish-gray dolomite with some thin beds of anhydrite.

The Silurian Interlake Formation may be divided into three units in North Dakota, mainly on the basis of mechanical-log markers. The lower and middle units are composed of pale-orange, light-yellowish-gray or light-brownish-gray dolomite with some light-gray to white chert. The upper unit consists of light-brownish-gray dolomite and calcareous dolomite.

The Elk Point Group, of Middle Devonian age, includes the Winnipegosis and Prairie Formations in North Dakota. Rocks equivalent to the Ashern Formation of Saskatchewan probably are included in the lower part of the Winnipegosis, which is a dark-brown, argillaceous limestone. The upper Winnipegosis is generally dark-brown limestone with thin anhydrite layers in a few wells. The Prairie is predominantly halite, but the very

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[2] North Dakota Geological Survey.

radioactive zones probably contain potash. Near its southern limit some carbonate beds are also present.

The Manitoba Group, of Middle to Late Devonian age, includes the Dawson Bay and Souris River Formations. The Dawson Bay consists mainly of light- to dark-brown dolomite and limestone. The Souris River Formation reflects a change to cyclic deposition of brownish-gray limestone, dolomite, and thin shale beds.

The Late Devonian Saskatchewan Group includes the Duperow and Birdbear Formations. Cyclic deposition continued, but shale is a minor constituent and evaporites are more abundant. The Duperow is predominantly light-brown to brownish-gray limestone with thin beds of anhydrite in the upper part. The Birdbear consists mainly of pale-brown limestone with some anhydrite.

The Three Forks Formation is also of Late Devonian age. It consists of reddish-brown shale, anhydrite, and dolomite in the lower part, and interbedded greenish-gray shale and pale-orange dolomite and siltstone in the upper part.

The Bakken Formation, of Late Devonian to Early Mississippian age, may be divided into three lithologic units—a lower brownish-black shale, a middle light-gray, calcareous siltstone and silty limestone, and an upper black shale.

The Madison Group, of Early Mississippian to Late Mississippian age, has been divided into the Lodgepole, Mission Canyon, and Charles Formations. The terms "Lodgepole" and "Mission Canyon" are derived from outcrop areas in central Montana, and the term "Charles" from the subsurface in eastern Montana. As exploration of the basin proceeded, it became evident that three gross lithologic types were recognizable in the basin and the threefold surface terminology was extended into the subsurface. The light- to dark-gray, argillaceous or cherty, generally dense limestone was referred to as the "Lodgepole Formation." The brownish- to yellowish-gray, fragmental, pelletoidal, and oölitic limestone beds were designated as "Mission Canyon." The predominantly evaporitic facies, consisting of halite and anhydrite, was named the "Charles Formation."

Because these facies intertongue and cross time planes, it became evident that subdivisions based on marker units would be more useful for petroleum exploration than the formational terminology. Fuller (1956) proposed such subdivisions, which were revised and adopted by the Saskatchewan Geological Society (1956). The revised terminology is shown for well 15. The Mississippian Committee of the North Dakota Geological Society subsequently found gamma-ray markers more useful for basin-wide correlations than the markers proposed by Fuller, but rather than introduce new terms, they redefined the Frobisher-Alida, Ratcliffe, and Poplar units on the basis of these markers, accepted the Tilston unit, and replaced the term "Souris Valley" with the term "Bottineau" (Smith, 1960). The North Dakota correlations are based on these redefinitions.

The Late Mississippian Big Snowy Group includes the Kibbey and Otter Formations. The Kibbey comprises a lower reddish-brown shale and siltstone, a middle light-gray limestone, and an upper pinkish-gray sandstone. The Otter consists of variegated shale.

The Tyler Formation, of Late Mississippian(?) to Early Pennsylvanian age, consists of interbedded sandstone and variegated mudstone and shale.

The Pennsylvanian Amsden Formation consists of interbedded light-gray to pinkish-gray limestone, sandstone, and red calcareous shale. The Minnelusa Formation is mainly white to pinkish-gray sandstone with some dolomite. Use of the Pennsylvanian-Permian terminology of South Dakota is practical northward to wells 4 and 5, but the terminology has not been accepted in North Dakota. North of these wells, use of the South Dakota terminology becomes difficult, as is correlation of an Amsden-Minnelusa contact. Therefore, no "arbitrary" lines of correlation are shown for this part of the section.

Permian rocks make up the Opeche and Minnekahta Formations and the lower part of the Spearfish Formation. The Opeche Formation consists of halite and redbeds, and the Minnekahta is light-gray and pinkish-gray limestone.

STRUCTURE

The cross section extends from the southern flank of the Williston basin through the central part to the northern flank. Two major folds, the Cedar Creek and Nesson anticlines, are present in this area.

