

OIL EXPLORATION AND DEVELOPMENT IN THE NORTH DAKOTA WILLISTON BASIN: 1986-1987 UPDATE

by

David W. Fischer
and
John P. Blucmle



MISCELLANEOUS SERIES NO. 72
NORTH DAKOTA GEOLOGICAL SURVEY

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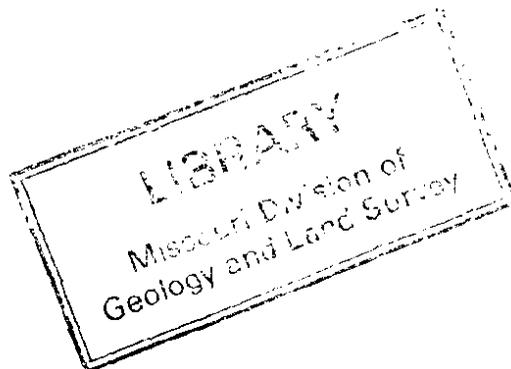
Frank Karner, *State Geologist*

1988

The cover shows a view of the Enron Oil & Gas Co. 18-33 BPNA-RR-BN well in Roughrider Field, McKenzie County (NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec 33, T145N, R101W). This shows the #2 drill-stem test from 9439-9474 feet in the Mission Canyon Formation. Photo courtesy of Roger Borchert, Harris, Brown, & Klemer Inc.

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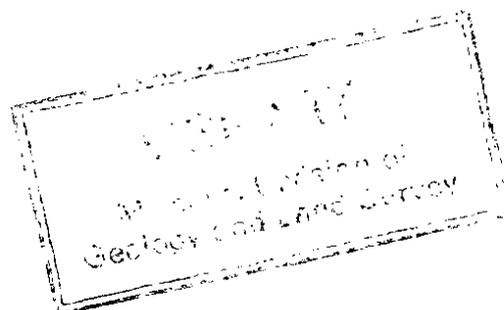
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INTRODUCTION

North Dakota is now experiencing a downturn in oil production, the result of the severe cutbacks in exploration over the past two years. After peaking at 52.6 million barrels of oil in 1984, North Dakota's production dropped off to 41.3 million barrels in 1987 and can be expected to continue dropping as older producing wells decline and fewer new wells are drilled to replace them. In this, as in previous versions of this report, we will briefly outline the several exploration cycles the Williston Basin has undergone, review development of the significant reservoirs, and list significant statistics about North Dakota's oil exploration and production trends. The data presented here are largely from the files of the North Dakota Geological Survey. Much of the data for the years since 1980 were provided by the Oil and Gas Division of the North Dakota Industrial Commission, but all of the interpretations are our own.

PRE-1951 EVENTS

Natural gas, known to most people around the turn of the century as "marsh gas," was first reported in southeastern North Dakota in 1892 in an artesian well producing from the "Dakota" sandstone. Subsequently, the gas was obtained from many artesian wells in a belt extending south from Jamestown to Merricourt. This methane gas was used for lights, cooking, and heating at Edgeley. It apparently occurred in an unsaturated solution with the artesian water and, as the water pressure was released when it flowed to the surface, the gas was collected in tanks. Although enough gas was found to supply the small towns in the area, improper drilling and maintenance of the wells resulted in blowouts, plugging, and loss of head. When the artesian head was lowered below the

land surface, gas production stopped, and by 1920 the gas was used only on a few scattered farms. No record was made of pressure or production of the gas, which occurred at a depth of about 1,100 to 1,200 feet.

Natural gas was also utilized in the Westhope and Lansford areas of Bottineau County prior to 1910. This gas, which was used to heat and light 13 homes in Lansford by use of an underground pipeline system, occurs in glacial deposits. Many local farmers in that area had installed separators and used the gas to heat barns and other structures, apparently for several years before 1910. At Lansford, the gas was found at depths of 175 to 210 feet from a 19-foot-thick glacial sand. At about that time too, a company known as the North Dakota Gas Company supplied gas to the town of Westhope. The gas was delivered to the town through a 20-mile pipeline. Eight wells cost 13.6 cents per foot to drill and charges to the townspeople were 30 cents per 1,000 cubic feet of gas in summer, 40 cents in winter.

In April, 1916, State Geologist A. G. Leonard visited the Williston area to determine the likelihood of finding oil or gas there. His report on his findings advised against going to the expense of drilling a well. The following month, Leonard visited Marmarth for a similar purpose at the request of Governor Hanna and recommended drilling in that area.

In September, 1916, a wildcat well was started by the Des Lacs Western Oil Company on the farm of A. F. Blum, about 1½ miles southeast of Lone Tree in Ward County. The well was abandoned at 244½ feet in October, 1916.

In September of 1917, the Des Lacs Western Oil Company asked the North Dakota Geological Survey to investigate the possibilities of finding oil and gas in the Minot area. Dr. Leonard and Assistant State Geologist, Howard Simpson, found enough evidence to recommend further ex-

ploration. On the basis of their report, a well was drilled about two miles west of Des Lacs in 1923. The well penetrated 3,980 feet deep, into the Cretaceous Inyan Kara Formation, but was nonproductive. It was located only two miles east of present Madison production in the Lone Tree Field.

In 1933, Professor William E. Budge of the School of Mines had taken an interest in the occurrence of oil shale and oil seeps along the Sheyenne River south of the Fort Totten Indian Reservation. These had been called to his attention by interested citizens of Warwick. He made several trips to the area and attempted to get an appropriation from the 1935 Legislature to make further studies of the area, but he was unsuccessful in obtaining funding. Professor Budge believed that the best way to evaluate the area would be by seismic methods as the area is covered by glacial sediment.

On August 15, 1938, the California Company abandoned its Nels Kamp #1 well in Williams County. This well was drilled less than one mile from what is now Capa Field and approximately one quarter of a mile from a well completed in 1984 in the Silurian. The Kamp well was junked at 10,281 feet in the Devonian. This well was the first in North Dakota on which an electric log was run. While State Geologist Wilson M. Laird was out of town, Acting State Geologist Nicholas Kohanowski signed the drilling permit for Amerada Petroleum Corporation's #1 Clarence Iverson well to be drilled in the SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec 6, T155N, R95W, Williams County. The permit was issued on August 4, 1950. Drilling began at 6:00 a.m. on September 3. On January 4, 1951, a drill-stem test (from 10,452 to 10,803 feet) recovered one pint of free oil in the bottom of the test tool. The recovery was from the Devonian Duperow Forma-

tion. However, the well was completed in the Silurian Interlake Formation on April 4, 1951.

POST-1951 EVENTS

North Dakota's 1951 Nesson Anticline discovery was not the first oil production from the Williston Basin (fig. 1). Oil was discovered in the Williston Basin in Montana on the Cedar Creek Anticline (fig. 2) in 1936 and in Manitoba in 1950. Since 1951, several significant cycles of exploration and production have been completed in North Dakota. Annual production increased in North Dakota until 1966 (26 million barrels) then declined until 1974 (19.6 million barrels). Production in 1979 (31 million barrels) surpassed the previous 1966 high and new highs were recorded each year until 1984 when production again began to decline.

Although the initial oil discovery in North Dakota was from Silurian rocks, the early development of the Nesson Anticline (fig. 2) was primarily from Madison reservoirs. The peak discovery period was 1952-1953, with development along the 75-mile anticline trend being nearly complete by 1960 (fig. 3). Producing capacity at that time exceeded the available market (the Mandan refinery). Production was limited then by prorationing until November of 1965, when natural decline of these reservoirs equaled the market demand. The only significant deeper horizons developed along the Nesson trend during the early 1960s were the Duperow and Interlake Pools in the Beaver Lodge and Antelope Fields. The Sanish Pool in Antelope Field was also undergoing development at this time.

Significant discoveries between 1952 and 1959 included the Mississippian oil fields of Bottineau, Burke, and Renville Counties (fig. 3). The

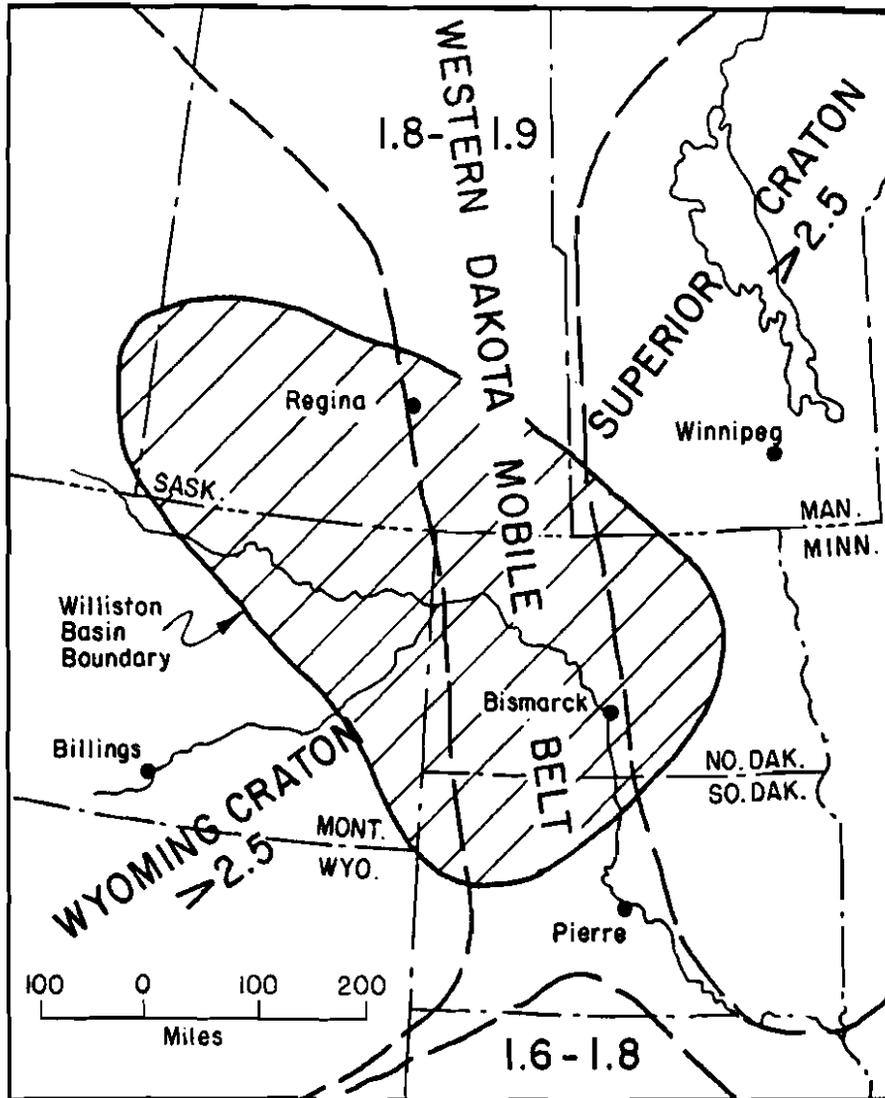


Figure 1. Map showing the extent of the Milliston Basin. The major Precambrian structural provinces (Superior Craton, Western Dakota Mobile Belt, and Wyoming Craton) are shown along with the approximate ages of the basement rocks in each area; e.g., rocks of the Wyoming Craton are greater than 2.5 billion years old; rocks of the western Dakota Mobile Belt range in age from 1.8 to 1.9 billion years old.

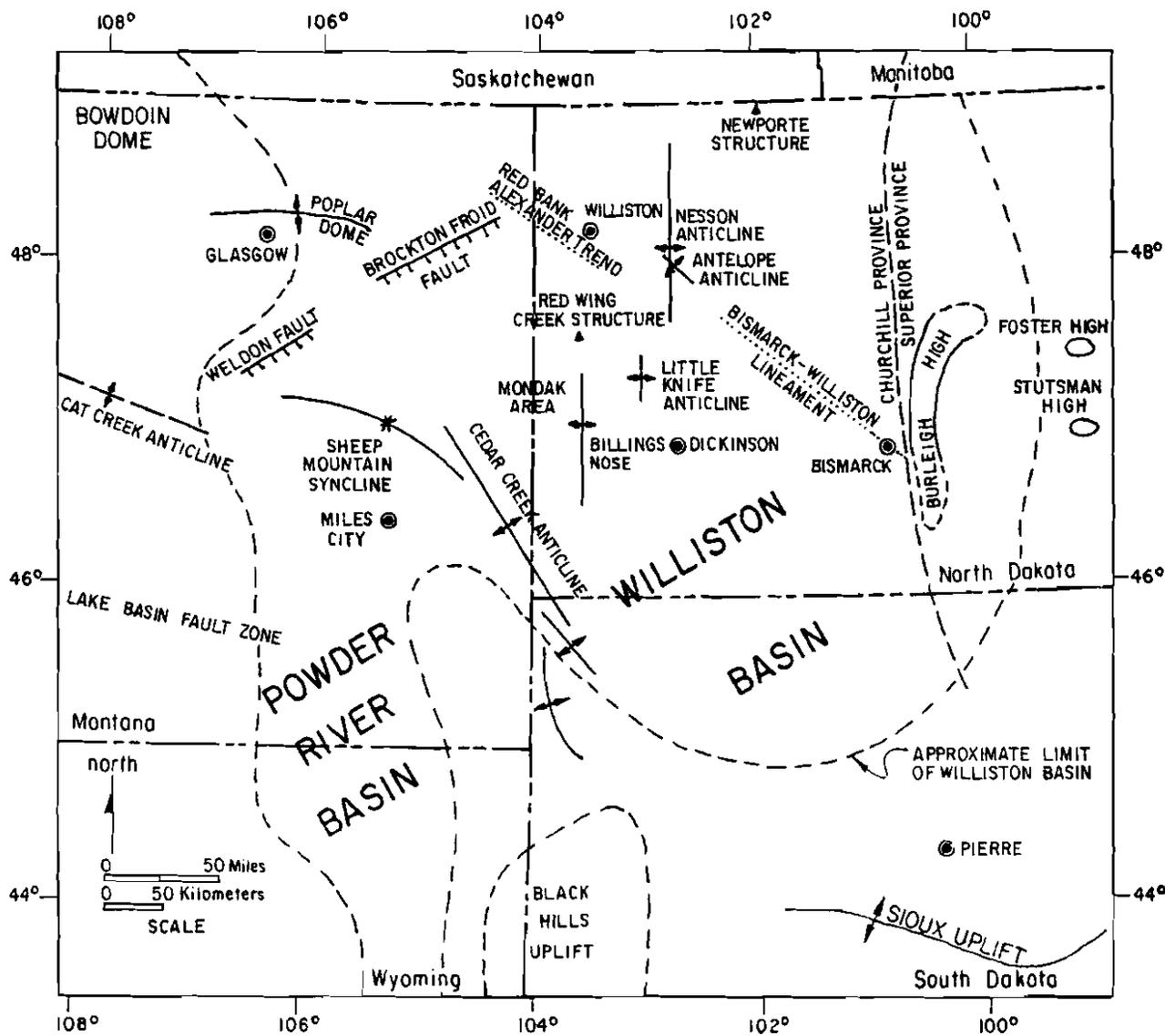


Figure 2. Map showing the major structural features in western North Dakota and South Dakota, eastern Montana, and northeastern Wyoming.

