NEWSLETTER
NDGS

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COVER PHOTO

The photo on the cover shows the Linton Member sandstone bed exposed on a butte top in southwestern Emmons County, North Dakota about 15 miles southwest of Strasburg (SW¼SW¼ sec 15, T129N, R78W). The Linton Member occurs in the uppermost part of the Upper Cretaceous (Maestrichtian) Fox Hills Formation. At this location, the Linton Member consists of 23 feet of hard, fine-grained, flaggy, brownish-gray to brown sandstone. This sandstone bed acts as a caprock on nearly all of the buttes in central and southwestern Emmons County and in parts of Sioux County and areas immediately to the south in South Dakota. The Linton Member forms resistant layers as thick as 20 to 25 feet. It is generally massive, consisting of subangular, fine-grained, moderately to poorly sorted, indurated, siliceous sandstone that weathers to varying shades of gray or to a distinctive copper brown with accompanying yellow stains. The unit is generally massive, but flat bedding and large-scale trough or planar crossbedding are present locally.

The Linton Member was first described and named by J. Mark Erickson in 1974 in the Bulletin of American Paleontology, vol. 66. Photo by John P. Bluemle.

CONTENTS

SURVEY ACTIVITIES

In an effort to more efficiently utilize the limited space available to us in our Survey offices, we are rearranging some of our facilities as we add needed equipment. We have set aside a room for studying electric logs. This has helped to relieve most of the congestion that had resulted from trying to work in the log storage room itself.

Although our new (1980) Wilson M. Laird Core and Sample Library is effectively filled to its capacity due to the great amount of core that we received over the past four years, we are building a mezzanine to take some of the pressure off the main storage area. We also recently moved some of the lighter weight materials to the top of the core stacks to make room available for more core storage. Improved equipment being installed in the core library includes a new slab saw, a new forklift, and tables on which the core can roll for easier inspection. We hope to hire another laboratory technician soon to help cope with the heavy use the core library receives. More than 700 people, most of them oil company geologists, examined over 51,000 feet of core materials in 1983 and, so far this year (through June 8), a total of 436 people have taken advantage of the facility, examining 32,000 feet of core.

The materials stored in the Wilson M. Laird Core and Sample Library are an extremely valuable scientific resource to the State of North Dakota. Although it is not possible to determine the precise role that knowledge gained by studying the core has played in recent oil and gas discoveries (other factors also enter into most discoveries), we know of a number of discoveries that oil company geologists tell us resulted as a direct consequence of research on materials in our core library. In view of the fact that a 100-barrel-a-day well will result in over $125,000 in direct gross production and extraction tax revenues to the state annually (as well as considerable indirect revenues such as income and sales taxes), it is easy to appreciate the monetary value of the facility to North Dakota's economy. The materials stored in the core library, and the fact that the facility allows efficient study of the samples by industry and consulting geologists, are certainly directly responsible for several million dollars in revenue to North Dakota each year.

OIL AND GAS ACTIVITY IN NORTH DAKOTA DURING 1983

In the June, 1982 and June, 1983 NDGS Newsletters, I included a summary of oil and gas activity, including new-pool discovery wells, during the preceding year. Some people have told me they appreciated this information, so I'll do the same thing again this issue.

First, some of the more obvious statistics (all of these figures must be considered to be "unofficial" as the NDGS does not compile official oil and gas statistics for North Dakota): Oil production in North Dakota during 1983 totaled 50.7 million barrels, up from 47.3 million barrels in 1982, which had been the previous annual record high figure. Production figures for the first four months of 1984 suggest an annual (1984) production in excess of 50 million barrels once again. A total of 473 wells were drilled for oil and gas, down from the 689 wells that were drilled in 1982 and the 848 wells drilled in 1981. Of the 473 wells drilled in North Dakota in 1983, a total of 289 (61 percent of them) were listed as being capable of production. A total of 123 wildcat (exploratory) wells were drilled in 1983 and 46 new oil or gas pools were discovered. Discoveries were recorded in 14 counties in 1983. Currently (late June), about 60 drilling rigs are operating in North Dakota.

Table 1 lists all of the 1983 oil and gas discoveries and includes pertinent statistics about each of these discoveries. Graphs depicting other statistics are also included with this article.

An added point of interest is the amount of tax revenue being delivered to the State of North Dakota as a result of oil production (I am not referring to any of the taxes and other revenues resulting indirectly from all of the activities associated with the industry, just to taxes on production). According to figures supplied by the Office of the State Tax Commissioner, taxes collected on oil and gas production during the 1981-83 biennium (ending June 30, 1983) became the most important single source of tax revenues to the state. In the 1981-83 biennium, collections of oil and gas taxes totaled $336 million, an increase of $218.8 million from the $117.2 million collected in 1979-81. Collections of oil and gas taxes stood at only $24.3 million during 1977-79 biennium. Of the total tax revenues to the state during the 1981-83 biennium ($956.1 million), the $336 million from oil and gas represents 35 percent of the total. By comparison, the number two producer of tax revenue for the state, the sales tax, amounted to 27.2 percent of the total tax revenues and income taxes accounted for 16.4 percent.

Collections of the oil and gas gross production tax (not the extraction tax) increased during the 1981-83 biennium to $159.7 million, up $66.1 million from the $93.6 million collected during 1979-81. The increase in oil and gas gross production tax revenues reveals the true extent of the impact of high oil prices and higher production on state revenues for the biennium. The remaining oil and gas tax revenues came from the oil and gas extraction tax. In summary, the reasons that oil and gas taxes became the number one source of tax revenues to North Dakota are: (1) the adoption of an initiated measure in 1980 creating the new oil and gas extraction tax; (2) dramatic increases in the price of oil on worldwide markets in recent years; and (3) significant increases in oil production in North Dakota.

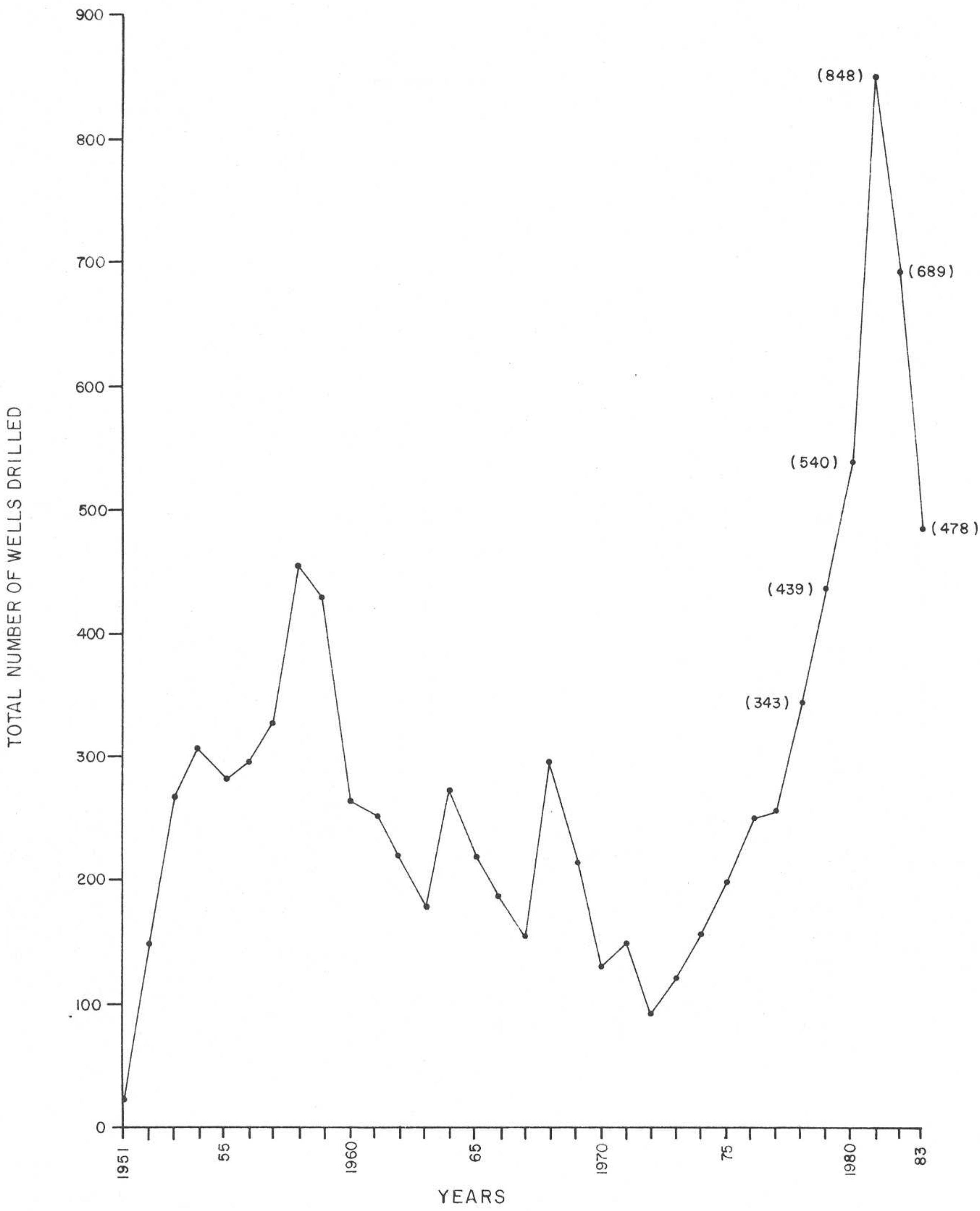


Figure 1. Graph showing the number of wells drilled in North Dakota each year since oil was discovered in 1951. Total includes both exploratory and development wells.