The Cedar Creek anticline is a southeast-trending fold in eastern Montana which extends across southwestern North Dakota. Wells 1–3 are on the northeast flank of this feature. The Nesson anticline trends northward in the central basin area. Wells 7–13 are along its axis.

GEOLOGIC HISTORY

Because most of the Paleozoic systemic boundaries are within formational units, it is easiest to present the geologic history if the stratigraphic column is separated into four major unconformity-bounded units or "sequences" (Carlson and Anderson, 1965). The four sequences recognized are the Sauk, Tippecanoe, Kaskaskia, and Absaroka (Sloss, 1963).

The Sauk Sequence consists of shelf-type rocks deposited in the Late Cambrian–Early Ordovician seas

which spread over the area from the west. Effects of pre-Middle Ordovician erosion are not apparent along the line of cross section because only four wells show the complete stratigraphic section, but east-west cross sections demonstrate that there was a major erosional episode before deposition of the Winnipeg Group.

The Tippecanoe sea probably spread into the area from the south and east before the Sioux arch became a positive feature. Deposition of the Winnipeg clastics was followed by deposition of carbonates and evaporites of the Bighorn and Interlake Groups, with only minor breaks in sedimentation in the Williston basin. Thickening of the Black Island in the central basin suggests that the area became slightly negative in Middle Ordovician time, but the relatively uniform thickness of subsequently deposited units demonstrates that subsidence during deposition was slight. Present thickness variations of the Tippecanoe Sequence are mainly the result of pre-Middle Devonian erosion.

The Kaskaskia Sequence began when the Middle Devonian sea spread across the Williston basin from the north and west. Southward thinning of Devonian rocks is mainly the result of nondeposition preceding onlap of these seas.

The Devonian-Mississippian boundary has been placed above the lower black shale of the Bakken Formation. Thus, along the line of cross section there is no break in sedimentation at the systemic boundary except toward the south where, in wells 1–4, the Bakken is absent and the Three Forks is thin or absent. This hiatus is minor in comparison with the regional pre-Middle Ordovician and pre-Middle Devonian unconformities and probably is related to changing basin tectonics. Renewed subsidence of the central basin in Mississippian time is reflected by thickening of the Madison Group in that area.

At the end of Mississippian time, there was a change from a predominantly carbonate-evaporite depositional environment to a terrigenous clastic depositional environment.

The Absaroka sea spread across the area from the west. Deposition began with nonmarine mudstone, followed by relatively thin marine terrigenous clastic and carbonate units, and then predominantly clastic and evaporite units of the redbed environment. These conditions prevailed in the Williston basin through the Permian and Triassic Periods, with only minor breaks, until the development of the pre-Middle Jurassic regional unconformity. Because this study is limited to Paleozoic rocks, most of the redbeds of this sequence were excluded from the cross section.

OIL AND GAS

Oil and gas are produced from rocks of each of the Paleozoic systems from Cambrian through Pennsylvanian along the line of cross section, but Mississippian reservoirs are the most prolific.

Production from the Deadwood and Black Island Formations in North Dakota is from only three wells (well 10 and two near well 11) in which condensate is found in the Beaver Lodge (Ordovician) pool. Production from the Ordovician Red River Formation has been established in wells 4 and 10 and in the vicinity of well 2, but the major known reserve is in the Cedar Creek pool in Bowman County. Production in the Silurian has been established from the upper part of the Interlake in wells 7, 8, and 10. These are the only known Silurian pools in North Dakota. Oil and gas are obtained from the Devonian in the Duperow, Birdbear, and Three Forks Formations in 16 pools along the Nesson anticline.

Production from Mississippian reservoirs is chiefly in the Frobisher-Alida and Ratcliffe units, with smaller quantities from the Bakken and Tilston units. Production in Pennsylvanian rocks is from sandstone near the base of the Tyler Formation, where six pools have been found in the vicinity of well 4.

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PLATE 5
STRATIGRAPHIC CROSS SECTION OF PALEOZOIC ROCKS IN NORTH DAKOTA

PREPARED FOR THE COMMITTEE ON STRATIGRAPHIC CORRELATIONS
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

BY

CLARENCE G. CARLSON
NORTH DAKOTA GEOLOGICAL SURVEY

DATUM TOP OF PALEOZOIC ROCKS
NO HORIZONTAL SCALE
1967

E — 1: 5524' - 8473' — Signal No. 1 Olson — NW NE Sec. 23, T.20N., R. 7 E. — Harding County — Altitude 2797' K.B.

2: 6363' - 9550' — Snowden No.1 Morrison — SE SW Sec. 34, T.13ON., R.103 W. — Bowman County — Altitude 3028' K.B.