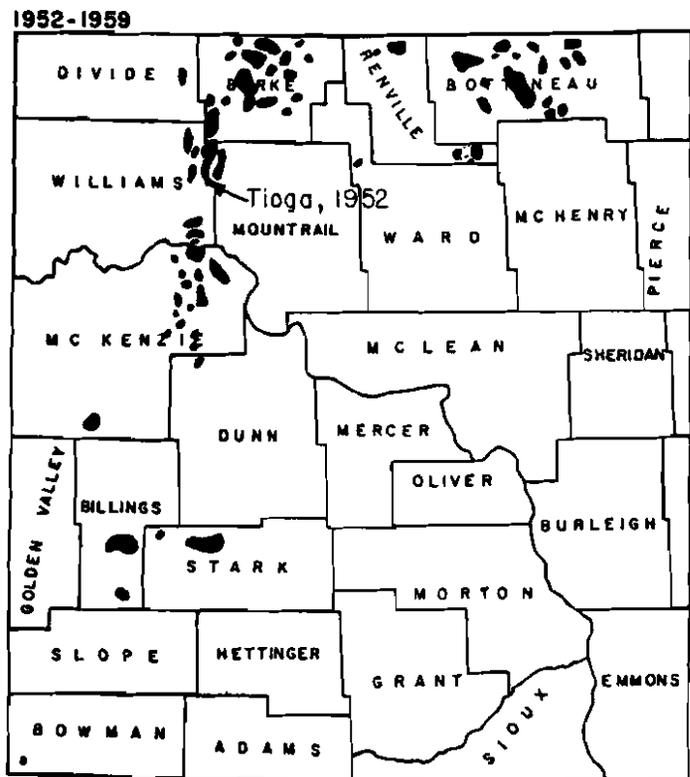
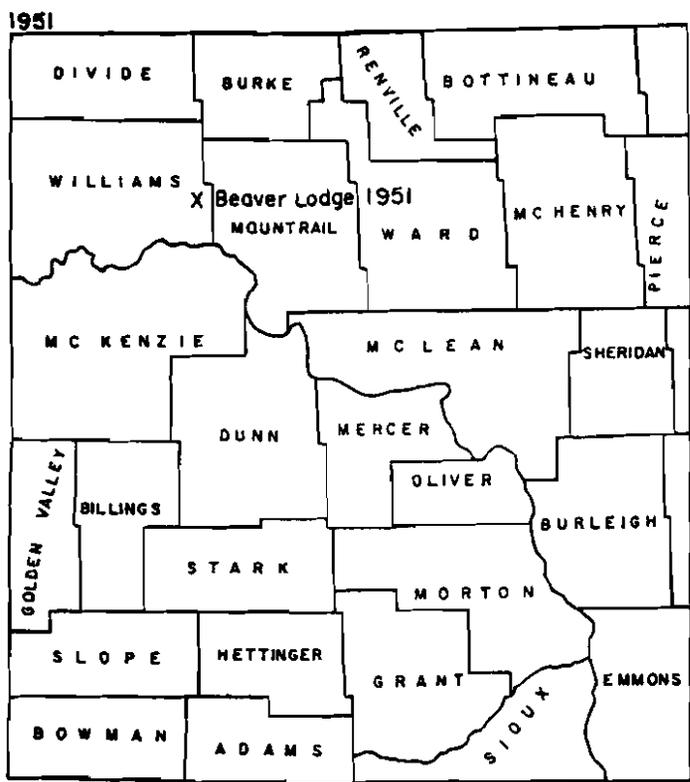


Figure 3. Discoveries in North Dakota during the 1950s. The upper map of western North Dakota shows the location of the Beaver Lodge discovery in 1951. The lower map shows oil fields developed by the end of the 1950s. The Tioga discovery of 1952 is also noted.

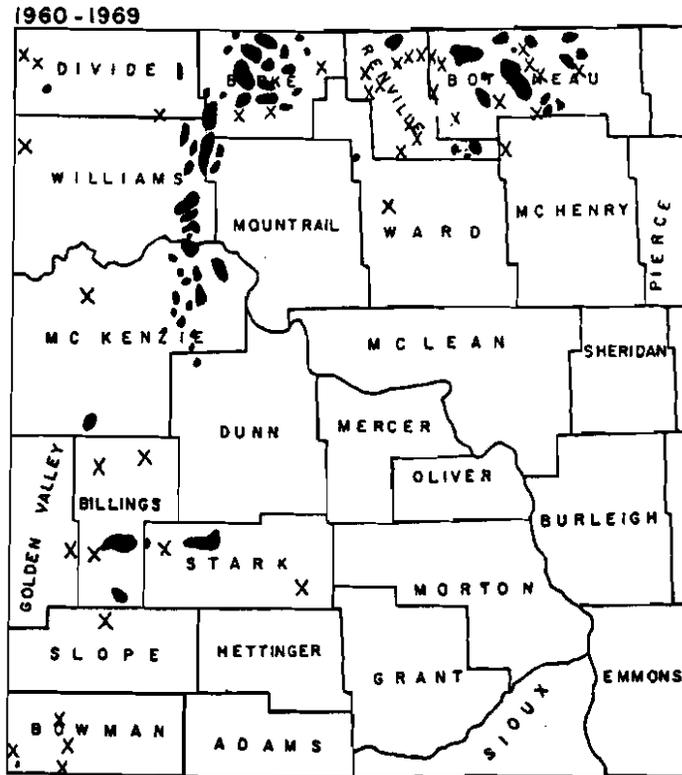


Figure 4. Major new field discoveries in North Dakota between 1960 and 1969.

increasing production between 1958 and 1961 largely reflects development of these pools.

Tyler sand reservoirs, which were discovered at Rocky Ridge in 1957 and Fryburg in 1959, became important developments in the mid-60s in the Stark and Billings County areas. Peak production occurred in 1966 at Medora Field and in 1967 in the Dickinson Field. This helped to offset declines in the older producing areas.

In 1960, discovery of the Cedar Creek Pool extended the Red River production along the Cedar Creek Anticline into North Dakota (figs. 2 and 4). The Bowman County Red River play extended production in southwestern North Dakota to small "bumps" along the eastern flank of the structure in the period from 1967 to the mid-70s.

The decline in production from 1966 to 1974 represents the failure of new discoveries to replace the natural decline of the major producing areas. The normal pattern is discovery, followed by development, leading to peak production for one to three years, followed by a gradual decline. Secondary recovery methods are used in an attempt to alter this pattern. Water injection for pressure maintenance was installed in many of the Madison reservoirs along both the Nesson trend and in Burke County, but this technique was relatively unsuccessful. Similar programs, begun in 1967 in the Newburg-Spearfish and Madison reservoirs, in 1970 in the Medora Field, and in 1973 in the Tyler sand reservoirs in the Dickinson Field, increased production levels above the initial development in those fields.

However, these successful programs could not offset the natural decline of the major producing areas.

The trend to lower exploratory activity during the 1960s generally followed the national trend. The upsurge of wildcatting in 1968 in North Dakota has been referred to as the "Muddy sand" (Newcastle) play. It followed development of the Bell Creek Field in Montana, but no similar occurrences were found in North Dakota and exploration activity again slowed down.

THE 1970s RESURGENCE

Two events that occurred close together in the early 1970s significantly changed Williston Basin production history. First, Red Wing Creek Field was discovered in 1972 in McKenzie County, North Dakota (figs. 2 and 5). Second, OPEC, which was formed in 1973, enacted production controls (embargoes) and price increases on production in OPEC countries.

OPEC created the first substantial worldwide increase in the price of oil. The price rose from about \$4.00 a barrel in 1973 to about \$9.00 in 1974 and prices continued to rise through the 1970s. As a result, exploration was once again a profitable venture. Prior to this, many companies found that exploration risk money had a better return in a regular bank savings account than in actual wildcat drilling. The increased price made risk capital available, and enhanced exploratory drilling.

The discovery of Red Wing Creek at about the same time excited basin operators because of the relatively high productivity of the wells and the anomalously thick pay section. Since no one really understood the nature of the Red Wing Creek structure (fig. 2) at the time, industry's response was to gain lease foothold in the area. The lease play set off by

the Red Wing Creek discovery set the stage for further development. The five-year-term leases taken in western North Dakota tended to increase exploratory activity. The availability of venture capital coupled with the approaching expiration of five-year leases, caused exploratory drilling to increase in 1975 and 1976.

In 1977, two additional significant discoveries were drilled. The first of these, the Charlson-Silurian Pool (fig. 5), proved that production rates in excess of 2,000 barrels of oil a day were possible in North Dakota. Although the multiple-pay Mondak Field, discovered in 1976, turned out to be one of North Dakota's largest oil fields, it was the discovery of Little Knife in 1977 (fig. 5) that drew national attention to North Dakota. Located at the junction of Billings, Dunn, and McKenzie Counties, Little Knife Field demonstrated potential for several zones of production. It is easily a giant field with over 100 million barrels of reserves.

Drilling continued to increase in 1978 and the wildcat success ratio also improved. Several important 1978 discoveries changed exploration ideas about North Dakota's Williston Basin. Perhaps the most interesting of these was the discovery of Shell Oil Company's Newporte Field in northern Renville County (fig. 6). This opened the first significant Cambrian production in the state, although some Cambrian gas and Cambro-Ordovician hydrocarbons had been produced on the Nesson Anticline. The discoveries at Missouri Ridge and Springbrook north of Williston opened production in southern Williams County and northern McKenzie County. The discovery of Bull Moose Field in McKenzie County and T. R. Field in Billings County were significant in establishing these counties as a region of major production, and delineated a major north-south struc-

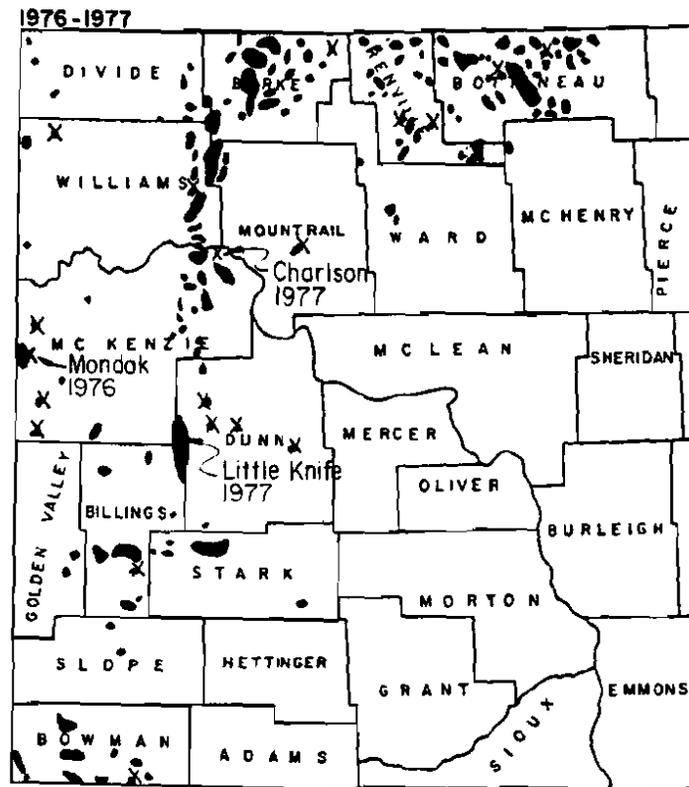
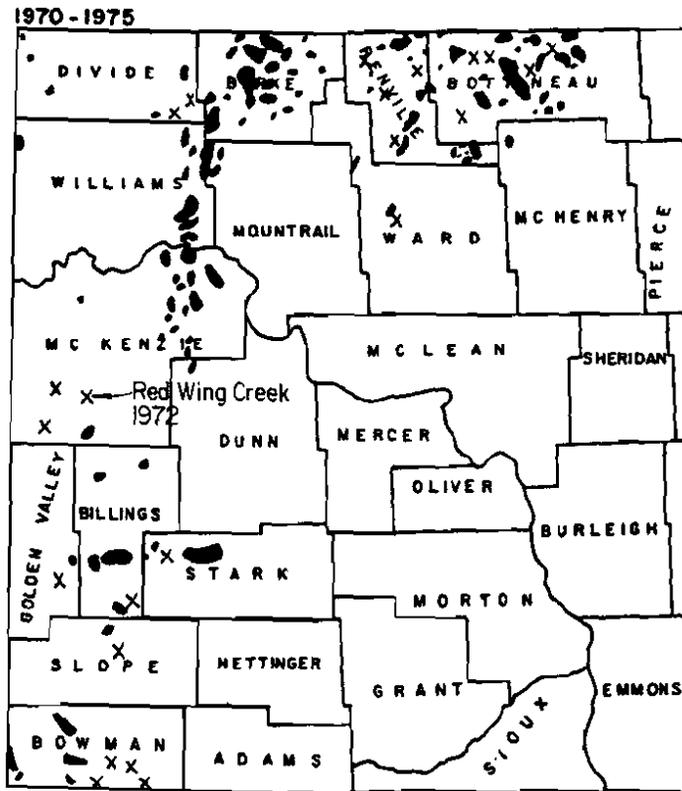


Figure 5. Major new field discoveries (x symbols) between 1970 and 1975 (upper map) and in 1976-1977 (lower map).

tural trend, the Billings Anticline (fig. 2).