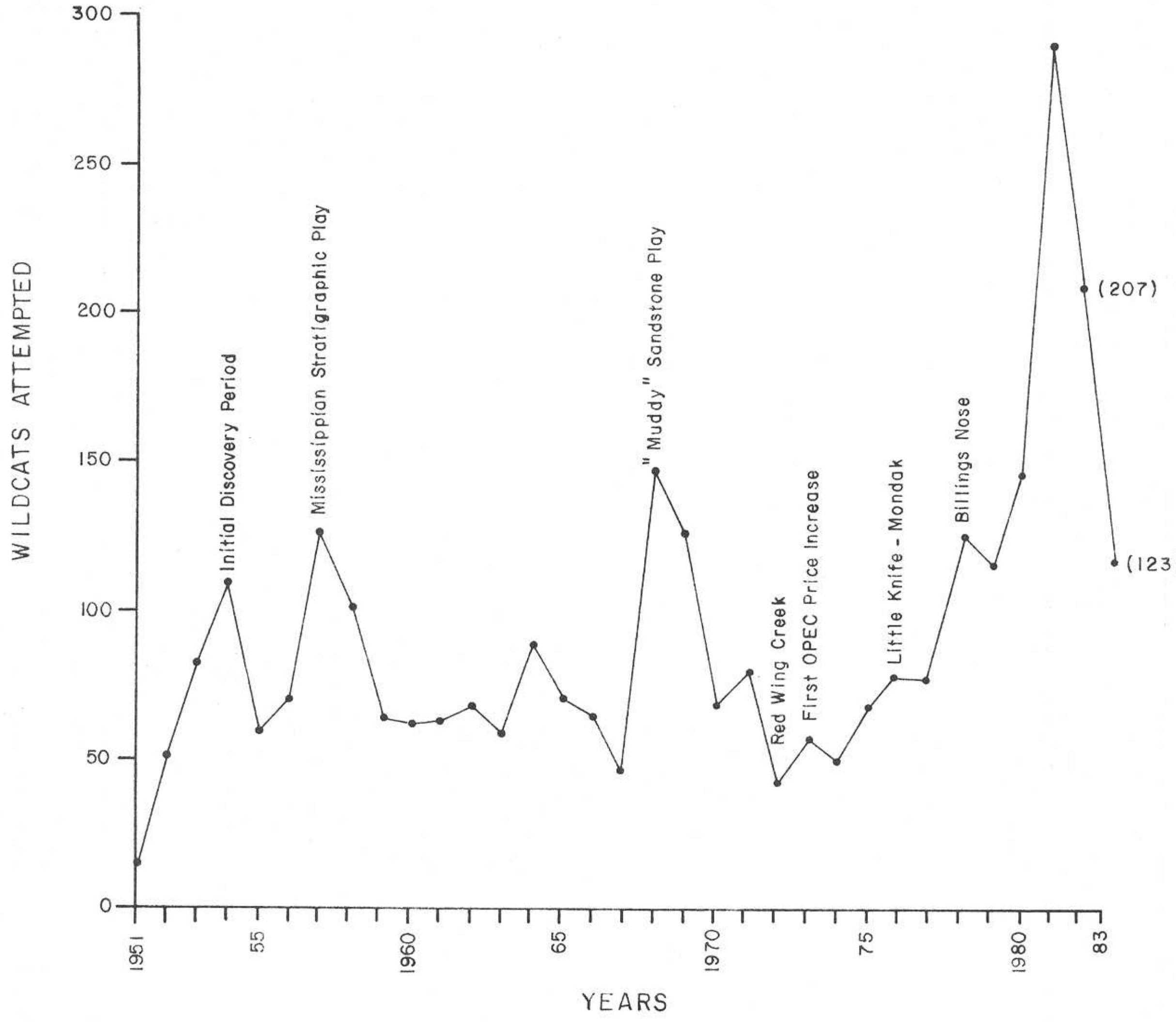


Figure 2. Graph showing the number of wildcat wells drilled in North Dakota each year since oil was discovered in 1951. Some of the major events affecting drilling activity are noted on the graph.

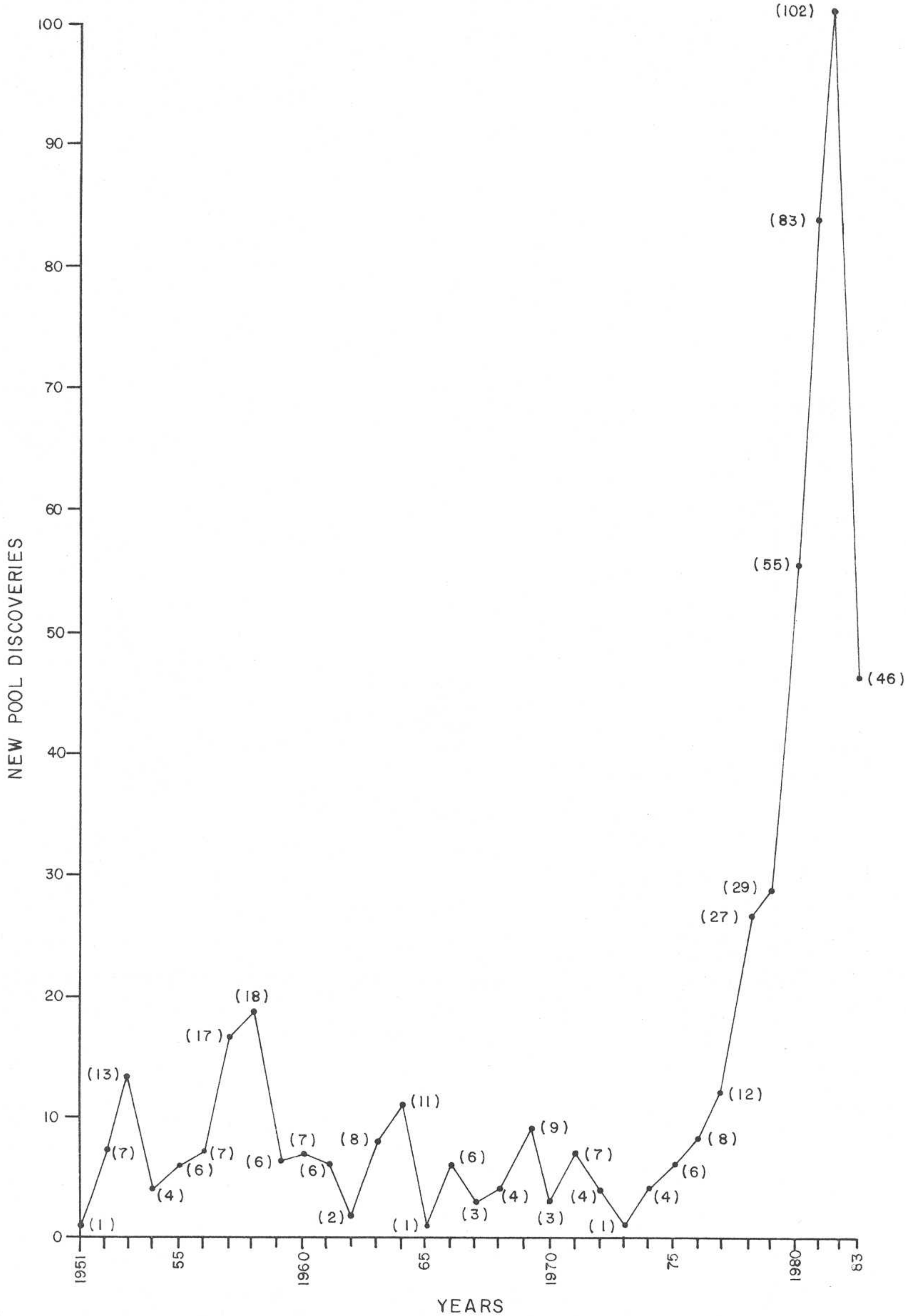


Figure 3. Graph showing the number of new pools discovered each year in North Dakota.