3: 6608' - 10,125' — Sun No. 1 Greer, Federal — SE SE Sec. 21, T.134 N., R.105 W. — Slope County — Altitude 2880' G.L.

4: 7056' - 13,745' — Amerada No.8 Scarja Unit — NE SW Sec. 10, T.139 N., R.101 W. — Billings County — Altitude 2540' K.B.

5: 7583' - 13,895' — Stanolind No.1 Northwest Improvement — SE SE Sec.17, T.143 N., R.100 W. — Billings County — Altitude 2815' K.B.

6: 7414' - 13,275' — Shell, Northern Pacific No. 32-16-1 State — SW NE Sec.16, T. 145 N., R. 101 W. — McKenzie County — Altitude 2463' K.B.

7: 7180' - 13,313' — Amerada Tr. 1, No.1 Shelvik — NE SW Sec.35, T. 150 N., R. 97 W. — McKenzie County — Altitude 2334' K.B.

8: 6914' - 10,756' — Amerada No.1 Reed, Norby Unit — NW NE Sec. 6, T. 152 N., R. 94 W. — Altitude 2198' K.B.
10,282' - 15,132' — Amerada No.1 Antelope Unit "A" — NE SE Sec. 1, T.152 N., R. 95 W. — McKenzie County — Altitude 2117' K.B.

9: 6066' - 8340' — Amerada No.1 E. Peterson Tract 1 — NW NW Sec. 5, T.153 N., R. 95 W. — Altitude 1946' K.B.
8320' - 13,765' — Texaco No. 5 S. Garland — NE Sec. 6, T.153 N., R. 95 W. — McKenzie County — Altitude 1983' K.B.

10: 6294' - 13,612' — Amerada No.1 Iverson, Nelson Unit — NE Sec. 2, T.155 N., R. 96 W. — Williams County — Altitude 2316' K.B.

11: 6425' - 14,820' — Amerada No.9 North Dakota Unit "A" — SE SW Sec. 16, T.156 N., R. 95 W. — Williams County — Altitude 2360' K.B.

12: 6518' - 13,715' — Amerada No.1 Bakken — SW NW Sec. 12, T.157 N., R. 95 W. — Williams County — Altitude 2442' G.L.

13: 6505' - 11,510' — Hunt No.3 Overlee — SW SW Sec.30, T.160 N., R.94 W. — Burke County — Altitude 2389' K.B.

14: 5800' - 11,516' — Dakamont No.1 Jacobson — SW NE Sec. 6, T.162 N., R. 96 W. — Divide County — Altitude 1943' K.B.

F — 15: 5022' - 10,398' — Imperial No.15-7 Halkett — LSD 15 Sec. 7, T. 3 N., R. 8 W.2 — Saskatchewan — Altitude 1923' K.B.

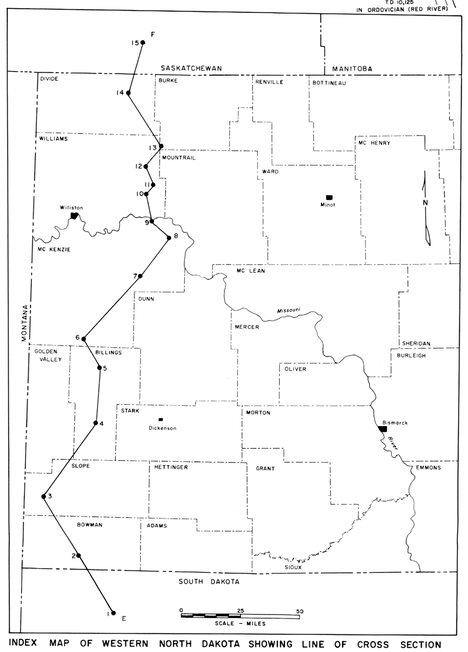
NORTH DAKOTA / SASKATCHEWAN

Distances: 28 Miles · 28 Miles · 38 Miles · 22 Miles · 14 Miles · 36 Miles · 20 Miles · 6 Miles · 12 Miles · 5 Miles · 8 Miles · 10 Miles · 26 Miles · 22 Miles