Continued success on the Billings Anticline and in Mondak Field were highlights in 1979 and 1980 (figs. 6 and 7). The success on the Billings Anticline vaulted Billings County into the number one producing county in North Dakota, where it remained until May, 1984, when it was overtaken once again by McKenzie County. Big Stick, Four Eyes, and Whiskey Joe Fields were discovered on the Billings Anticline in 1979. These fields are multiple pay, producing from the Ordovician Red River, Devonian Duperow, Mississippian Bakken, and Mississippian Madison, with the Madison being the major producing interval. Big Stick Field has many wells with initial productions exceeding 500 barrels of oil per day and several with initial productions above 2,000 barrels of oil per day.

Mondak Field is another multiple-pay field with the Madison being the primary producing horizon. The wells there are not as prolific as those on the Billings Anticline, but the field currently covers about 125 square miles in North Dakota alone with 171 wells in the Madison, 4 in the Red River, and 1 each in the Bakken, Duperow, and Tyler.

THE 1980s

1980-1985

Deep pool successes on the Nesson Anticline highlighted this older producing feature during the early to mid-80s. Notable among them were Texaco's Silurian and Ordovician Red River discoveries in Blue Butte Field (an old Madison field), and Northwest Exploration's Dawson Bay and Red River successes along its western flanks, near the north end of

the anticline. Dawson Bay production was also important because it was the first production from that formation.

Two new counties were added to the list of North Dakota producers in 1980 with Amoco's Red River discovery in Hettinger County (Tepee Butte Field) and Conoco's Red River success in Mercer County (Dodge Field) (fig. 7), though the Mercer County production was short-lived.

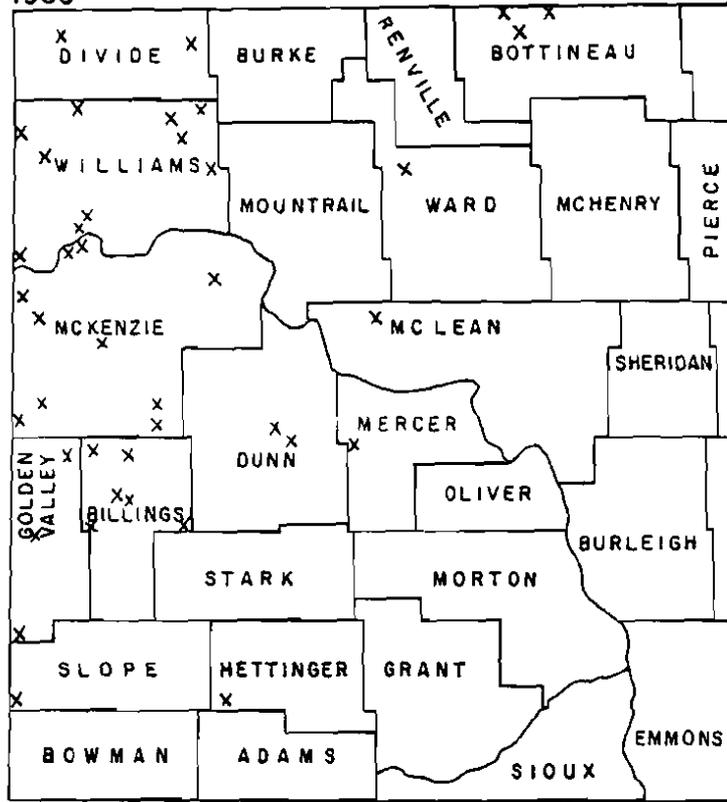
Discoveries were also made in Golden Valley and Slope Counties in 1980, far from already-existing production. Amerada Hess completed the southernmost Madison producer in North Dakota in Golden Valley County (Bull Run Field) and Terra Resources completed a Red River well in what is now the Marmarth Field in western Slope County.

In northern Williams County, Hunt completed a Lodgepole producer in the Corinth Field near the town of Wildrose. This was not a big well, but it was important because it produced from a horizon that was largely overlooked in the past. The two wells that were completed in Corinth Field have since been abandoned.

The discovery of oil in 1981 in the Bluell beds of the upper Mission Canyon Formation in north-central Burke County (fig. 7) heightened interest in this horizon as well as in the slightly deeper Sherwood beds. Earlier production was primarily from the stratigraphically higher Midale and Rival subintervals.

Lower prices resulting from an oversupply of crude oil, high drilling costs, and other economic factors resulted in a downturn in exploratory drilling activity in 1982 in the Williston Basin (fig. 8). Since then, activity has been characterized by development drilling and tests for deeper producing horizons

1980



1981

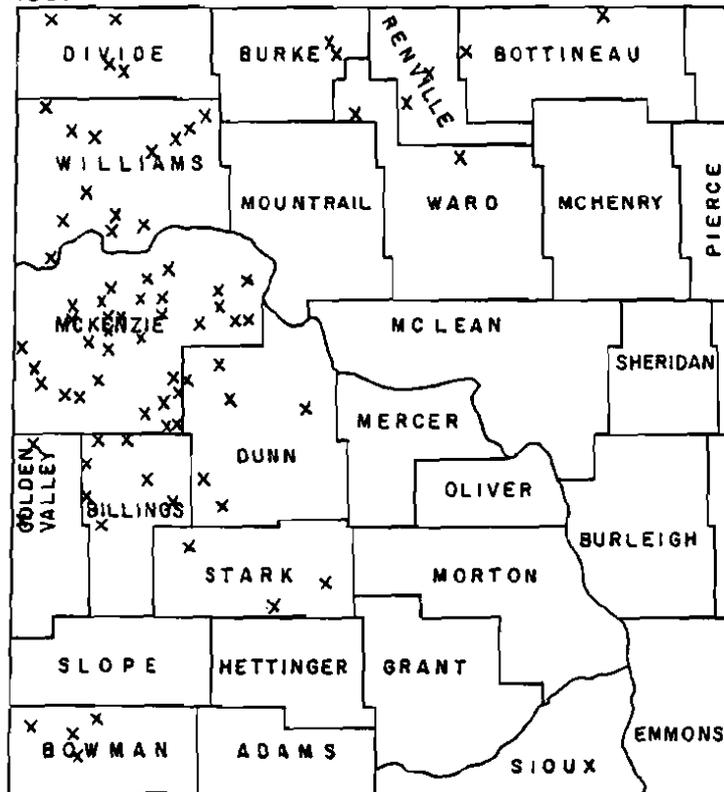


Figure 7. New field discoveries in North Dakota in 1980 (upper map) and in 1981 (lower map). Existing oil fields at the time are not included on the remaining discovery maps to minimize clutter.

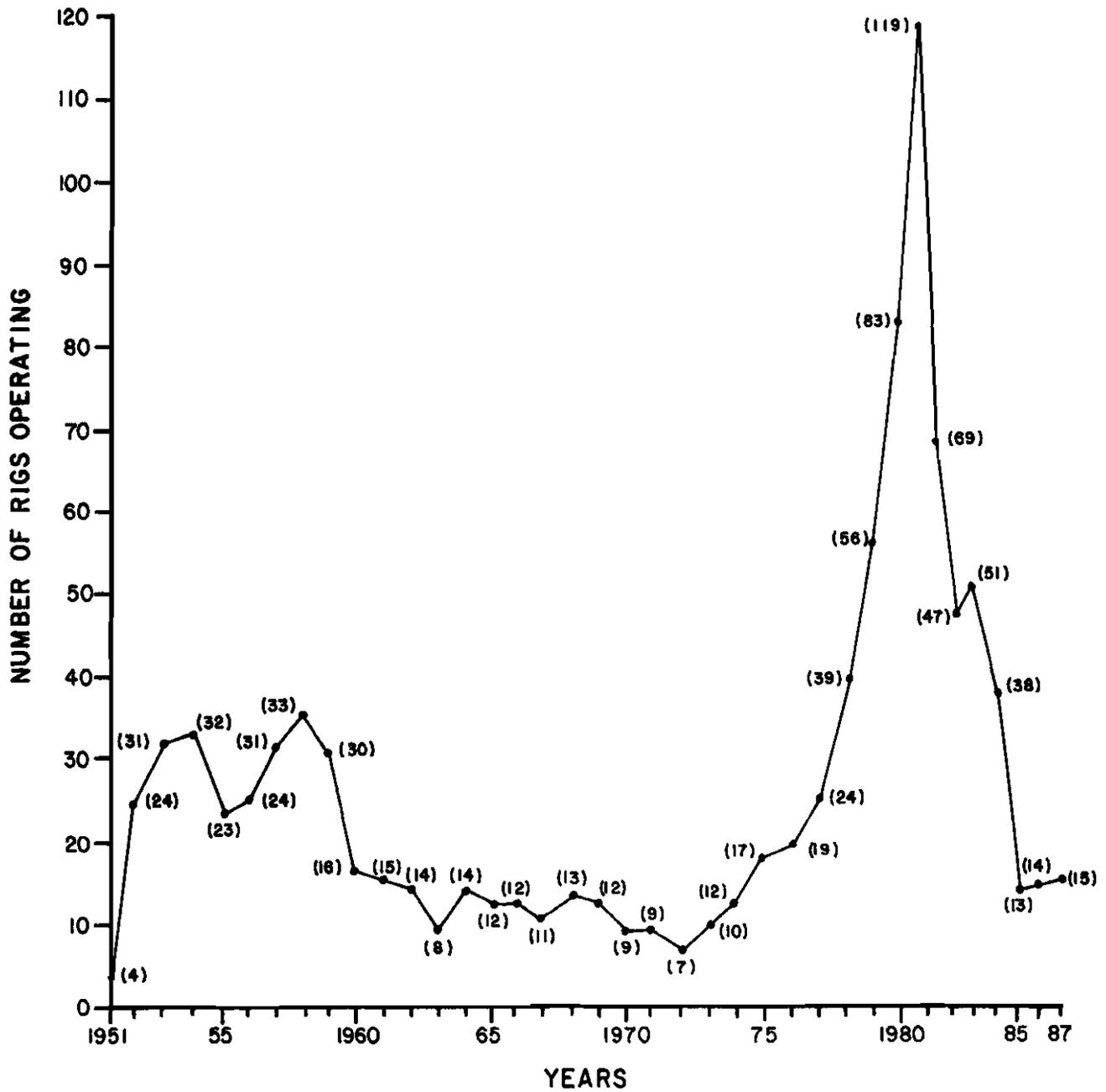


Figure 8. Average number of drilling rigs operating in North Dakota each year since 1950 (sum of the weekly averages divided by 52).

in existing fields, and wildcat drilling has been confined primarily to extending producing trends.

In 1983, as exploration continued to slow in North Dakota in response to lower and unstable oil prices, a shift in drilling strategy also occurred. Rather than drilling to Red River, many operators opted to drill only to Mississippian. The obvious effect was not only a marked decrease in the number of new reserves from the Red River, but also from the "multiple pay" Pre-Mississippian Paleozoic section.

The discovery of significant Sherwood reserves in Renville County in 1983 sparked a resurgence of interest in this horizon in the northeast portion of the basin as exploration for the Bluell waned. Winnipegosis discoveries in Temple Field (Williams County) in 1982 and in Moraine Field (Divide County) in 1983 were also important (fig. 9). Although neither field produces from the much sought-after "pinnacle reef facies" of earlier Winnipegosis drilling programs, these discoveries pointed to the possibility of the formation becoming an increasingly sought-after target.

Three Devonian-Duperow fields were discovered in Divide County in 1984 (fig. 10). Although the Duperow production in Divide County is of relatively low volume, it is interesting because of its unique trapping mechanism. Other 1984 discoveries in Divide County were in the Gunton and Red River.

Significant Madison production was also established by Atlantic Richfield Oil Corporation in East Fork Field, Williams County, from an apparently fracture-enhanced Rival reservoir. The discovery created a flurry of activity in the area that still continues.

Development drilling in Billings/Golden Valley County's Knutson Field

was in full swing by 1985, proving significant reserves.

1986-1987

INTRODUCTION

Although drilling activity slowed dramatically during 1986 and 1987, two Devonian discoveries in 1986, one in Saskatchewan the other in Divide County, set in motion a flurry of land and seismic acquisition programs in North Dakota's portion of the deep basin of the Devonian Elk Point Basin.

In early 1986 Home Petroleum successfully completed a well in the pinnacle reef facies of the Devonian Winnipegosis Formation in Saskatchewan, less than 15 miles from the North Dakota border. The Tablelands 8-22-2N-9W2 was reported flowing 750 BOPD from perforations at approximately 8,500 feet in depth, though the well was capable of higher rates of production. In May, 1988, Western Oil World reported 9 successful completions in the pinnacle reef play in Saskatchewan in 31 attempts. Since the Saskatchewan discovery there have been four wells drilled in North Dakota to test for reef production, with no reported successes. In fact, at least three have missed the reef facies entirely.