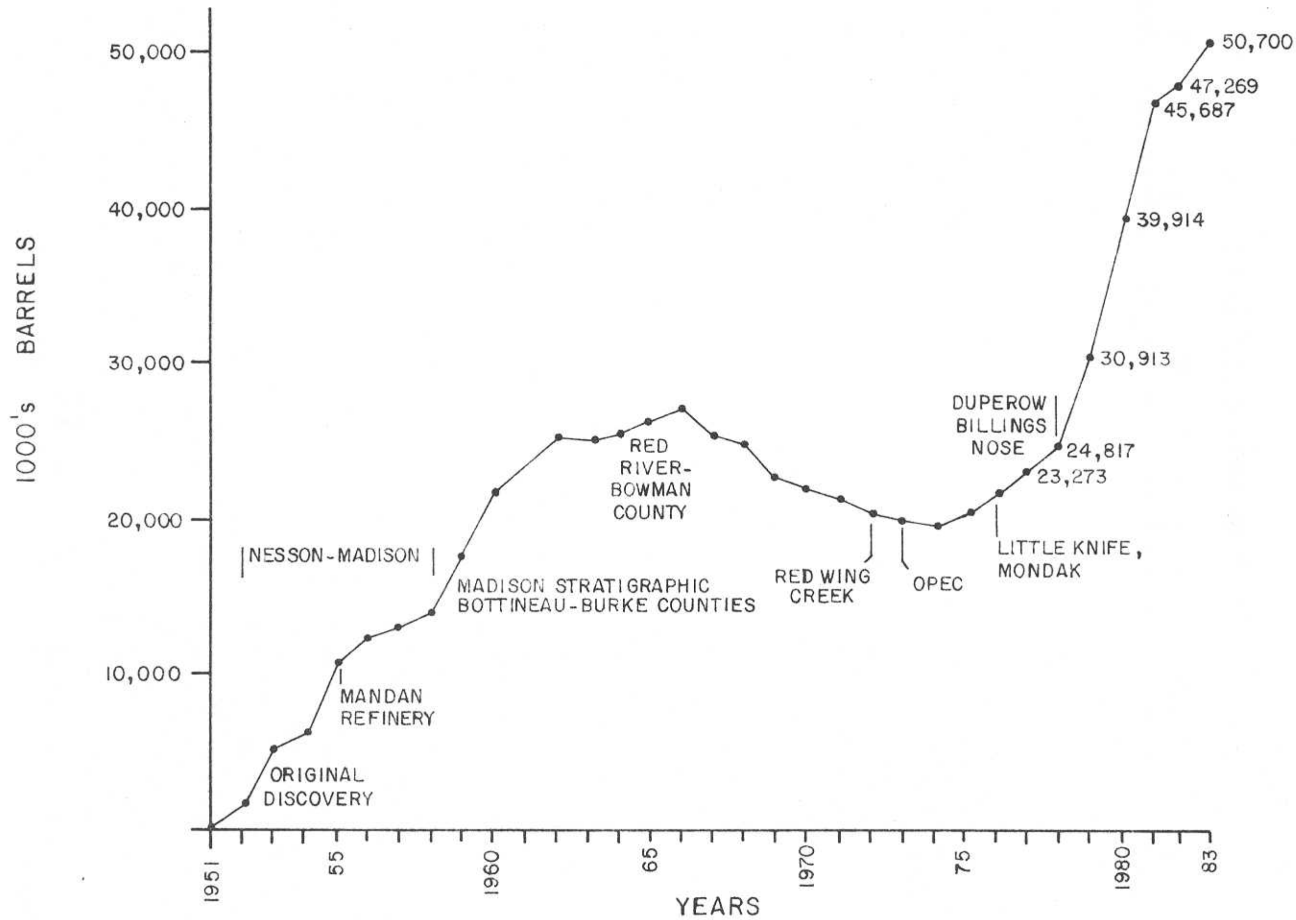


Figure 4. Annual crude oil production in North Dakota. Figures (since 1977) are given in thousands of barrels; thus, the production in 1982 was 47,269,000 barrels. Major events affecting oil production history are noted on the graph.

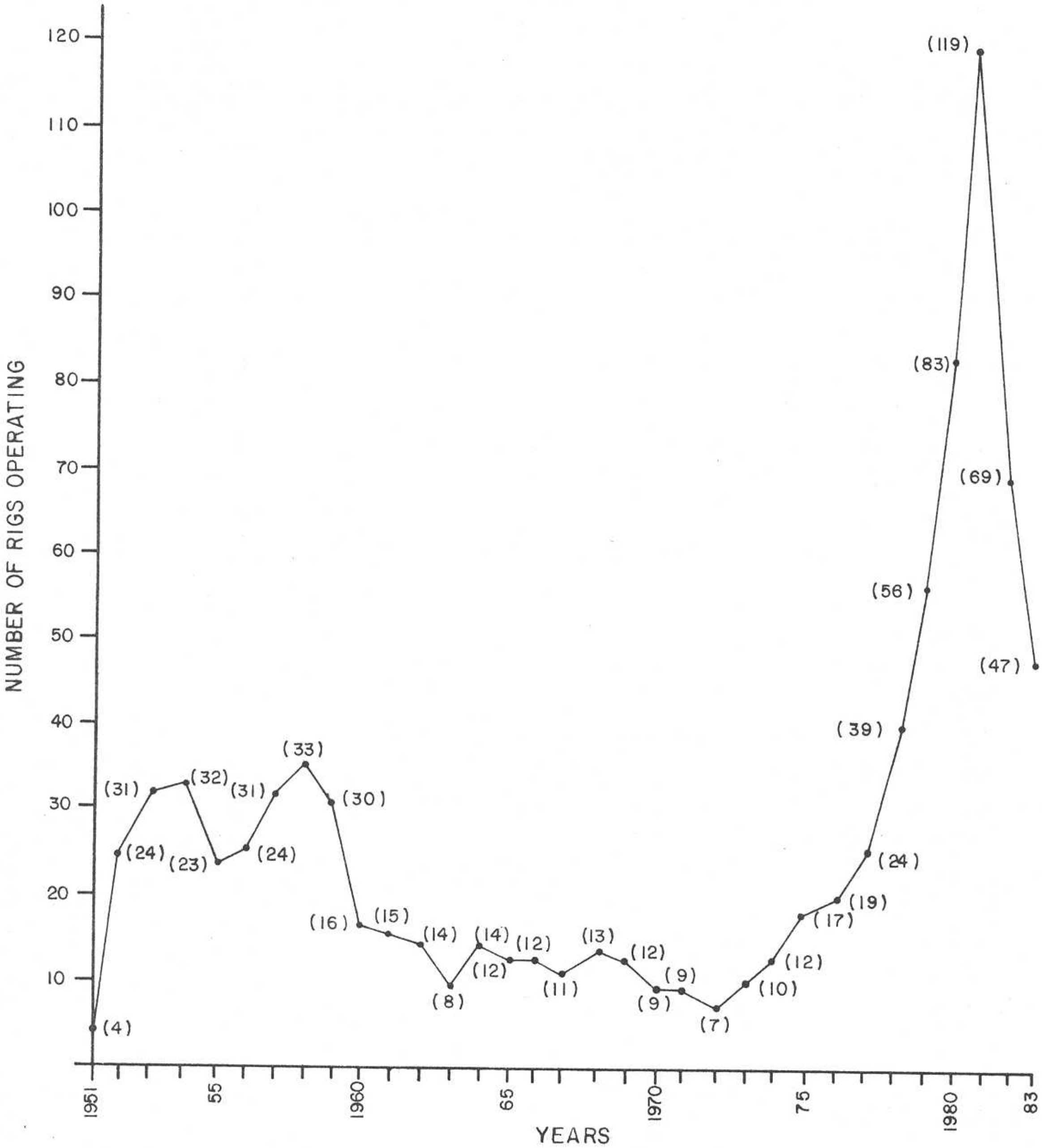


Figure 5. Average number of drilling rigs operating in North Dakota each year since 1950 (weekly average total divided by 52).

Table 1.--Oil and gas discoveries in North Dakota during 1983.

County, File No., Order No.	Comp. Date	Operator, Well, Location	Field, Pool (Number of Wells Currently in Pool)	Spacing	Total Depth	Interval Perforated	Initial Prod. (Current Daily Production) (Bbls. Oil)	Gravity	GOR	Water
Billings 10385 3478	11-29-83	Samson Resources Co. Cameron #1-20 NESW Sec. 20-139-102	Dance Creek- Mission Canyon (-) (recompleted in the Tyler)	160	9,000	8,905- 8,907	(37)	35.2°	N/A	98%
Billings 9534 3100	04-07-83	Coastal Oil & Gas Corp. Canterra 29-142-102 BN #1 NWSE Sec. 29-142-102	Divide-Red River & Three Forks (1)	320	12,730	10,576-10,592 12,557-12,566	30 (SI)	49°	600	85%
Billings 10220 3353	10-09-83	Diamond Chemical Ramona Federal #21-6 NENW Sec. 6-140-102	Knutson-Madison (3)	160	9,335	9,139- 9,146	151 (137)	34.9°	--	92 bbls.
Billings 10479 3469	12-16-83	Adobe Oil & Gas Corp. Kordonowy-Fryburg #34-31 SWSE Sec. 31-142-98	Bullsnake-Madison (2)	320	9,858	---	515 (521)	41°	900	20%
Bottineau 10443 3534		ICG Petroleum, Inc. ICG Norcen-Sveen #2 SESW Sec. 18-163-78	North Roth- Spearfish (1)				(15)			
Bottineau 9956 3083	01-13-83	Norcen Energy, Inc. Fylling #1 NWNE Sec. 35-164-78	Souris-Spearfish (4)	40	3,085	2,940- 2,945 2,974- 2,978 2,987- 2,996 3,002- 3,008 2,952- 3,072	23 (4)	38°	400	74%
Bowman 10307 3406	09-28-83	Quadra Oil & Gas, Inc. #21-8 Battes Palczewski SENE Sec. 21-129-100	Gold-Red River (1)	320	9,600	9,360- 9,374	156 (85)	42.4°	984	20%
Burke 10507 3540	12-15-83	Monsanto Oil Co. Castor State #1 SWSW Sec. 16-159-90	Vanville-Madison (3)	--	7,525	7,282- 7,294	23 (35)	26.85°	1,869	32 bbls.
Burke 10081 3254	05-10-83	Conoco Peterson #20-1 NWNW Sec. 20-161-90	Coteau-Madison (1)	160	7,100	6,414- 6,426	52 (16)	35.6°	288	30 bbls.
Burke 10383 3452	10-31-83	Monsanto Oil Co. Kinson-Hilbert #1 SWSE Sec. 13-162-90	Carter-Madison (2)	40	6,100	5,850- 5,858	67 (12)	34°	896	100 bbls.
Burke 10392 3471	11-08-83	Monsanto Co. Kinson-Hansen #1 NWSE Sec. 12-161-90	Ward-Madison (1)	80	6,410	6,146- 6,156 6,165- 6,168	7 (.6)	34°	1,085	175 bbls.
Burke 10382 3470	11-17-83	Monsanto Co. Kinson-Leo #1 NWNW Sec. 11-163-89	Northgate- Madison (1)	80	5,500	5,212- 5,220	10 (5.5)	39.1°	1,500	30 bbls.
Burke 10504 3521	12-15-83	Chandler & Assoc., Inc. Schultz #14-28 SESW Sec. 28-162-90	Dale-Madison (4)	160	6,283	6,027- 6,055	46 (16)	43°	2,430	22 bbls.
Divide 9942 3160	03-12-83	Getty Oil Wildrose #36-5 SWNW Sec. 36-161-98	Moraine- Winnepegosis (2)	320	12,035	10,472-10,482	497 (223)	45.2°	1,368	20%
Divide 9918 3138	03-15-83	Texaco P. A. Landstrom #1 SESW Sec. 33-164-97	Crosby-Madison (3)	160	10,845	10,725-10,785	71 (57)	30.4°	TSTM	66.97%
Divide 9913 3250	04-03-83	Texaco Gov't Gin Han Prospect NCT-1 #1 SWNE Sec. 11-163-97	Paulson-Red River (1)	320	10,805	10,573-10,589 10,602-10,610	594 BC 2,389 MCF (232)	53.6°	4,021	25%