SOUTH DAKOTA TERMINOLOGY — SPEARFISH FORMATION — SASKATCHEWAN TERMINOLOGY

SYSTEM	SERIES	GROUP	SOUTH DAKOTA TERMINOLOGY	SPEARFISH FORMATION	SASKATCHEWAN TERMINOLOGY	FORMATION	GROUP	SERIES	SYSTEM
PERMIAN	WOLF CAMP	OPECHE	OPECHE / CASSA	OPECHE	OPECHE	CHARLES		U. MISS	MISSISSIPPIAN
PENNSYLVANIAN	VIR. / MISS.	MINNELUSA	BROOM CREEK / WENDOVER / MEEK / HAYDEN	MINNELUSA & AMSDEN	MINNELUSA & AMSDEN				
	DES MOINES		ROUNDTOP / FAIRBANKS	TYLER	TYLER				
	BIG SNOWY		KIBBEY	KIBBEY	OTTER / KIBBEY				
MISSISSIPPIAN	MERAMEC	MADISON	CHARLES	POPLAR INTERVAL / RATCLIFFE INTERVAL	POPLAR INTERVAL / RATCLIFFE INTERVAL	POPLAR BEDS / RATCLIFFE BEDS / MIDALE BEDS			
	?			FROBISHER - ALIDA	FROBISHER, ALIDA —	FROBISHER BEDS / KIRBY / ALIDA BEDS			
	OSAGE		MISSION CANYON	TILSTON & BOTTINEAU INTERVALS	TILSTON & BOTTINEAU INTERVALS	TILSTON BEDS / SOURIS VALLEY BEDS	LODGEPOLE — MISSION CANYON	LOWER	
	KINDERHOOK		LODGEPOLE			BAKKEN	THREE FORKS		
DEVONIAN	UPPER	JEFFERSON	DUPEROW	DUPEROW	BIRDBEAR / DUPEROW	BIRDBEAR	TORQUAY	SASKATCHEWAN	UPPER DEVONIAN
			SOURIS RIVER	SOURIS RIVER	SOURIS RIVER	DUPEROW	SOURIS RIVER	MANITOBA	MIDDLE DEVONIAN
SILURIAN	ALBIAN		INTERLAKE	INTERLAKE	DAWSON BAY / PRAIRIE EVAPORITE / WINNIPEGOSIS	SOURIS RIVER	PRAIRIE EVAPORITE	ELK POINT	
ORDOVICIAN	CINCINNATI	BIGHORN	STONEWALL / STONY MOUNTAIN / RED RIVER (UNIT A)	STONEWALL / STONY MOUNTAIN / RED RIVER	INTERLAKE	DAWSON BAY	WINNIPEGOSIS / ASHERN		
			RED RIVER (UNIT B)		STONEWALL / STONY MOUNTAIN / RED RIVER	PRAIRIE EVAPORITE			
						WINNIPEGOSIS			
						INTERLAKE		MIDDLE SILURIAN	SILURIAN
					STONEWALL / STONY MOUNTAIN / RED RIVER	STONEWALL			
						STONY MOUNTAIN			
						RED RIVER	BIG HORN	ORDOVICIAN	
						WINNIPEG			
						DEADWOOD		CAMBRIAN	
						PRECAMBRIAN			

T.D. 8473 IN ORDOVICIAN (RED RIVER)
T.D. 9550 IN ORDOVICIAN (RED RIVER)
T.D. 10,125 IN ORDOVICIAN (RED RIVER)
T.D. 13,745 IN PRECAMBRIAN
T.D. 13,275 IN ORDOVICIAN (RED RIVER)
T.D. 13,313 IN SILURIAN (INTERLAKE)
T.D. 13,895 IN ORDOVICIAN (WINNIPEG)
T.D. 13,790 IN ORDOVICIAN (WINNIPEG)
T.D. 13,612 IN PRECAMBRIAN
T.D. 14,820 IN PRECAMBRIAN
T.D. 15,132 IN PRECAMBRIAN
T.D. 11,510 IN SILURIAN (INTERLAKE)
T.D. 15,715 IN ORDOVICIAN (WINNIPEG)
T.D. 11,516 IN ORDOVICIAN (WINNIPEG)
T.D. 10,573 IN PRECAMBRIAN



INDEX MAP OF WESTERN NORTH DAKOTA SHOWING LINE OF CROSS SECTION

EXPLANATION

ROCK SYMBOLS: Salt · Limestone · Dolomite · Anhydrite · Shale · Siltstone · Sandstone

PARTICLE SYMBOLS: Calcite · Anhydrite or gypsum · Sand · Clay · Oolites · Dolomite · Chert · Silt · Glauconite

MISCELLANEOUS SYMBOLS: Precambrian (igneous and metamorphic basement rocks) · No sample (N.S.) (lithology interpreted from electric and radioactivity logs and samples from adjacent wells)

- Symbol on left side of column indicates oil (and or gas) production from stratigraphic unit in general vicinity of well.

CORRELATION LINES
System boundary
Series or group boundary
Formation boundary

ABBREVIATIONS
Kelly bushing..... K.B.
Total depth..... T.D.
Sensitivity Change.... Sens. Ch.
Ground Level..... G.L.