Although all pinnacle reef tests in North Dakota to date have been dry, a rumored reef test discovered significant reserves in another Devonian formation. In November, 1986, Raymond Duncan completed the #1 Bakken (NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec 32, T161N, R95W, Divide County) the discovery well for Dolphin Field (fig. 11), flowing 1,559 BOPD; 2.0 MMCF; 11.7 BOPD from a perforated interval at 10,002 to 10,008 feet in the Devonian Dawson Bay Formation. By July,

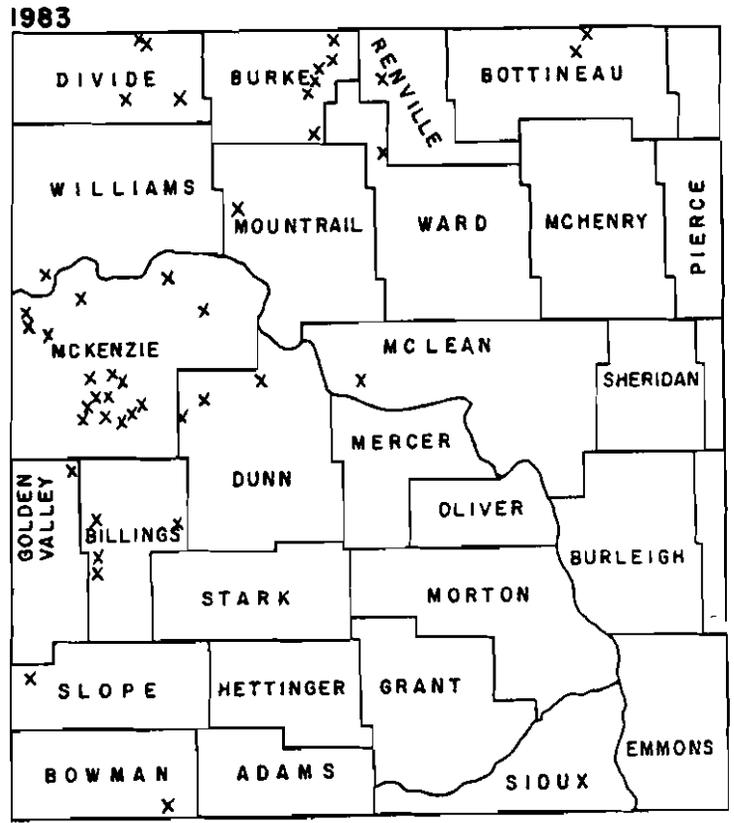
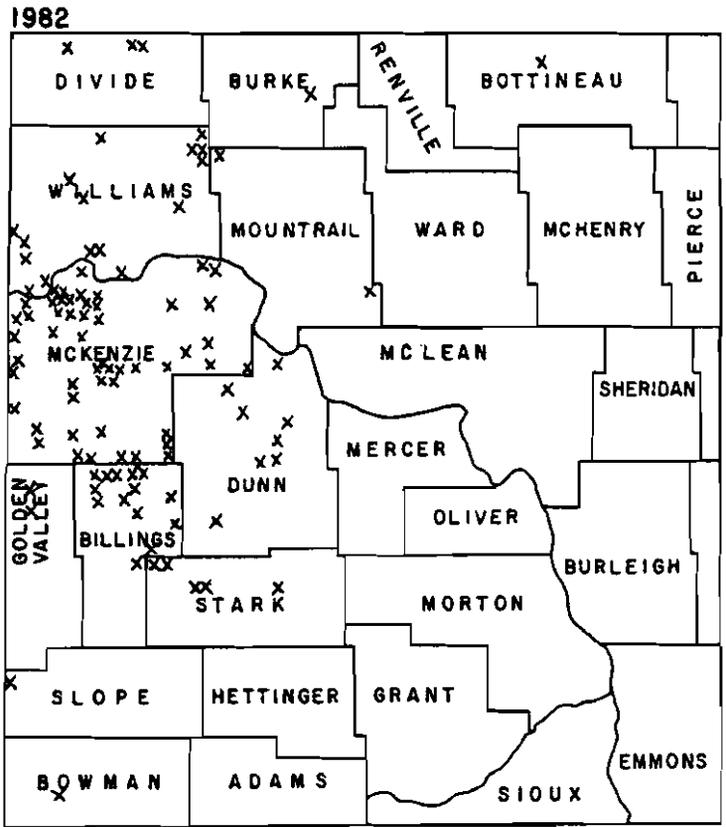
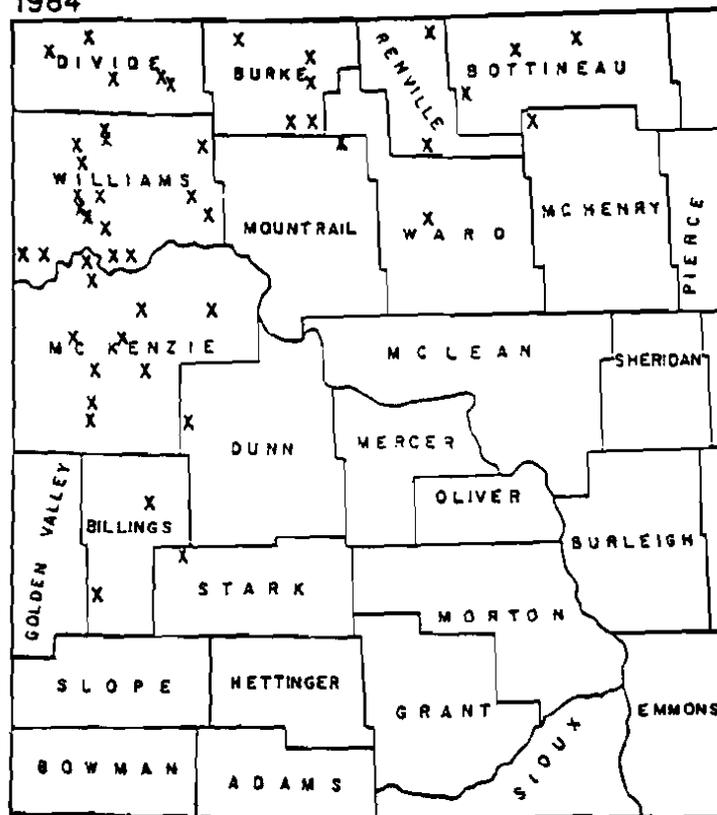


Figure 9. New field discoveries in 1982 (upper map) and 1983 (lower map).

1984



1985

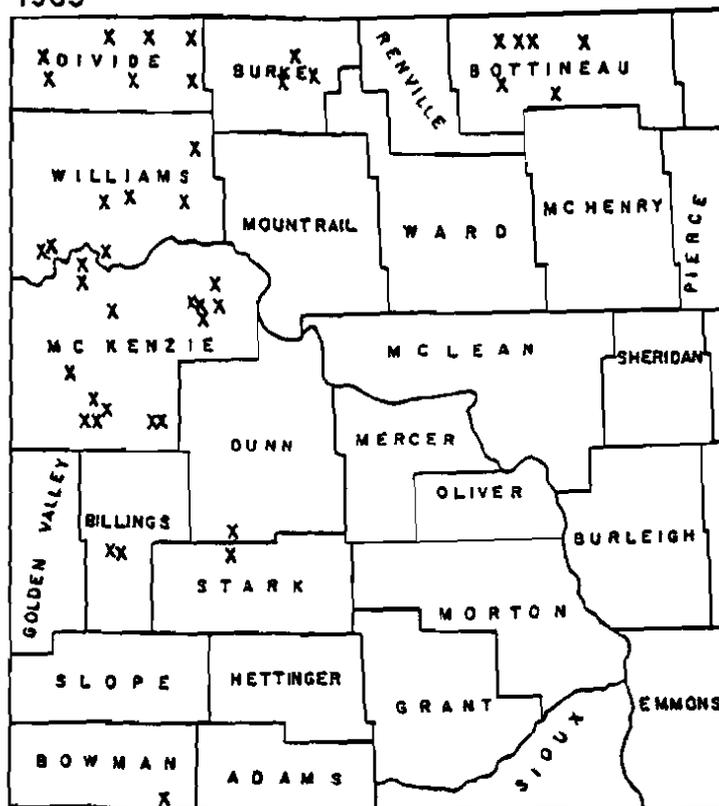


Figure 10. New field discoveries in 1984 (upper map) and 1985 (lower map).

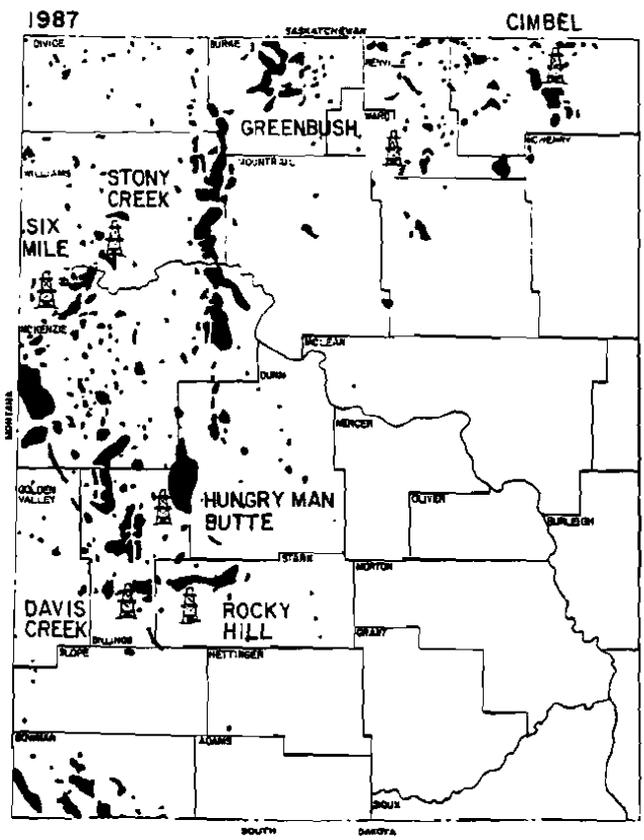
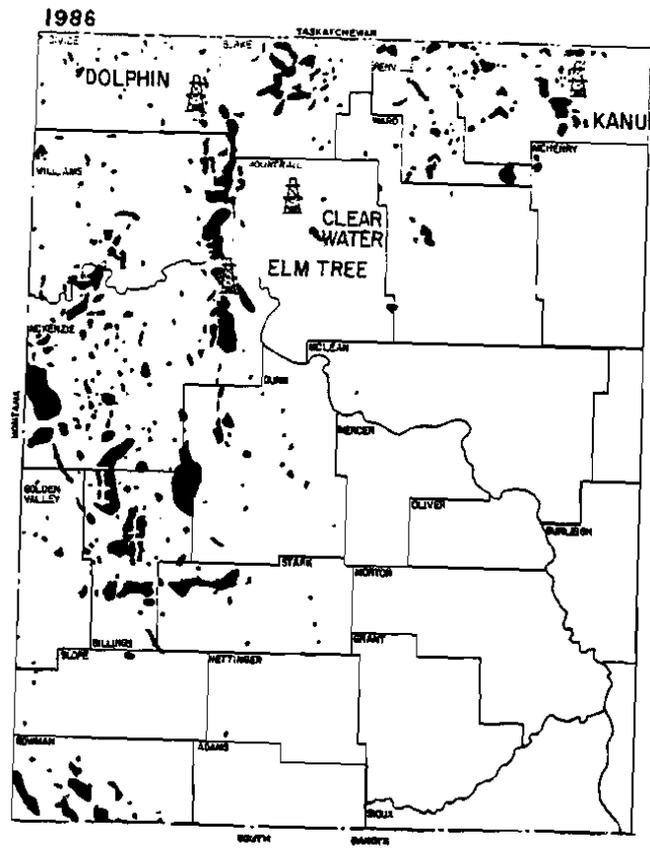


Figure 11. New field discoveries in 1986 (upper map) and 1987 (lower map).

1987, four wells were producing from the Dawson Bay in Dolphin Field, at an average daily well rate of approximately 500 BOPD. Reservoir pressures were rapidly falling--already approaching bubble point--when in September, 1987, because of the precipitous pressure decline, production was restricted to 200 BOPD per well at the request of the field operator and working-interest partners. In December, the field was shut in pending unitization. Devonian Souris River production was also established in Dolphin Field with the completion of the Rivers #1, in March, 1987, flowing 182 BOPD. Prior to the completion of the Rivers well, there were no wells with Souris River production in North Dakota, though at least one well (Gulf, #1-16-4B Gobbs: 16-T30N-R52E) produces from the Souris River in Montana.

Table 1 lists the discoveries in each county in North Dakota, by producing horizon in 1986 and 1987.

1986

A total of 224 wells¹ were drilled in North Dakota in 1986 (fig. 12), a decrease of 284 wells from 1985. This is greater than a 50 percent decrease from 1985. Successful completions were 107 for a 48 percent success rate. This compares to an overall success rate of 52 percent in 1985. Of the total wells drilled in 1986, 54 were listed by the Oil and Gas Division as wildcats² (fig. 13). A total of 20 new oil pools were discovered in

1986 (app. 1; fig. 14). A total of 1,879,659 feet were drilled in 1986, down 2,716,938 feet from 1985. Oil production in 1986 was 45,604,775 barrels, down more than 5 million barrels from 1985 (fig. 15).

Development drilling and deeper pool discoveries highlighted McKenzie County activity in 1986 as it has throughout the 1980s. Of the 13 new pools discovered there during 1986, 7 were Devonian in age, including 4 Birdbear (Nisku) discoveries. Birdbear production was established in Snowcover, Haydraw, North Branch, and Indian Hills Fields.

Sinclair Oil discovered a Devonian Duperow pool in Rough Rider Field with the completion of the Federal #6-18 (NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec 18, T145N, R100W). The Federal #6-18 was dually completed, flowing 865 BOPD from the Duperow and Red River, with 668 barrels attributed to the Duperow. In December, 1985, 1,561 BOPD were produced during testing. By year's end, two additional Duperow wells were producing in the field. Rough Rider Duperow production for December, 1986, totaled well over 20,000 barrels of oil, while producing less than 1,000 barrels of water. In addition to the Devonian tests, there were four additional infill wells completed as Madison producers in Rough Rider Field during the year.

Meridian Oil continued to develop Pierre Creek Field (Tps146-147N, Rs102-103W), successfully completing an additional four wells, and Texas Eastern Skyline completing another.

¹Figures were compiled by the Oil and Gas Division of the North Dakota State Industrial Commission.

²The Oil and Gas Division of the North Dakota State Industrial Commission defines a wildcat as any well 1 mile from a field boundary, a development well as any well within a field boundary (regardless of the depth penetrated), and an extension as any well within 1 mile of a field boundary.

TABLE 1.--North Dakota Oil and Gas Discoveries in 1986 and 1987,
Listed by County and Geologic Horizon.

	1986	1987		1986	1987
Billings County Total	3	2	McKenzie County Total	13	1
Madison	2	2	Madison	1	0
Bakken	1	0	Bakken	1	0
Bottineau County Total	1	1	Birdbear	4	0
Madison	1	1	Duperow	3	0
Burke County Total	0	2	Silurian	2	1
Bakken	0	1	Red River	2	0
Red River	0	1	Mountrail County Total	1	0
Divide County Total	1	1	Madison	1	0
Souris River	0	1	Stark County Total	0	1
Dawson Bay	1	0	Madison	0	1
Golden Valley County			Ward County Total	0	1
Total	0	1	Madison	0	1
Birdbear	0	1	Williams County Total	1	5
			Madison	0	3
			Stonewall	0	1
			Red River	1	1

Pierre Creek Field, typical of most central McKenzie County fields, has multiple pay, with production from the Red River, Birdbear, Bakken, and Madison. In December, 1986, Pierre Creek produced over 20,000 BOPD from eight wells. Flying J Exploration reported the successful completion of a deeper pool test in Bear Den Field. The Bear Den #4 was completed flowing 1,476 barrels of oil, 14 barrels of water, and over 9 million cubic feet of gas from the Red River. The well was the first Red River penetration in the field.