Table 1.--(Continued)

County, File No., Order No.	Comp. Date	Operator, Well, Location	Field, Pool (Number of Wells Currently in Pool)	Spacing	Total Depth	Interval Perforated	Initial Prod. (Current Daily Production) (Bbls. Oil)	Gravity	GOR	Water
Divide 10210 3362	09-22-83	Superior Tangsrud #12-1 NWNE Sec. 12-160-96	Nelson Lake- Madison (1)	160	9,916	7,660- 7,756	33 (183)	38.6°	818	67.6%
Dunn 9710 3196	03-15-83	Patrick Petroleum BIA Hale #1-7 NESE Sec. 7-148-94	Eagle Nest- Red River (1)	320	14,350	14,090-14,101	81 (31)	49.0°	1,605	59%
Dunn 9682 3373	09-13-83	Mesa Petroleum Co. Fenton 27 #1 NWSW Sec. 27-148-96	Bear Creek-Duperow (4)	320	14,176	11,432-11,464	926 (208)	44°	660	13%
Golden Valley 10076	11-01-83	Coastal Oil & Gas Eagle Draw Prospect #1 NWSE Sec. 33-144-103	Eagle Draw- Red River (-)	160	12,836	12,616-12,628 12,670-12,676 12,684-12,688	35 (--)	42°	23 MCF	70.1%
McKenzie 9762 3122	01-11-83	Belco Development Corp. Sheep Creek Storm #2-1 SENE Sec. 1-145-100	Beicegal Creek- Madison (1)	160	9,850	9,704- 9,709	63 (31)	39°	1,158	58%
McKenzie 9669 3013	10-26-83	W.H.H.T.E. Brockmeir #2 SWNE Sec. 1-146-98	Mary-Interlake		14,170	13,436-13,445 13,448-13,462 13,479-13,491	534 MCF 13	53.6°	41,041	7 bbls.
McKenzie 10094 3311	07-27-83	Milestone USA #11-9 NWNW Sec. 9-146-99	Butte-Madison (1)	160	10,023	9,850- 9,870	18.5 (10)	39.6°	--	21 bbls.
McKenzie 9995 3159	03-24-83	Getty Oil Dore #3-10X NWSE Sec. 3-150-104	Nelson Bridge- Red River (1)	320	12,930	12,770-12,778	249 (89)	47.1°	402	27%
McKenzie 9957 3191	04-05-83	Texaco L. S. Grantier A #1 Lot 8, Sec. 5-152-97	Twin Valley- Red River (1)	320	14,644	13,922-13,935 12,401-12,461	Condensate 2,500 MCFG	N/A	N/A 2.7 MMCF	100% 261 BSW
McKenzie 9858 3205	04-22-83	Pennzoil Snowcover #13-33 BN NWSE Sec. 13-147-102	Snowcover- Red River (2)	320	13,450	13,280-13,335	543 (26)	48.1°	1,599	0%
McKenzie 9212 2999	02-08-83	Aminoil USA, Inc. State Nelson #1-6 SWSE Sec. 6-148-100	Buffalo Wallow- Duperow (2)	320	13,880	11,595-11,602	79 (10)	42.2°	1,215	4.8%
McKenzie 9655 3111	02-07-83	Aminoil, USA, Inc. Schultz #1-8 NENW Sec. 8-148-100	Buffalo Wallow- Mission Canyon (6)	320	14,000	11,618-11,674 13,835-13,895	106 (52)	39.3°	830	16.5%
McKenzie 9860 3112	02-13-83	Aminoil, USA, Inc. USA Ketterling #1-21 SENW Sec. 21-151-104	Dore-Red River (1)	320	12,935	12,740-12,751	209 (71)	47.1°	2,086	29%
McKenzie 9698 3315	06-28-83	Pogo Producing Co. Pogo/Martin-Scott #1-13 NWSE Sec. 13-151-102	Lonesome-Duperow/ Madison (1)	160	11,514	9,360- 9,393	90 (61)	39°	952	3.2%
McKenzie 10053 3312	08-12-83	Milestone BN #14-35 SWSW Sec. 35-148-101	South Red Wing Creek- Madison (1)	320	13,682	9,424- 9,450 9,488- 9,520	41 (9)	38°	1,258	38%
McKenzie 9982 3235	06-01-83	Basic Earth Science Systems, Inc. Beicegel-Carson #1-34 W/2 NW/4 Sec. 34-146-101	Flat Top Butte- Bakken (2)	320	11,300	10,474-10,522	33.36 (44)	44.8°	749	0%
McKenzie 9909 3239	05-26-83	Milestone Petroleum, Inc. BN #21-7 NENW Sec. 7-147-101	Bowline-Red River (2)	320	13,410	13,202-13,294	153 (67)	43°	850	3 bbls.

Table 1.--(Continued)

County, File No., Order No.	Comp. Date	Operator, Well, Location	Field, Pool (Number of Wells Currently in Pool)	Spacing	Total Depth	Interval Perforated	Initial Prod. (Current Daily Production) (Bbls. Oil)	Gravity	GOR	Water
McKenzie 9882 3251	06-02-83	Getty Oil Co. Covered Bridge #10-11 NESW Sec. 10-146-102	Covered Bridge-Birdbear (1)	320	13,297	10,881-10,920	140 (135)	44.6°	1,071	82 bbls.
McKenzie 9806 3234	02-11-83	Adobe Oil & Gas Corp. Adobe Western Federal Storm #13-6 NWSW Sec. 6-145-99	Beicegel Creek-Red River (1)	320	13,862	13,661-13,682	180 (94)	59°	16,600	25%
McKenzie 9727 3131	01-16-83	Pennzoil Expl. Spring Creek BN #27-31 NWNE Sec. 27-148-102	Boxcar Butte-Duperow (1)	320	13,475	11,410-11,426	781 (94)	43.5°	870	0.2%
McKenzie 7479 3435	08-31-83	Pennzoil Co. Grassy Butte #16-24 SESW Sec. 16-146-99	Grassy Butte-Madison (1)	160	14,620	---	132 (103)	44°	1,133	5%
McKenzie 10320 3426	11-06-83	Tom Brown, Inc. Federal #19-42 SENE Sec. 19-150-103	Randolph-Duperow (1)	320	13,410	11,374-11,389	1,119 (228)	37.4°	829	0%
McKenzie 10226 3390	11-04-83	Ranger Oil Co. Tank Exchange #13-2 SWSW Sec. 2-151-96	Camel Butte-Three Forks (1)	320	12,561	10,714-10,750	58 (8)	43°	810	11%
McLean 9941 3264	04-25-83	Davis Oil Co. Bears Tail #12-1 NESE Sec. 12-148-90	Bears Tail-Madison (1)	40	10,200	8,102- 8,118	10 (SI)	31.4°	--	83 bbls.
Mountrail 8936 3363	08-22-83	Bonray Energy Corp. Thompson #1 NENE Sec. 4-155-94	Manitou-Red River (1)	320	14,277	13,956-13,971	70 (20)	43.6°	1,181	35%
Renville 10381 3454	11-02-83	Monsanto Corp. Kinson-Davidson #1 SESW Sec. 7-161-86	McKinney-Madison (8)	160	5,500	5,332- 5,340	120 (80)	28.2°	185	0%
Slope 9883 3114	04-22-83	Anadarko Tennant #1-A SWSE Sec. 26-135-106	Cannonball-Red River (1)	320	9,900	9,658- 9,666 9,726- 9,756	90 (39)	39°	444	70%
Ward 10275 3355	10-05-83	Inexco Oil Co. Wehrman #1-32 NWNW Sec. 32-158-87	Aurelia-Madison (1)	80	6,865	6,611- 6,634 6,626- 6,637	50 (0)	26°	400	83%
Williams 9241 3282	06-12-83	Mosbacher Charles Bowen #21-1 NWNE Sec. 21-153-102	Trenton-Duperow (1)	320	13,300	10,883-10,888 13,052-13,196	202 (103)	42.3°	619	85 bbls.

FOSSIL EXCAVATIONS UNDERWAY IN WESTERN NORTH DAKOTA

--John Bluemle

Excavation of an assemblage of rich vertebrate fossil beds, located on the Fitterer Ranch south of Dickinson in Stark County, will continue in June. Late last fall, North Dakota Geological Survey paleontologist John Hoganson, working with paleontologist George Lammers of the Manitoba Museum of Man and Nature, Winnipeg, and a team of Manitoba and North Dakota geology and anthropology students, began study of the Oligocene fossil beds. Oligocene rocks range in age from 37 to 26 million years old.

Although their existence has been known for many years, the recent excavations at the Fitterer Ranch have shown that the fossil beds there are among the most important so far discovered in North Dakota. Specimens collected to date include a fossil rhinoceros skull and femur; the lower jaw of a Mesohippus (a three-toed horse somewhat smaller than a modern sheep); parts of a small deer; parts of a weasel-like carnivore; and portions of primitive rodents and insectivores.

A number of other important fossil sites have been discovered in western North Dakota in recent years, but in most instances, these fossils were studied and excavated by paleontologists from eastern U.S. universities and the collections were taken from the state. Our present cooperative arrangement with the Manitoba Museum will enable us to acquire an important collection of representative western North Dakota fossil specimens, while utilizing the expertise of Dr. Lammers and his staff. The specimens will be curated at the museum in Winnipeg and then loaned for display in North Dakota. Our first prepared specimens are now on display in Leonard Hall on the University of North Dakota campus. We hope to be able to provide representative displays for the North Dakota Heritage Center in Bismarck as well.

COUNTY GROUNDWATER STUDIES NEARING COMPLETION

--John Bluemle

Two North Dakota Geological Survey geologists will be mapping the geology of Bottineau and Dunn Counties this summer. Ed Murphy will be mapping in Dunn County and John Bluemle expects to finish mapping Bottineau County. Both of these two counties are included in a series of County Groundwater Studies that have been underway for several years. The studies involve several cooperating agencies, including the North Dakota Geological Survey, the North Dakota State Water Commission, the U.S. Geological Survey, and the respective County Water Management Districts. Considerable test drilling has already been completed to determine the location, quantity, and quality of groundwater resources in Dunn and Bottineau Counties.

Reports on the groundwater basic data of Dunn and Bottineau Counties have already been published and a report on the hydrology of Dunn County is also available. The current studies will result in reports on the geology of each county. In addition to the knowledge gained about groundwater, the geologic studies help to identify all other mineral resources and they result in a much better understanding of the geologic history of the areas.

The North Dakota Geological Survey, along with the other cooperating agencies, has now completed and published studies of most of North Dakota's counties. Apart from Bottineau and Dunn, the only counties remaining that have not yet had geologic studies published are McKenzie, Ward, Renville, Ramsey, and Emmons. We have a report ready to publish on Emmons County and a report is now being prepared for McKenzie County, where field studies are complete. We hope to complete our studies of Ward, Renville, and Ramsey Counties within the next two years.

NEW PUBLICATIONS

The following new publications were issued by the Survey during the first six months of 1984:

"General Rules and Regulations for Geothermal Energy Production" was compiled by the North Dakota Geological Survey for the North Dakota Industrial Commission. This 14-page publication defines the statute dealing with geothermal resource development regulation and it states the State Industrial Commission's rules and regulations governing geothermal energy production. It defines the State Geologist's role in supervising the regulations and orders applicable to geothermal energy extraction facilities. The permitting procedure is outlined, the posting of bond, procedures for filing necessary reports, and other procedures are also spelled out. The General Rules and Regulations for Geothermal Energy Production can be obtained without charge from the North Dakota Geological Survey.

Bulletin 79, Part 1--"Geology of Towner County, North Dakota," was written by John P. Bluemle. A recent report is also available on the groundwater basic data for Towner County. The new report describes the subsurface and surface geology, the geologic history, and the economic geology of Towner County. It emphasizes the stratigraphy of the near-surface glacial deposits in the county.

This report on Towner County should be useful to anyone interested in knowing more about the physical nature of the materials underlying the area. Such people may be water-well drillers or hydrologists interested in the distribution of sediments that have potential to produce usable groundwater; civil engineers and contractors interested in such things as the gross characteristics of foundation materials at possible construction sites, criteria for selection of and evaluation of waste disposal sites, and the locations of possible sources of borrow material for concrete aggregate; industrial concerns looking for possible sources of economic minerals; residents interested in knowing more about the area; and geologists interested in the physical evidence for the geologic interpretations.

Bulletin 79, Part 1 is 44 pages long and includes a colored geologic map scale ½-inch to a mile. The report is available free of charge.

PROTECTING NORTH DAKOTA'S GROUNDWATER RESOURCES

--Quentin Paulson

(Editor's Note: Most of the material in this article is adapted from a 1983 U.S. Geological Survey Publication by Mr. Paulson. The publication is entitled "Guide to North Dakota's Ground-Water Resources" (U.S.G.S. Water-Supply Paper 2236). It is a short, well-written, easy-to-understand discussion of our knowledge about groundwater resources in North Dakota today.)

A recent survey showed that, during 1980, an average of about 121 million gallons per day of groundwater were withdrawn from aquifers in North Dakota. This

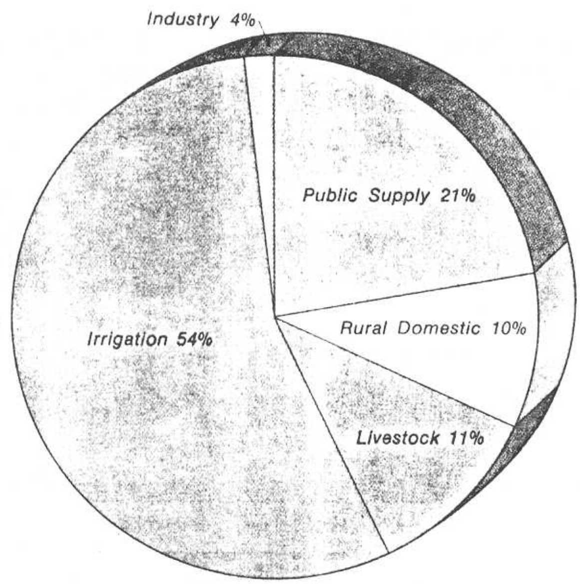


Figure 1. Percentage of water use for various purposes during 1980. Irrigation accounts for more than 50 percent of the groundwater used in North Dakota.

is an increase of nearly 14 percent since a similar survey was made in 1975. The use was mainly for the following purposes:

* Public supply
* Rural domestic
* Livestock
* Irrigation
* Industry (self-supplied).

The volumes used for each purpose are shown on the accompanying diagram (fig. 1). The largest withdrawals are for irrigation use, followed by public supply, and rural domestic. Irrigation alone accounts for more than 50 percent of the groundwater withdrawals in North Dakota.

Irrigation of crops with groundwater has increased steadily in North Dakota since about 1960, when there were about 6 irrigation wells in the state. By 1980, there were nearly 1,500 wells pumping a total of 65 million gallons per day during the irrigation season. Today, almost 100,000 acres of land are irrigated by groundwater in North Dakota.

The significant increase in irrigation use can be attributed mainly to two nearly simultaneous developments--one informational and the other technological. The first relates to the statewide program of county groundwater investigations, which began in 1955 and is now nearing completion. The reports and maps resulting from this program provided much of the decision-making information necessary for the potential irrigators. Also, during this same period, technology produced the center-pivot, sprinkler-irrigation system, which can be adapted so well for use with groundwater sources of supply.

The increased use of North Dakota groundwater has made us more aware of the danger of harming the resource, either through overuse or contamination. Until recently, water pollution control activities have focused mainly on rivers and lakes. Groundwater was considered a pristine source, protected from the effects of man's activities by virtue of burial within the earth. We are becoming increasingly aware, however, that not only is groundwater vulnerable to pollution, but that serious degradation already has occurred in places, particularly in parts of the industrialized eastern United States where toxic chemicals have been detected in drinking water supplies. It is because groundwater is widely used as a source of drinking water that we need to be constantly alert to the hazards of pollution. As the use of North Dakota's groundwater resources increases, we are becoming more aware of problems with them. Recently, for example, high levels of arsenic were discovered in parts of southeastern North Dakota, levels higher than permitted in public drinking water (table 1). It is not known, however, whether these high arsenic levels are due to contamination or whether they are the result of naturally high arsenic concentrations in the aquifer rocks. The State Health Department is investigating the problem.

North Dakota is not an industrial state, and the likelihood of serious groundwater pollution resulting from industrial processes may seem to be remote at this time. However, little is presently known concerning the long-term hydrologic effects of the state's rapidly expanding energy-related industries, such as coal and oil production and coal-fired electrical plants. Studies of the present and potential impacts due to these activities are currently underway, but few data are yet available.

It appears that the most likely sources of groundwater contamination in North Dakota are related to agricultural activities, which is not unexpected, considering the intensity of farming within the state. Some pesticides and herbicides as well as fertilizers leave residues that can and do leach downward to shallow aquifers. To date, monitoring efforts within the state have indicated very little contamination due to these sources. Other possible sources of groundwater contamination include cattle feedlots, municipal landfills, septic tanks, sewage lagoons, oil wells, and the mud pits used during oil well drilling operations. Even groundwater wells themselves can be sources of contamination if they are not properly constructed.

The location, construction, or both, of potential sources of contamination need to be based on geologic considerations. Information is available at a number of state and federal agencies (including the North Dakota Geological Survey, State Water Commission, and U.S. Geological Survey) that would aid in the location or construction of wells so that aquifer contamination can be avoided or minimized.

Absolute protection against groundwater contamination probably is an impractical, if not impossible goal. The first and foremost consideration needs to be the protection of aquifers that are now being used, or have the potential for being used, as sources of drinking water. In North Dakota, these sources would include most aquifers in the unconsolidated rocks and in some of the bedrock formations. Much of the water in the deeper bedrock formations is too saline to be used for drinking purposes, although treatment may be economically feasible in some instances if the water is needed for drinking water purposes.

Table 1.--Maximum contaminant levels permitted for public supply use: inorganic chemicals, organic chemicals, radionuclides, and microbiological. (From North Dakota State Department of Health, 1977).