Significant infill/development drilling programs were carried out in two other McKenzie County fields: Indian Hills (Tps152-153N, Rs101-102W) and Charlson. An additional seven wells were successfully drilled in Indian Hills Field and eight more wells were completed as producers in Charlson Field (Tps153-154N, R95W). Of the Charlson Field wells, seven were completed in the Interlake.

Initial production rates for the Interlake are typically in excess of 1,000 BOPD. Of the nearly 2.4 million barrels produced in the Charlson during 1986, 75 percent is from the Interlake.

A single new field discovery was posted for McKenzie County in 1986 (fig. 11). Cox Oil and Gas discovered a Bakken pool in section 18 of T153N, R94W--Elm Tree Field. The Froholm #1-18 was completed in March, flowing 364 BOPD from perforations between 10,580 feet and 10,600 feet. By year's end the well had produced less than 6,000 barrels of oil and had not been offset.

Development drilling in East Fork Field, Williams County, continued at a rapid rate. Of the 25 development wells drilled in the county, 10 were located in East Fork. By year's end, 33 producing wells were located in East Fork Field. In 1986, East Fork produced more than 600,000 barrels of oil. A Red River pool was discov-

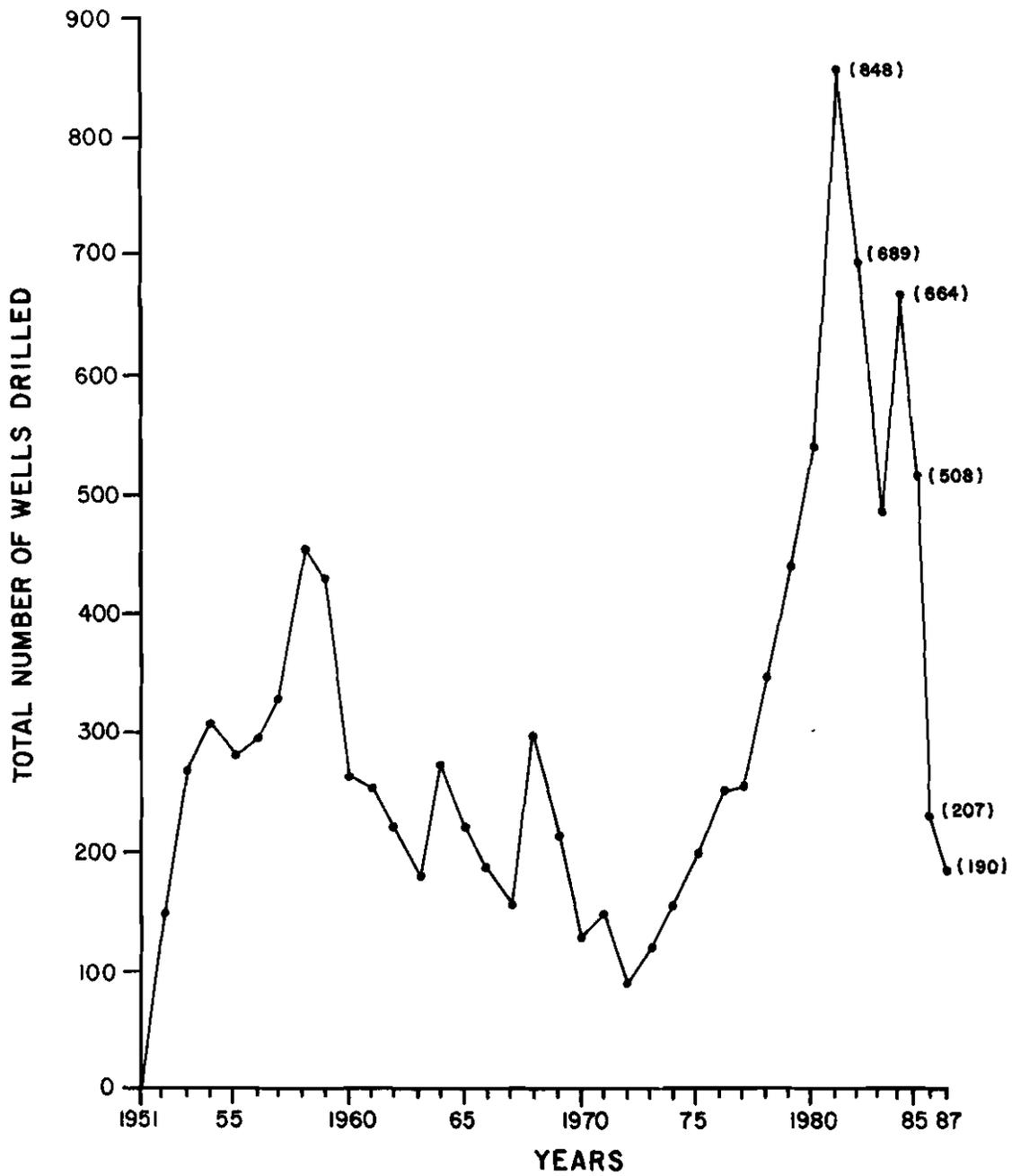


Figure 12. Graph showing the number of wells drilled in North Dakota each year since oil was discovered in 1951. The total for each year includes both exploratory and development wells.

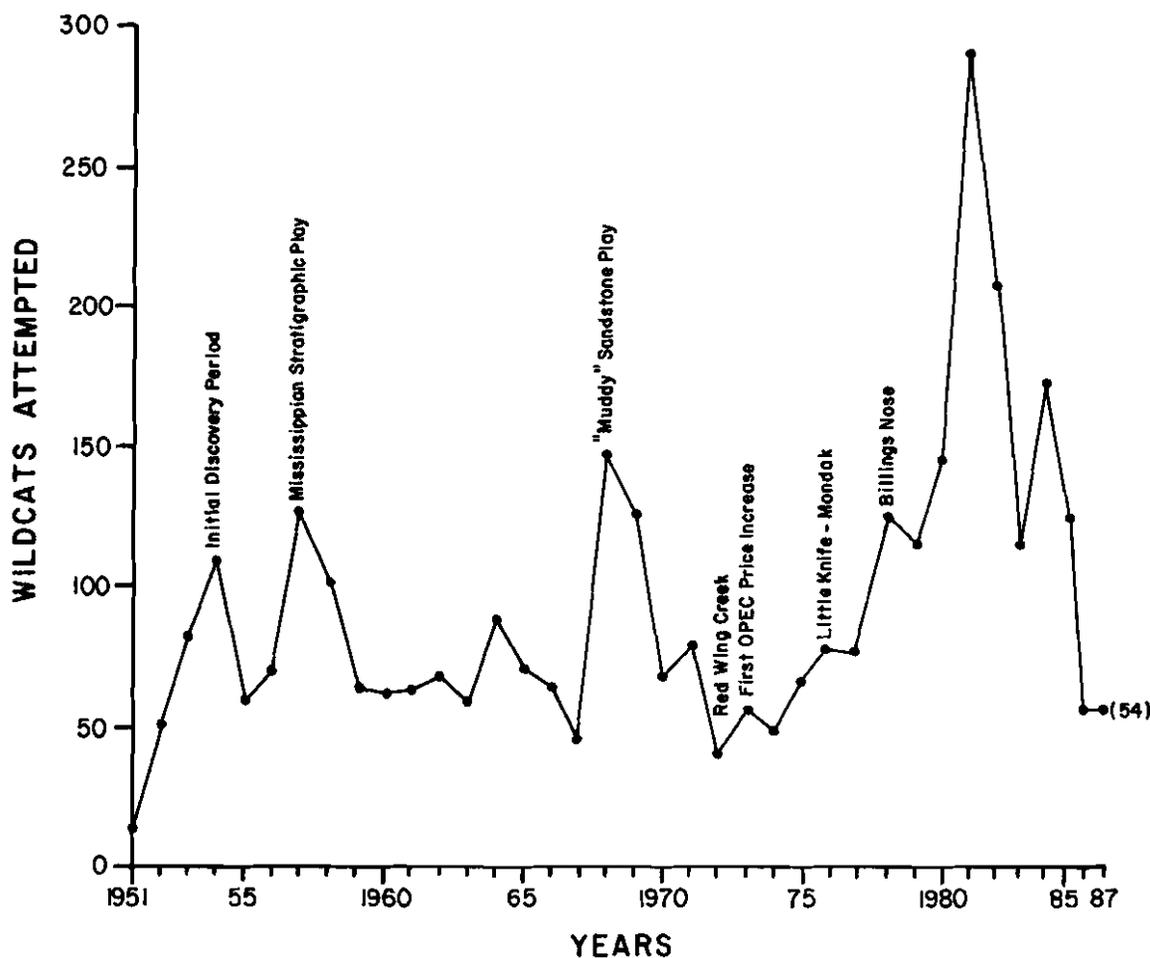


Figure 13. Graph showing the number of wildcat wells drilled in North Dakota each year since oil was discovered in 1951. Some of the major events affecting drilling activity are noted on the graph.

ered in Buford Field by Columbia Gas. The Zimmerman #10-1 was completed flowing 664 BO, 417 mcf, and 9 BWPD from perforations at approximately 13,000 feet. In its first 11 months, the Zimmerman well produced nearly 100,000 barrels of oil.

In Bonetrail Field, Ladd Petroleum successfully completed an Ordovician test, the Fjerstad #14-11, flowing 1,170 barrels of oil. The Fjerstad was the first development well drilled in Bonetrail since its discovery in 1979.

In the northeast producing portion of the basin, Petro Lewis successfully

completed four additional wells in Smith Field (T160N, R86W), Renville County. In January, the Petro Lewis Peterson #2-28 was completed flowing 641 BOPD with no water from Sherwood perforations, with additional Bluell "pay" indicated behind pipe. In December, Smith Field produced approximately 25,000 barrels of oil from five wells. In Sherwood Field, Chandler successfully completed two wells in the continued trend of "downspacing" in this field; both were completed for 100 barrels of oil or better. To date, five "down-

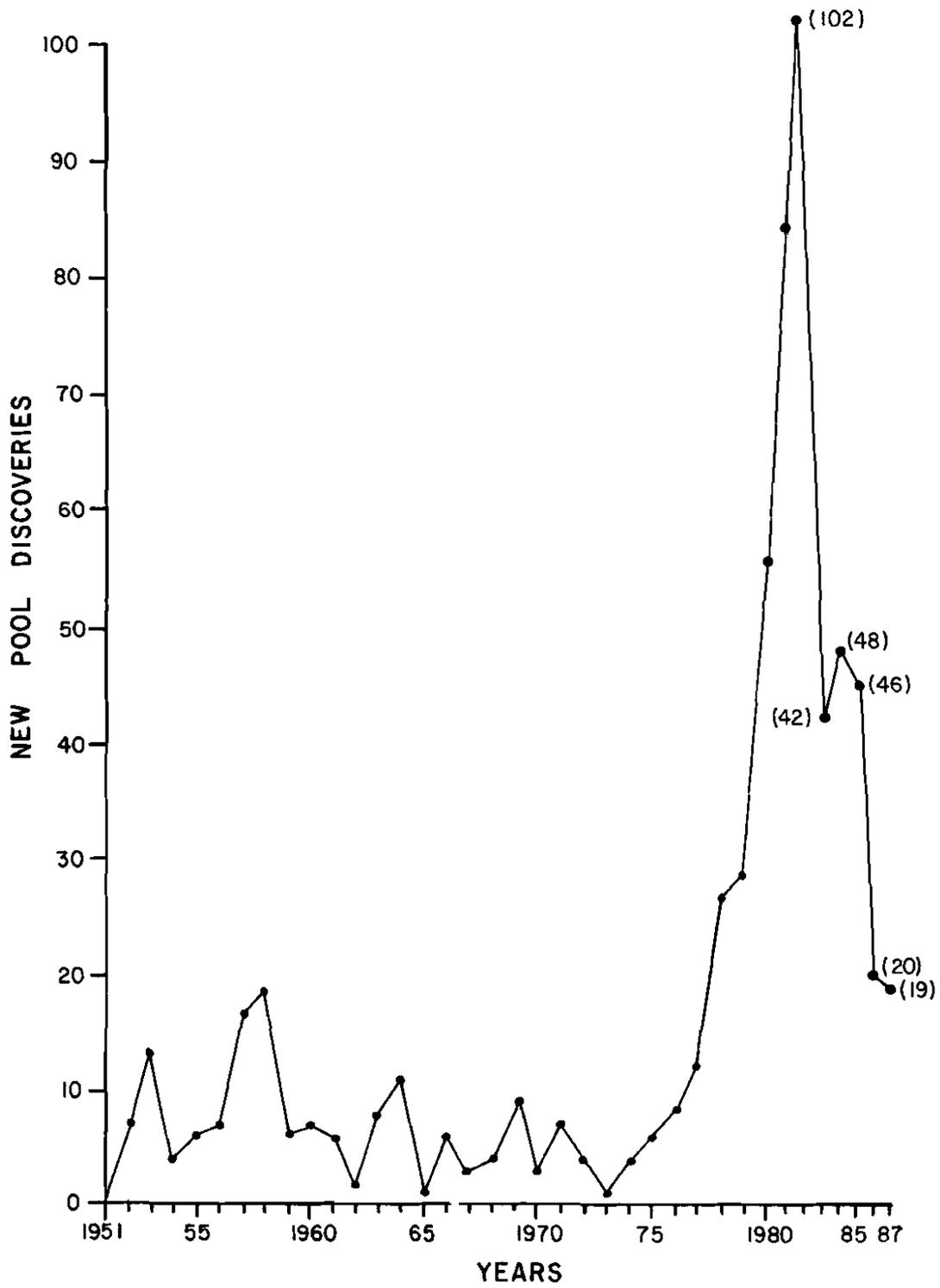


Figure 14. Graph showing the number of new oil pools discovered each year in North Dakota.

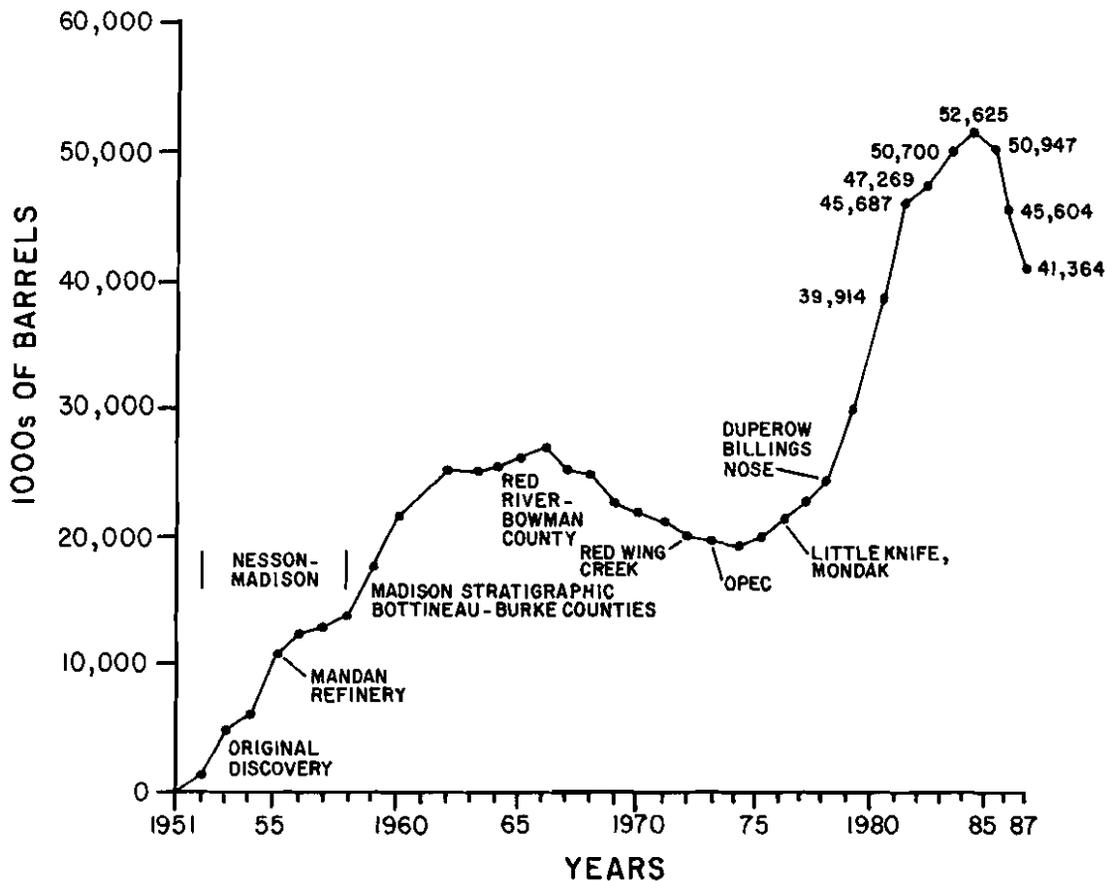


Figure 15. Annual crude oil production in North Dakota. Figures (since 1980) are given in thousands of barrels; thus, production in 1984 was 52,625,000 barrels of oil. Major events affecting oil production history are noted on the graph.

spaced" wells have been drilled in the field, which already had 36 producers. Of the 394,619 barrels of oil produced in Sherwood Field during 1986, 141,782 barrels, or more than 33 percent of the production was from the "downspaced" locations.

Wildcat exploration in the northeast producing portion of the basin was disappointing. Of the 19 wildcats drilled in 1986 in Bottineau, Burke, and Renville Counties, only one was successful. Citation Oil and Gas discovered a Midale pool in central Bottineau County. The Christenson #1-12 (12-161-79) was completed, pumping 85 barrels of oil per day. At press, the discovery well for Kanu Field had yet to be offset. In Mountrail County, A&M Oil re-entered

and successfully completed a well that had been abandoned in 1984. The #1 Hill was completed in the Bluell, pumping 20 BOPD and 5 BWPD. There has been no further development in Clearwater Field to date.

1987

A total of 185 wells were drilled in North Dakota during 1987, 39 less than in 1986 (fig. 12), for a 17.5 percent decrease in drilling activity. The overall successful completion rate of 55 percent, or 107 wells, compares favorably to the 48 percent success rate of 1986 (fig. 13). Nineteen new oil pools were discovered in North Dakota during 1987 (fig. 14). A total

of 1,685,793 feet of hole was drilled, nearly 200,000 feet less than in 1986. North Dakota's production continued to drop in 1987, falling to 41,364,295 barrels (fig. 15).

No new fields were discovered in McKenzie County during 1987. Of the 30 wells completed there, 24 were listed as capable of production, with 3 wells credited as new pool discoveries within existing fields. Only two wildcats were drilled. ANR Production discovered a Duperow pool at Cartwright Field (T150N, R104W). The Iszley-USA #1 was completed for 112 BOPD from perforations between 10,871 and 11,024 feet. In Hay Draw Field (Tps146-147N, R102W), Meridian Oil discovered a Duperow pool in August with the completion of the Hay Draw #22-33 well. The Hay Draw #22-33 is also credited as the field's Stonewall discovery well. Completed for 190 BOPD in February, the Stonewall was on line for only 5 months, producing less than 10,000 barrels of oil. Raymond Duncan extended Sanish pool production in Antelope Field (Tps152-153N, Rs94-95W) nearly one mile to the southeast with the completion of the Rose #1, flowing 167 barrels of oil, 169 MCF, and 7 BOPD from perforations at approximately 10,600 feet.

Meridian Oil successfully completed a horizontally drilled Bakken test in Billings County during 1987. The MOI-Elkhorn #33-11 was completed flowing 259 barrels of oil, and 299 MCFPD with no water from over 1,000 feet of open hole. Elsewhere in Billings County, significant extensions of older producing features were completed during the year. Jerry Chambers Exploration extended Fryburg Field to the southwest with the completion of the Tracy Mountain #7-19. By year's end, Chambers had successfully completed four Tyler and Madison wells along a two-mile trend with Amerada Hess completing another. Immediately south of the

Fryburg Field, Amerada Hess completed as a producer, a wildcat in the Mississippian, and opened Davis Creek Field (T138N, R100W). The well was completed for 77 BOPD from perforations between 9,097 and 9,103 feet. Union Oil Company also discovered a new field in Billings County, Hungry Man Butte (T143N, R98W), when the Machnicki #1-J32 was completed for 83 BOPD in the Mississippian-Fryburg Interval (fig. 11).

In Stark County, Chambers had another Mississippian wildcat success. The discovery well for Rocky Hill Field (T138N, R99W), the Sun #10-7 was completed for 32 BOPD. Primary reserves are estimated to be 109,000 barrels of oil for the well.

Sun Exploration discovered a field in Williams County with the completion of the Seel Federal #1 (T153N, R103W). The discovery well for Six Mile Creek Field was completed for 660 barrels of oil, 581 MCF and no water from Red River perforations. The field was temporarily spaced on 160 acres. TXP Operating discovered what may be a significant new Mississippian Rival Interval field near year's end. The TXPOC-State #23-26, opening Stony Creek Field (T155N, R100W), was completed for 347 BOPD with no water at an approximate depth of 9,450 feet. At press, 15 wells were permitted within the field boundary, with most still officially carried as "tight holes."

Ladd Petroleum successfully twinned their recent Red River well in Bonetrail Field (T156N, R102W) completing it in the Silurian Stonewall Formation. The Fjerstad #14-11A flowed 526 BOPD, 500 MCFPD, and no water from perforations at approximately 12,650 feet.

Depco extended East Fork Field (T156N, Rs99-100W) production approximately two miles to the east with the completion of the Bakken #42-33 (sec 33, T156N, R99W).

Completion rate for the well was 313 BOPD and 0 BWPD. In December, East Fork produced 61,733 barrels of oil from 33 wells with water production of less than 4,100 barrels.

Home Petroleum successfully completed three offset wells in Wabek Field (T152N, R88W). The Rovig-Ness #31-11, the first well drilled in Wabek in two years, was completed flowing 314 BOPD, 300 MCF, and no water from the Madison Sherwood subinterval. Of the two additional Wabek wells drilled by Home, one was completed for 308 BOPD, the other for 382 BOPD. Numerous offsets have been staked. In this sparsely drilled portion of the basin, Home's Wabek program has caused many in industry to re-evaluate a portion of the basin once thought to be marginal.

Exploratory activity in North Dakota's northeast producing portion of the basin resulted in two new field discoveries in 1987.

In Ward County, Wesseley Exploration discovered Greenbush Field (T159N, R87W) when they completed the Johnson #4-24 well flowing 354 BOPD, 35 MCF, and 19 BWPD from the Sherwood subinterval. Wesseley successfully offset the discovery well in the Sherwood and Ritter, Laber, and Associates extending production approximately a mile and a half to the northwest with the successful completion of the Fargo #31-15. This well is reported to be a Mohall completion.

In Bottineau County, CNG Producing discovered Cimbel Field (T163N, R78W) with the completion of their Brandjord #1-20. Completion was in the Wayne subinterval with initial production of 160 BOPD and 17 BWPD. Elsewhere, Wacker Oil continued development in nearby Haram Field (T163N, R77W), successfully completing two additional wells. Production in Haram Field is from the Tilston (at an approximate depth of 3,200 feet). December, 1987, production from five wells in Haram Field

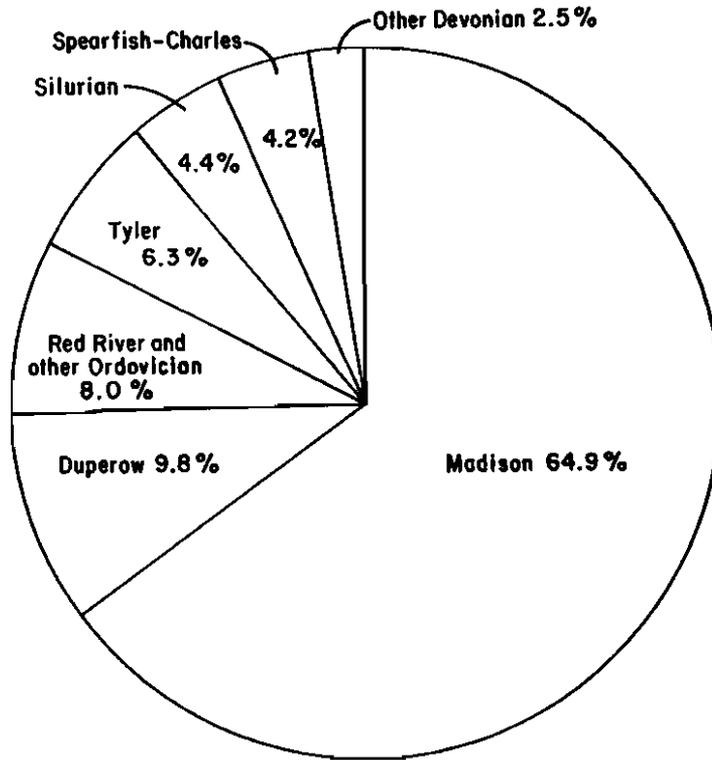
totaled 18,581 barrels of oil and 169,406 barrels of water. The large volume of fluid is handled with large (up to 85 hp) downhole pumps. Projected primary oil recovery is 72,500 barrels of oil per 40-acre location.

ADDITIONAL COMMENTS

As a point of general interest, we have included a graph (fig. 16) indicating the geologic distribution of oil production in North Dakota. Figure 16 breaks down the total cumulative oil production from each producing horizon. Thus, the Madison Group has accounted for 65 percent of the state's total oil production. This amounts to about 604 million barrels of oil; a total of about 930 million barrels of oil have been produced in North Dakota since 1951.

In 1982, as the price of oil began to drop in response to a considerable oversupply of crude, worldwide exploratory activity, including North Dakota, declined. Since 1985, the price of oil not only continued to decline, but became quite unstable, with rapid price fluctuations. All levels of activity in North Dakota were profoundly affected. As the number of drilling rigs continued to decline (fig. 8), confidence in the future of the industry in North Dakota also seemed to slip. Income to the state from the sale of state oil and gas leases dropped from a maximum of \$69 million in 1980, to \$5.6 million in 1985, and only \$1.3 million during the first three sales in 1986 (four sales are held each year) (fig. 17). Annual production dropped from a maximum of 52.6 million barrels of oil in 1984 to 50.9 million barrels in 1985 and is projected to be about 46 million barrels in 1986 (fig. 14).

Finally, tax revenues raised as a result of oil production in North Dakota are very significant to the state in recent years (figs. 17, 18,



**NORTH DAKOTA OIL PRODUCTION BY FORMATION
(Sorted Stratigraphically)**

<u>FORMATION</u>	<u>BARRELS OIL PRODUCED</u>	<u>PERCENT</u>
SPEARFISH	615,372	.0662
SPEARFISH/MADISON	38,534,347	1.1453
TYLER (HEATH)	58,348,040	6.2768
MADISON	604,052,853	64.9816
LOGEPOLE	3,797	.0004
BAKKEN	16,997,550	1.8286
BIRDBEAR (NISKU)	1,329,896	.1431
DUPEROW	90,677,451	9.7547
SOURIS RIVER	11,881	.0013
DANSON BAY	812,091	.0874
WINNIPEGOSIS	3,669,879	.3948
SILURIAN	40,468,853	4.3535
STONEMALL	1,159,018	.1247
GUNTON	98,969	.0106
RED RIVER	72,638,025	7.8141
WINNIPEG	75,707	.0081
WINNIPEG/DEADWOOD	81,950	.0088
TOTAL	929,575,679	100.00%

Figure 16. Geologic distribution of oil production in North Dakota, indicating percentage of total production from each horizon.

and 19). Tax revenues collected from oil and gas production during the 1983-85 biennium decreased from those of the previous biennium (table 2). During the 1983-85 biennium, \$327.4 million was collected, a decrease of \$8.2 million from 1981-83. The tax revenues from oil and gas production represented 28 percent of the state's total tax income during the 1984 fiscal year; and dropped to 24 percent of the total during the 1985 fiscal year (table 2). (Tax figures were supplied by the Office of the State Tax Commissioner.)