	CONTAMINANT	LEVEL Milligram Per Liter
INORGANIC CHEMICALS The maximum contaminant level for nitrate is applicable to both community and non-community water supply systems. The levels for other inorganic chemicals apply only to community water supply systems. The maximum contaminant levels for inorganic chemical contaminants are as follows:	Arsenic	0.05
	Barium	1.
	Cadmium	0.01
	Chromium	0.05
	Lead	0.05
	Mercury	0.002
	Nitrate (as N)	10.
	Selenium	0.01
	Silver	0.05
	Fluoride	2.4
ORGANIC CHEMICALS	CONTAMINANT	LEVEL Milligram Per Liter
The maximum contaminant levels for organic chemical contaminants, applicable only to community water supply systems, are as follows:	Chlorinated Hydrocarbons:	
	Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa-hydro-1,4-endo, endo-5, 8-di-methano naphthalene).	0.0002
	Lindane (1,2,3,4,5,6-hexachloro-cyclohexane, gamma isomer).	0.004
	Methoxychlor (1,1,1-Trichloro-2,2-bis [p-methoxyphenyl] ethane).	0.1
	Toxaphene ($C_{10}H_{10}Cl_8$ -Technical chlorinated camphene, 67-69% chlorine).	0.005
	Chlorophenoxys:	
	2,4-D (2,4-Dichlorophenoxyacetic acid).	0.1
	2,4,5-TP Silvex (2,4,5-Trichloro-phenoxypropionic acid).	0.01
RADIONUCLIDES	CONTAMINANT	LEVEL Picocuries Per Liter
The maximum contaminant levels for radionuclides, applicable only to community water supply systems, are as follows:	(1) Combined Radium-226 and Radium-228.	5
	(2) Gross alpha particle activity, including Radium-226, but excluding radon and uranium.	15

MICROBIOLOGICAL

The maximum contaminant levels for coliform bacteria, applicable to both community and non-community water supply systems, are as follows:

(1) MEMBRANE FILTER METHOD

When the membrane filter method is used, the number of coliform bacteria colonies shall not exceed:

(a) One per 100 milliliters as the arithmetic mean of all routine and check samples examined per month; or
(b) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or
(c) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(2) FERMENTATION TUBE METHOD

When the fermentation tube method and 10 milliliter standard portions are used, coliform bacteria shall not be present in:

(a) More than ten percent of the portions from both routine and check samples examined in any month; or
(b) Three or more portions in more than one sample when less than 20 samples are examined during the sampling period; or
(c) Three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

Although total protection against groundwater contamination may not be attainable, or even desirable, measures can be taken that will minimize the hazards. A thorough knowledge of the geohydrology is necessary to determine the direction and rate of movement as well as the eventual fate of contaminants. Numerous studies by several state and federal agencies are underway in an effort to gain knowledge needed to thoroughly understand the geohydrology of North Dakota's groundwater resources. During the past 30 years, the groundwater resources have been systematically identified and described on a county-by-county basis. The program has been a cooperative effort involving each county of the state, the North Dakota State Water Commission, the North Dakota Geological Survey, and the U.S. Geological Survey. In some counties with large areas of federally owned lands, other federal agencies such as the U.S. Forest Service and U.S. Bureau of Land Management have also been involved. Similarly, for the past ten years, the NDGS has been investigating the chemical evolution of groundwater in western North Dakota as well as changes in groundwater quality associated with lignite mining and reclamation of mined lands. Also, the Survey has, in cooperation with the State Health Department, been involved in evaluating existing and proposed landfill and lagoon sites. These are only a few of the many studies currently being carried out to assess a variety of potential groundwater pollution problems.

Water beneath the earth's surface generally moves very slowly (a few feet per year is not uncommon). This slow movement may result in optimism by some regarding the possibility of a slug of contaminants ever reaching a point of withdrawal. Added comfort may be derived from the knowledge that, as the contaminant moves through the subsurface, it is continually being dispersed and diluted. However, studies have shown that, given enough time and driving energy, a contaminant can travel considerable distances from the point of origin. Also, unfortunately, once the contaminant reaches a point of withdrawal, the damage may be complete and a remedy impossible in terms of a lifetime or even several generations because of the slow movement.

Many inorganic and most synthetic substances that move through the subsurface remain relatively unchanged except for dilution and dispersal. Contamination associated with human and animal wastes generally is decreased to acceptable limits by bacterial processes within the soil, if the depth to the water table (or top of the aquifer) is sufficient. Once the contaminant reaches the water table, however, these processes are no longer effective. Thus, the depth to the water table is a critical factor in regard to contamination from such sources as septic tanks and animal feedlots, as shown by the accompanying diagrams (figs. 2 and 3).

Also of importance is the texture of the materials through which the contaminant moves. Obviously, coarse sand or gravel will permit a much faster rate of movement than will clay or shale. In fact, the existence of a thick continuous bed of clay or shale overlying an aquifer may, for practical purposes, be considered sufficient protection against non-point sources of contamination (fig. 4).

In summary, the possible sources of groundwater contamination are many and diverse. This field of study is relatively new, and some of the findings to date have resulted in controversy. Unfortunately, there are few generally accepted standards regarding the effects of various contaminants or the limits that should be defined for various uses. However, the North Dakota State Department of Health, in cooperation with the U.S. Environmental Protection Agency, has adopted regula-

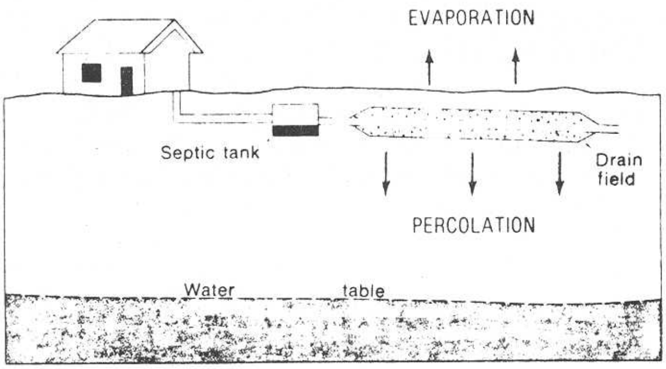


Figure 2. Operation of a septic system. Bacterial action and sorption by soil particles will remove bacterial contaminants, provided the depth to the water table is sufficient.

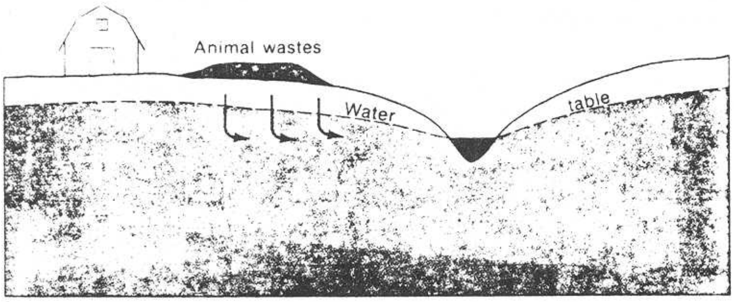


Figure 3. Contamination of groundwater from a surface source. Where the water table is shallow, contaminants such as feedlot wastes can move considerable distances through groundwater systems and may eventually discharge into surface-water bodies.

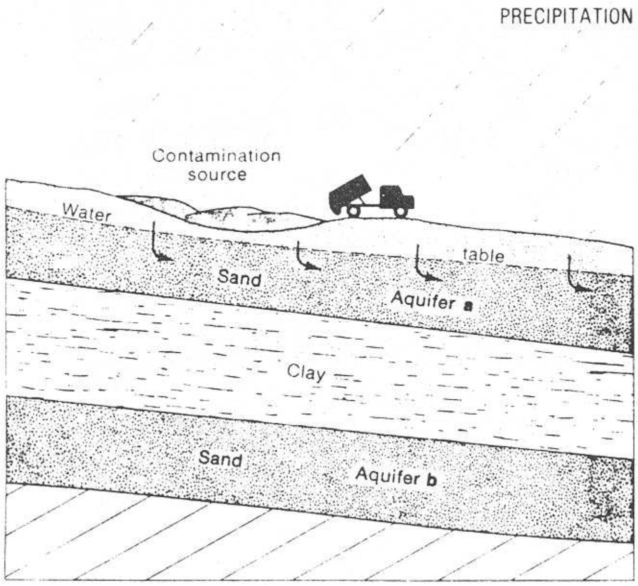


Figure 4. Protection against contamination provided by clay deposits. Aquifer "a" is vulnerable to contamination from surface source. Ground water carries the contaminant downward until it reaches the clay deposit and then moves laterally through aquifer "a." Aquifer "b" is protected by the clay deposit and is unaffected by the contaminant.

tions regarding maximum acceptable levels of certain contaminants in water used for public water supply systems. These are listed on table 1.

It should be stressed that the protection of groundwater quality is complex, and involves all components of the terrestrial hydrologic systems. Control of contaminants at their source is the most practicable means of excluding them from groundwater aquifers.

SURVEY PROFILES

Anne Behl

Anne Behl has been with the Survey since 1981, first as a publications clerk and currently as a Secretary I. She graduated from Apollo High School in St. Cloud, Minnesota and from the Area Vocational Technical Institute in East Grand Forks where she completed a clerk/typist program. Prior to attending the AVTI, Anne worked at a resort in Battle Lake, Minnesota and for a time pinning and stretching mink at a mink ranch in Ottertail, Minnesota.