Appendices 1 and 2 include com-

plete listings of all of the discovery wells drilled in North Dakota during 1984 (app. 1) and in 1985 (app. 2). These appendices also include information on discovery date, permit and order number, the number of wells currently producing in the new fields, spacing, interval perforated and initial production in each discovery well, gravity, gas-oil ratio, and water production. We have also included a map of western North Dakota showing the approximate current extent of all the known oil pools (fig. 20).

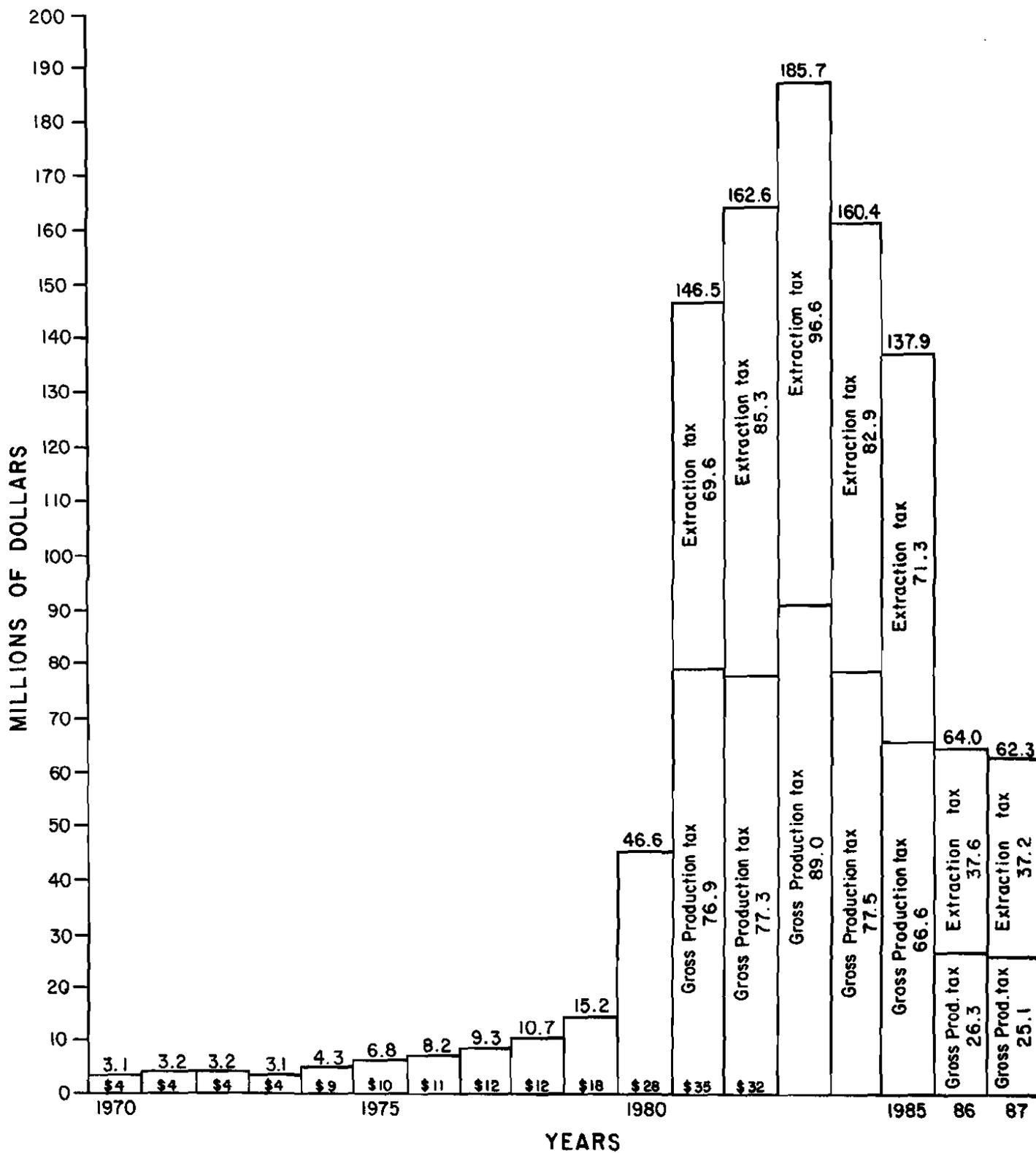


Figure 17. Graph showing the dramatic increase in oil and gas tax revenue to the State of North Dakota resulting from increased production, increased prices, and implementation of the extraction tax. Figures are in millions of dollars; thus, oil and gas tax revenue in calendar year 1983 totaled \$185,700,000. Refer also to table 2.

BONUS TOTAL

70,000,000—

60,000,000—

50,000,000—

40,000,000—

30,000,000—

20,000,000—

10,000,000—

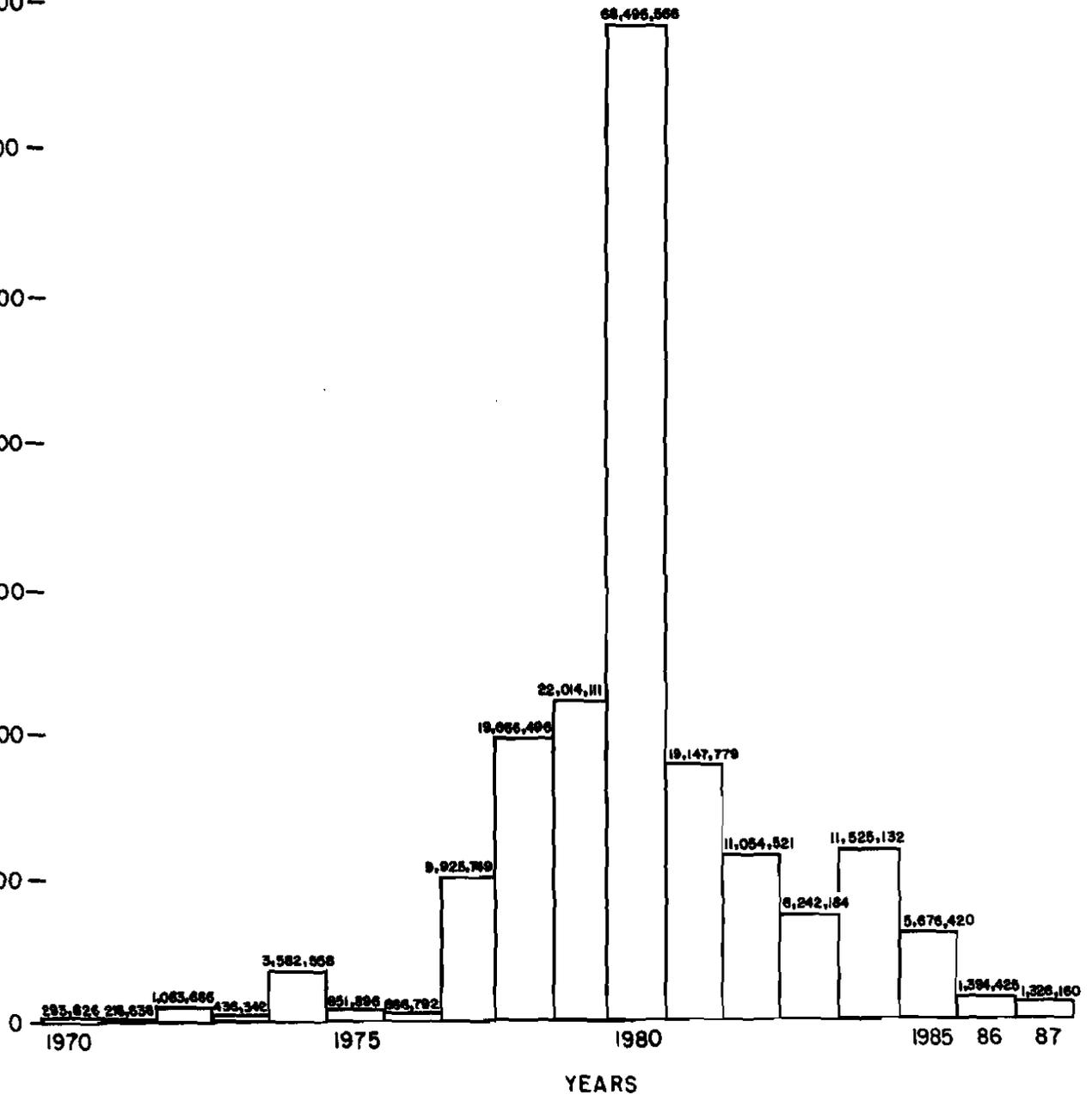


Figure 18. Income to the State of North Dakota from the sale (public auction) of oil and gas leases for state-owned lands. The leases are commonly for a 5-year term, with a 1/6 royalty rate and an annual rental of \$1.00 per mineral acre. Bidding is on the bonus, which is for a minimum of \$1.00 per mineral acre.

Table 2.--Percentage of Tax Income to State of North Dakota from Various Sources (figures given as percent of total revenues).

Tax	1980	1981	1982	1983	1984	1985	1986	1987
Oil and Gas*	9	22	35	35	28	24	16	14
Sales	33	29	26	27	29	26	40	43
Income	26	25	17	16	20	27	30	29
Motor Vehicle	14	10	10	7	11	11	6	7
Coal Severance	4	4	4	4	5	6	4	4
Cigarette	3	2	2	2	2	2	2	3
Other	12	8	6	9	5	4	2	1

* Oil and gas taxes equal the sum of the revenues from the gross production tax and the oil extraction tax.

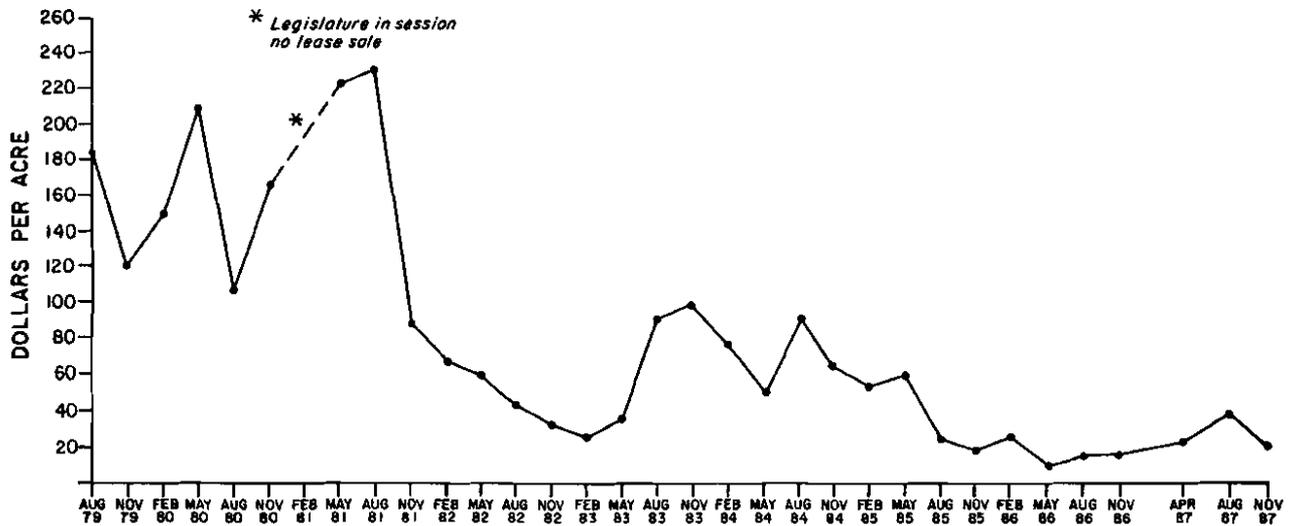


Figure 19. Average price per acre paid in oil and gas lease sales (see fig. 16 also). Lower per-acre prices reflect large offerings in eastern North Dakota away from known producing areas. Highest prices are for lands with good potential.

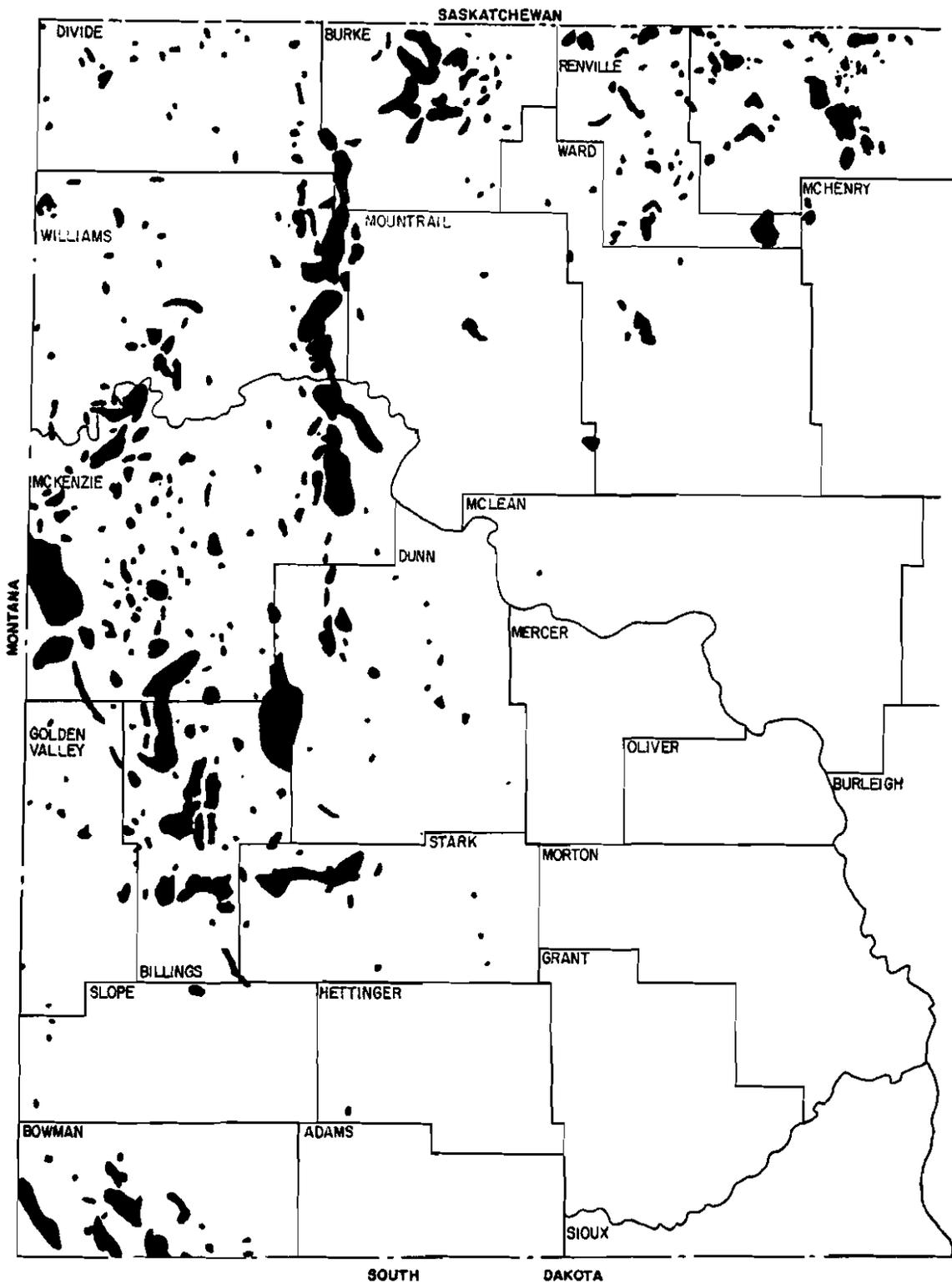


Figure 20. Map of western North Dakota showing approximate extent of all known oil pools as of December 31, 1987.