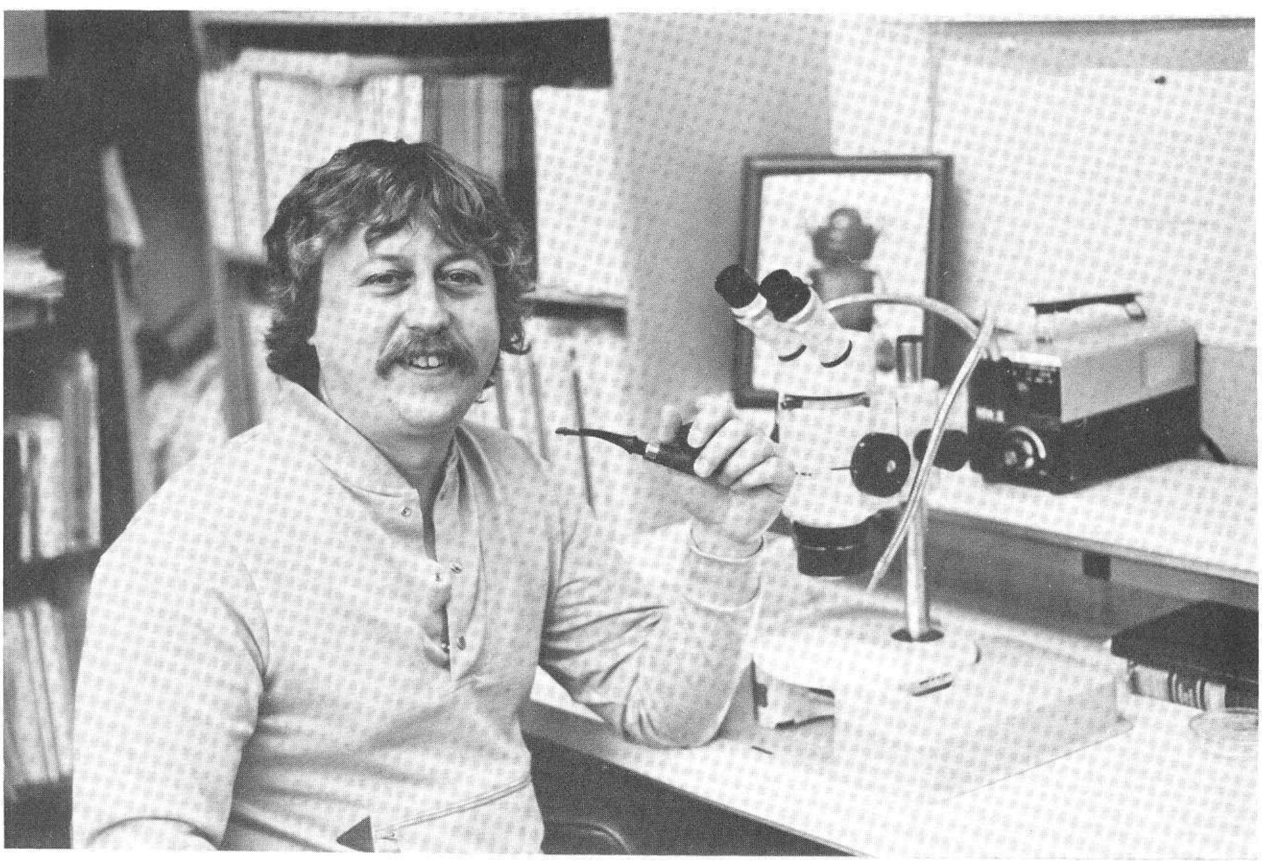
Anne types most of the Survey's correspondence. In addition to her Survey job, she also types the University of North Dakota's weekly University Letter. As part of her Survey job, she answers the phone at times and helps visitors to the Survey find whatever they need.

John Hoganson

John Hoganson has been a surface geologist with the Survey since 1981, specializing in Quaternary paleoenvironmental research. Although he specializes in paleontology, John is also in charge of our geological evaluations of existing and potential sanitary landfill sites as well as assisting in other waste-management problems, especially by-products from coal-burning power plants.

John was born in Fargo and received his B.A. in geology in 1970 from North Dakota State University. He received an M.S. in geology in 1972 from the University of Florida where he studied Eocene paleontology and biostratigraphy. He expects to complete his Ph.D. in geology at the University of North Dakota within the next few months, with a dissertation on late Quaternary paleoclimates of southern Chile. He has been on two geological expeditions to Chile, in 1977 and 1979. His doctoral research project is concerned with the interpretation of late Quaternary and Holocene climatic changes in southern Chile as deduced from changes in fossil beetle assemblages. In addition to his experience with the Survey, John worked for 3 years as a micropaleontologist and biostratigrapher for Union Oil Company of California, in their Gulf Region Office in Houston, Texas. He has also taught courses in carbonate geology at the University of North Dakota.

John and his wife, Shelly, who is a UND student majoring in anthropology, have four children.

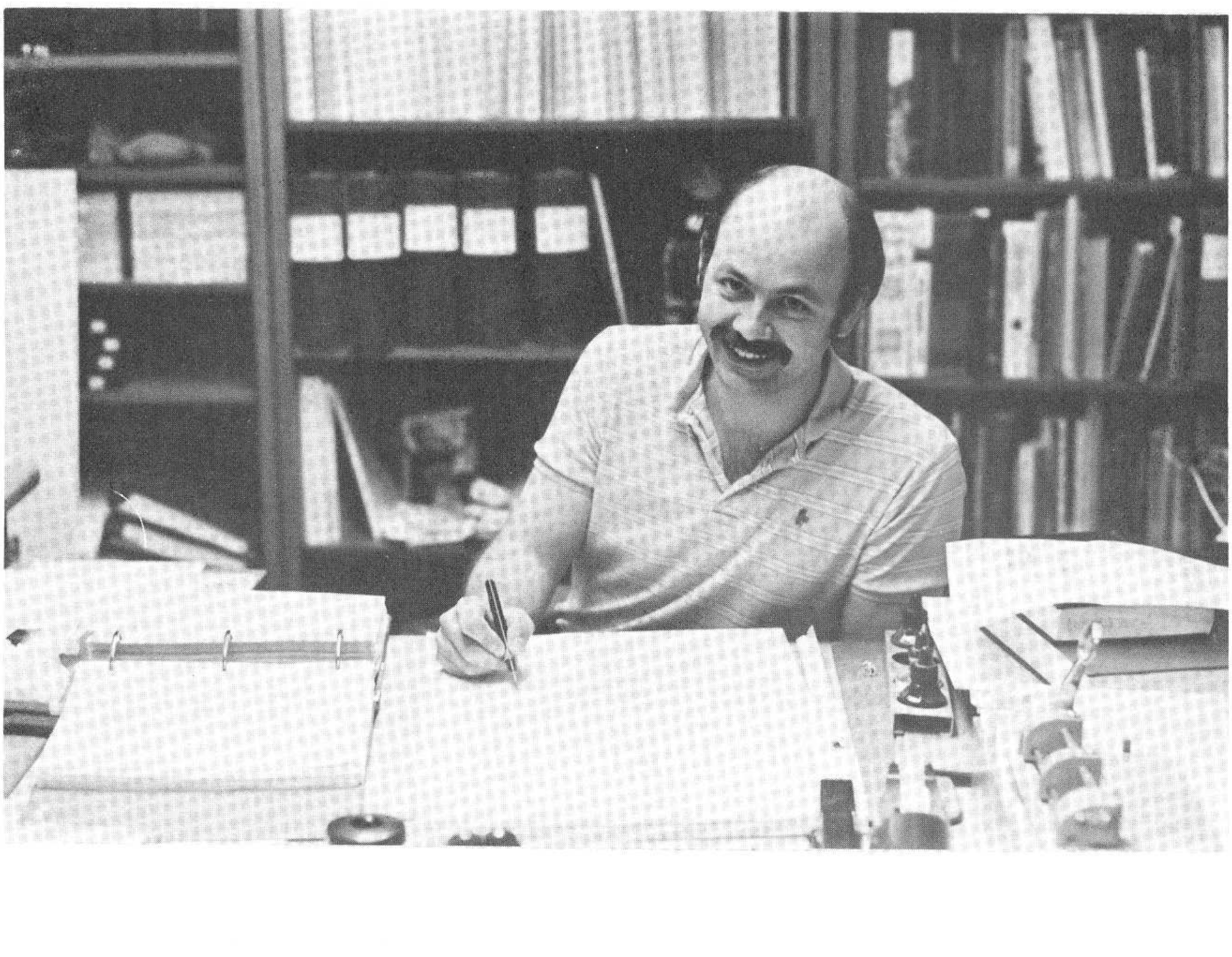


Rod Stoa

Rod Stoa has been curator of the Wilson M. Laird Core and Sample Library since 1980. He is responsible for seeing that visiting geologists are provided with the specimens they want to study and with the necessary equipment they need for conducting their studies.

Rod was born in Langdon, North Dakota and graduated from high school in Fergus Falls, Minnesota. He is currently working on a Bachelors degree in geology at the University of North Dakota as a part-time student. Prior to coming to the Survey, Rod worked at the Anti Ballistic Missile (ABM) site in northeastern North Dakota. He also owned and operated a business for a year before moving to Grand Forks.

Rod, and his wife Jo-Anne who works at the Westward Ho Motel here in Grand Forks, have two children, 4½-year-old Leah and 2½-year-old Christopher.



SUBGLACIALLY MOLDED SURFACE IN McHENRY COUNTY

--John Bluemle

An unusual group of landforms can be seen in southern McHenry County in the region between Verendrye and Balfour. Here, a series of remarkably straight, parallel, northwest-southeast trending ridges were shaped by the glacier when it flowed southeastward through that area. The ridges are not outstanding features from the point of view of a ground-based observer. In fact, unless one is aware of their presence, most of them might not be noticed. However, viewed from an airplane or on an airphoto, the ridges are spectacular features (figs. 1, 2, and 3).

The largest of the ridges, the so-called "Hogback Ridge," is an obvious enough ridge to a ground-based observer, but its length and spectacular straightness can't be appreciated except from an aerial viewpoint. Hogback Ridge is about 13½ miles long. It decreases in height from about 50 feet at its northwest end to less than 5 feet near its southeast end. Throughout much of its length, it is about 30 feet high, it is even and sharp crested, and it has a nearly symmetrical cross profile. Superficially, it resembles a large railroad or highway grade. The average base width of Hogback Ridge is about 300 feet, giving a length to width ratio of about 240 to 1.

Most of the linear ridges found in the Verendrye-Balfour region trend in a direction that is approximately 35° East of South (S 35° E), although a few do bend slightly along their courses. An individual ridge commonly tapers to extinction near its southeast end, but in many cases, another ridge begins, aligned parallel a few hundred feet away, in an en echelon fashion, to the ridge that is ending. The smaller linear ridges tend to occur in localized swarms and they are closely associated with numerous intervening grooves. The larger ridges, like Hogback Ridge, tend to be more isolated.

Most of the larger ridges are composed mainly of gravel and sand, along with blocks of glacial till. The gravel and sand is commonly stratified; its bedding is not flat, but slopes away from the crest of the ridge or, in some instances, it slopes either northeast or southwest across the entire width of the ridge. Most of the larger ridges are veneered with a layer of till, whereas the smaller ridges usually consist entirely of till.

Streamlined glacial features are most often referred to as "drumlins," which are elongated hills, or "flutings," which are grooves or furrows. Both drumlins and flutings form as a result of streamlining by the moving glacial ice. In most places where they have been identified, drumlins are not more than a few miles long and shaped roughly like inverted spoons with the blunt ends toward the upglacier direction. This is the more typical shape of drumlins found in the eastern part of the United States and Canada. However, exceptionally long, narrow ridges, similar to those I have just described, have been seen in other places, especially in Saskatchewan and Alberta.

Most of the ridges in the Verendrye-Balfour area have upglacier (northwest) ends that consist of small, molded blocks of glacial sediment, probably ice-thrust blocks. These ridges were initiated by obstructions at their heads. The ice-thrust blocks were apparently pushed up into the glacier, causing low-pressure zones in the ice, or even tunnels downglacier from them; water-saturated material flowed into the low-pressure zones and was molded by squeezing, thrusting, shearing, flowing, or folding.

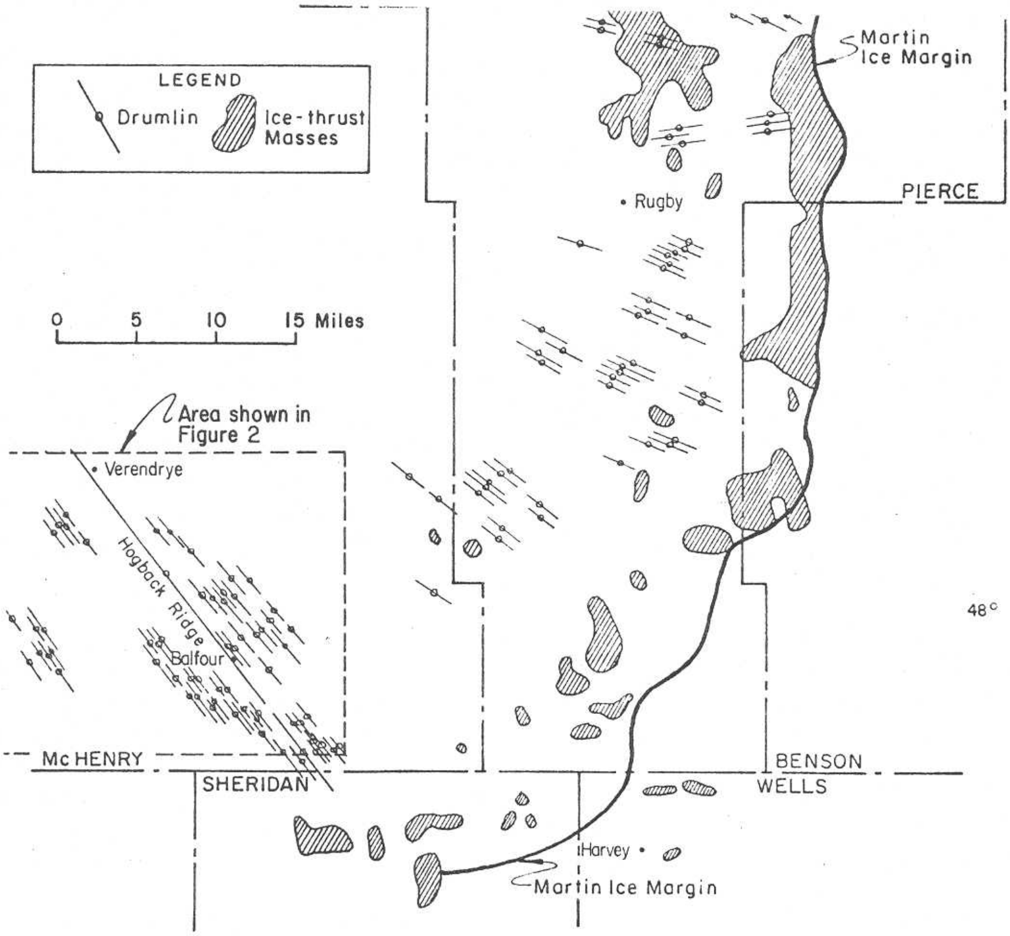


Figure 1. Map of a part of central North Dakota showing the occurrence of streamlined ridges described in this article. The ridges occur behind the Martin ice margin (the "Martin Moraine"), which is characterized by a large number of ice-thrust masses. Dashed line shows the extent of the area shown on figure 2.

Clearly, ridges like those found in the Verendrye-Balfour area are closely associated with glacial thrusting; they always occur in conjunction with ice-thrust features. The geologic conditions that resulted in glacial thrusting must have also resulted in the formation of the streamlined ridges. Thrusting by the glacier was dependent primarily on groundwater conditions beneath the ice; thrusting occurred only where hydrologic conditions were appropriate. It is logical to infer that conditions the same or similar to those that caused thrusting are also necessary for streamlined ridges to form.

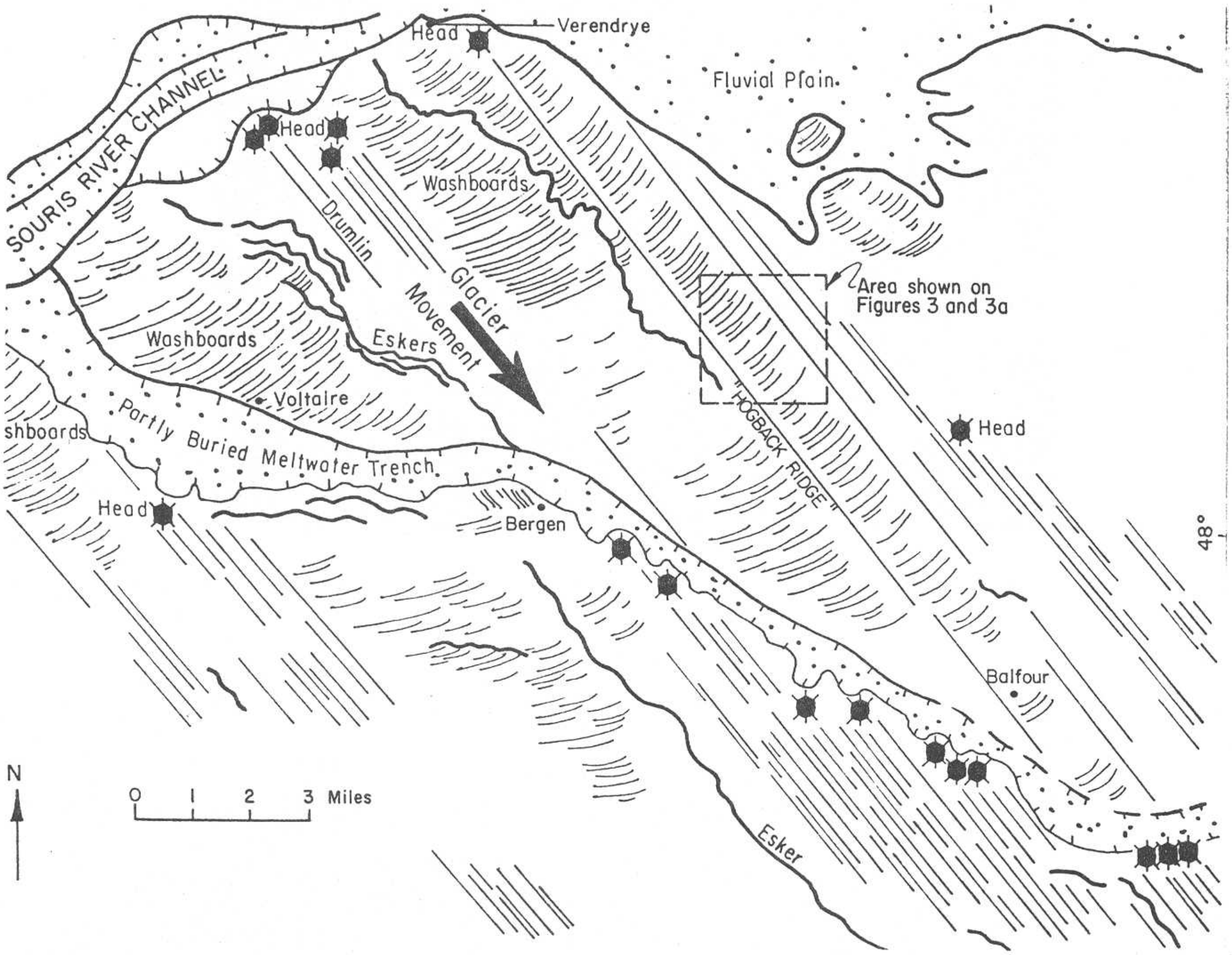


Figure 2. Map of the Verendrye-Balfour area showing the distribution of streamlined ridges. Some of the ice-thrust blocks of till situated at the heads of the ridges are shown (symbols marked "Head"). Notice that many of the ice-thrust blocks occur in an immediately down-glacier direction from a buried meltwater trench and several others occur immediately down-glacier from the Souris River channel.

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COMMENTS