APPENDIX 1--Oil and Gas Discovery Wells
In North Dakota During 1986.

COUNTY FILE NO. ORDER NO.	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (NUMBER OF WELLS CURRENTLY IN POOL)	SPACING	TOTAL DEPTH	INTERVAL PERFORATED	INIT. PROD. (CURRENT DAILY PROD. -BLS. OIL)	GRAV.	GOR	WATER
BILLINGS 7466 4280	01JAN86	MOSBACHER-PRUET OIL CO. VOLESKY #34-1 SNNW SEC. 34-141- 98	UKRAINA -HPFB (1)	40	12900	9472- 9488	24 (SI)	36.0	500.00	170.00 B
BILLINGS 11527 4271	02JAN86	CANTERRA PETROLEUM, INC. STATE 2-16 MNE SEC. 16-141-102	CHATEAU -HM (2)	160	10890	9196- 9216	24 (SI)	.0	800.00	35.00 B
BILLINGS 11467 4515	05FEB86	LADD PETROLEUM CORPORATION NORTHROP 1 MNNW SEC. 7-144-100	ICE CAVES -HBK (1)	160	11460	10733-10834	30 (8)	44.6	1667.00	.00 X
BOTTINEAU 11914 4448	27FEB86	CITATION OIL & GAS CORP. CHRISTENSON 1-12 SESE SEC. 12-161- 79	KANU -HM (1)	80	3365	3246- 3256	85 (14)	30.0	200.00	9.00 B
DIVIDE 12017 4826	10NOV86	RAYMOND T. DUNCAN BAKKEN 1 NENW SEC. 32-161- 95	DOLPHIN -DOB (6)	Unit	10650	10002-10008	1559 (SI pending unit)	42.0	1300.00	12.00 B
MC KENZIE 8322 4756	21SEP86	HNG OIL COMPANY LINK #34-1 SNSE SEC. 34-151-102	NAMELESS -DB (1)	320	13700	11464-11475	486 (71)	40.6	947.00	.00 X
MC KENZIE 10463 4796	25NOV86	LADD PETROLEUM CORPORATION THORSON #24-32 SNNE SEC. 24-151-104	ASSINIBOINE -HNS (3)	160	13300	9320- 9342	283 (47)	37.4	600.00	202.00 B
MC KENZIE 10910 4811	02DEC86	COLUMBIA GAS DEVELOPMENT CORP. DEER PASS 20-2 SESW SEC. 20-153-101	INDIAN HILL -DB (3)	160	12908	10432-10440	335 (39)	39.4	597.00	20.00 B

APPENDIX 1--(Continued)

COUNTY FILE NO. ORDER NO.	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (NUMBER OF WELLS CURRENTLY IN POOL)	SPACING	TOTAL DEPTH	INTERVAL PERFORATED	INIT. PROD. (CURRENT DAILY PROD. -BBLs. OIL)	GRAV.	GOR	WATER
MC KENZIE 11619 4274	11FEB86	SINCLAIR OIL CORPORATION FEDERAL 6-18 N4W SEC. 18-145-100	ROUGH RIDER -DD (6)	160	14266	11096-11258	668 (135)	41.6	1003.00	.00 X
MC KENZIE 11762 4845	18NOV86	EXXON COMPANY, USA STATE OF N.D. "E" 1 NENE SEC. 7-151-101	SIOUX -DD (1)	160	13660	11131-11197	350 (105)	38.9	905.70	149.00 B
MC KENZIE 11794 4524	07MAR86	TEXACO INC. EISENLOHR TRUST 1 N4SW SEC. 29-150- 96	PERSHING -SI	160	14214	13487-13524	82 PNA	43.5	1195.00	2.00 B
MC KENZIE 11832 4844	18DEC86	MERIDIAN OIL, INC. FEDERAL-CRIGHTON 31-24 N4NE SEC. 24-147-102	SNOWCOVER -DB (1)	160	13480	11050-11053	63 (50)	46.6	460.00	83.00 B
MC KENZIE 11847 4555	02MAR86	MERIDIAN OIL, INC. MOI 31-33 N4NE SEC. 33-147-102	HAY DRAW -DB (4)	160	13200	10882-10922	217 (82)	43.0	1070.00	20.00 B
MC KENZIE 11856 4310	24JAN86	JOHN L. COX MTS BOWLINE FEDERAL 34-1 S4SE SEC. 34-148-102	NORTH BRANCH -DB (1)	320	11450	11014-11054	137 (59)	44.0	930.00	.00 X
MC KENZIE 11874 4684 or 5041	23APR86	TEXACO INC. E. A. CHAPMAN "A" 1 S4SE SEC. 10-153- 96	SAND CREEK -SI	320	13488	12813-12823	0 TA	52.1	31132.00	17.00 B
MC KENZIE 11913 4552	20MAR86	FLYING J EXPLORATION & PRODUCTION CO. BEAR DEN UNIT 4 N4SE SEC. 25-149- 96	BEAR DEN -ORR (1)	320	14475	14188-14352	1476	56.3	6104.00	14.00 B

APPENDIX 1--(Continued)

COUNTY FILE NO. ORDER NO.	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (NUMBER OF WELLS CURRENTLY IN POOL)	SPACING	TOTAL DEPTH	INTERVAL PERFORATED	INIT. PROD. (CURRENT DAILY PROD. -BBL. OIL)	GRAV.	GOR	WATER
MC KENZIE 11918 4740	26MAR86	TENNECO OIL COMPANY KARST 1-5 NWNW SEC. 5-150-104	HARDING -ORR (1)	160	12800	12641-12665	789 (72)	48.5	830.00	41.00 B
MC KENZIE 11935 4777	29MAR86	EDWIN L. COX & BERRY R. COX FRIDHOLM 1-18 SWSE SEC. 18-153- 94	ELM TREE -MBK (1)	160	10760	10580-10600	364 (43)	44.3	1150.00	35.00 B
MOUNTRAIL 10550 4449	27JAN86	JN OIL & GAS JN-HILL #1 SESW SEC. 20-157- 90	CLEAR WATER -MWB (1)	80	7900	7732- 7746	27 (SI)	29.0	.00	7.00 B
WILLIAMS 11466 4773	14NOV86	COLUMBIA GAS DEVELOPMENT CORP. ZIMMERMAN 10-1 SESW SEC. 10-152-104	BUFORD -ORR (1)	320	13132	12906-12925	664 (247)	47.1	628.00	9.00 B

**APPENDIX 2--Oil and Gas Discovery Wells
In North Dakota During 1987.**

COUNTY FILE NO. ORDER NO.	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (NUMBER OF WELLS CURRENTLY IN POOL.)	SPACING	TOTAL DEPTH	INTERVAL PERFORATED	INIT. PROD. (CURRENT DAILY PROD. -BBLG. OIL)	GRAV.	GOR	WATER
BILLINGS 12117 5044	19AUG87	UNION OIL COMPANY OF CALIFORNIA MACHNICKI #1-J32 NWSE SEC. 32-143- 98	HUNGRY MAN BUTTE -MFB (1)	160	10180	9844- 9868	83 (29)	36.6	.00	187.00 B
BILLINGS 12134 5080	10SEP87	AMERADA HESS CORPORATION KOCB FEDERAL #7-21 NENW SEC. 7-138-100	DAVIS CREEK -MM (2)	160	9130	9097- 9103	77 (39)	36.6	143.80	41.00 B
BOTTINEAU 12280 5124	19DEC87	CNG PRODUCING CO. BRANDJORD #1-20 NWSE SEC. 20-163- 78	CIMBEL -MM (6)	40	3315	3164- 3176	160 (43)	34.8	.00	9.60 X
BURKE 12035 4917	03MAR87	TRUE OIL COMPANY PETERSON 1 NWSW SEC. 8-159- 94	NORTH TIOGA -MBK (2)	160	12600	9146- 9287	51 (18)	36.0	1433.00	10.00 B
BURKE 12062 5026	20JUL87	SUN EXPLORATION & PRODUCTION COMPANY STROMBECK 1 SWSW SEC. 31-160- 94	NORTH TIOGA -SI (3)	160	12560	11970-12408	368 (90)	35.5	240.00	28.00 B
DIVIDE 12085 4885	06APR87	RAYMOND T. DUNCAN RIVERS #1 SWNE SEC. 29-161- 95	DOLPHIN -DSR (1)	160	10810	9764- 9774	182 (17)	40.0	1098.00	16.00 B
GOLDEN VALLEY 12227 5089	10DEC87	BERCO RESOURCES, INCORPORATED GEAREY #1 SWNE SEC. 22-137-106	WILLIAMS CREEK -DB (1)	160	10734	9540-10668	251 (109)	42.0	.00	2.00 B
MC KENZIE 4839 4864	03MAR87	SHELL OIL CO. USA #43-11 NESE SEC. 11-150-104	CARTWRIGHT -SI	320	13100	11816-11838	49 PNA	41.6	650.00	368.00 B

APPENDIX 2--(Continued)

COUNTY FILE NO. ORDER NO.	COMP. DATE	OPERATOR, WELL NAME, LOCATION	FIELD -POOL (NUMBER OF WELLS CURRENTLY IN POOL)	SPACING	TOTAL DEPTH	INTERVAL PERFORATED	INIT. PROD. (CURRENT DAILY PROD. -BBL. OIL.)	GRAV.	GOR	WATER
STARK 12078 4974	02MAY87	JERRY CHAMBERS EXPLORATION CO. SUN 10-7 N4SE SEC. 7-138- 99	ROCKY HILL -MMFB (1)	160	9350	9218- 9245	32 (20)	41.3	1464.00	63.00 B
WARD 12127 4975	28JUL87	WESSLEY EXPLORATION COMPANY JOHNSON #4-24 NNW SEC. 24-159- 87	GREENBUSH -MMSB (5)	80	6130	5907- 5915	354 (282)	28.0	100.00	19.00 B
WILLIAMS 6680 1816	07APR87	LAMAR HUNT ROLFSTAD #1 N4SW SEC. 29-155-100	SPRINGBROOK -MMNS (1)	160	13621	9166- 9184	27 (24)	37.6	800.00	8.00 B
WILLIAMS 8922 4894	19MAR87	SUN EXPLORATION AND PRODUCTION COMPANY O. H. SEEL FEDERAL 1 NESE SEC. 32-153-103	SIXHILE -ORR (1)	160	13392	13188-13204	660 (180)	44.0	880.00	24.00 B
WILLIAMS 12120 4972	14JUL87	COLUMBIA GAS DEVELOPMENT CORPORATION ROGERS-FEDERAL #15-1 NNW SEC. 15-152-104	BUFORD -MM (5)	160	9200	8914- 9022	279 (128)	.0	.00	912.00 B
WILLIAMS 12186 5105	17DEC87	TXP OPERATING COMPANY TXPOC-STATE #23-36 N4SW SEC. 36-155-100	STONY CREEK -MMNS (5)	160	14000	9445- 9458	347 (363)	37.8	624.00	.00 X
WILLIAMS 12189 5093	17NOV87	LADD PETROLEUM CORPORATION FJERSTAD #14-11 A S4SW SEC. 11-156-102	BONETRAIL -SOS (2)	160	13269	12654-12678	526 (88)	42.0	950.00	.00 X

REFERENCES

- Anderson, S. B., and Eastwood, W. P., 1968, Natural gas in North Dakota: American Association of Petroleum Geologists Memoir 9, v. 2, p. 1304-1326.
- Anderson, S. B., and Bluemle, J. P., 1982, Oil exploration and development in the North Dakota Williston Basin: 1981 update: North Dakota Geological Survey Miscellaneous Series 62, 29 p.
- Anderson, S. B., and Bluemle, J. P., 1984, Oil exploration and development in the North Dakota Williston Basin: 1982-1983 update: North Dakota Geological Survey Miscellaneous Series 65, 33 p.
- Bluemle, J. P., Anderson, S. B., Andrew, J. A., Fischer, D. W., and LeFever, J. A., 1986, North Dakota Stratigraphic Column: North Dakota Geological Survey Miscellaneous 66, 3 sheets.
- Dow, W. G., 1974, Application of oil correlation and source-rock data to exploration in Williston Basin: American Association of Petroleum Geologists Bulletin, v. 58, p. 1253-1262.
- Fischer, D. W., and Bluemle, J. P., 1986, Oil exploration and development in the North Dakota Williston Basin: 1984-1985 Update: NDGS Miscellaneous Series 67, 40 p.
- Folsom, C. B., Jr., 1980, A history of the North Dakota Geological Survey: North Dakota Geological Survey Miscellaneous Series 58, 51 p.
- Gerhard, L. C., and Anderson, S. B., 1981, Oil exploration and development in the North Dakota Williston Basin: 1980 update: North Dakota Geological Survey Miscellaneous Series 59, 19 p.
- Gerhard, L. C., Anderson, S. B., LeFever, J. A., and Carlson, C. G., 1982, Geological development, origin, and energy and mineral resources of the Williston Basin, North Dakota: American Association of Petroleum Geologists Bulletin, v. 66, p. 989-1020.

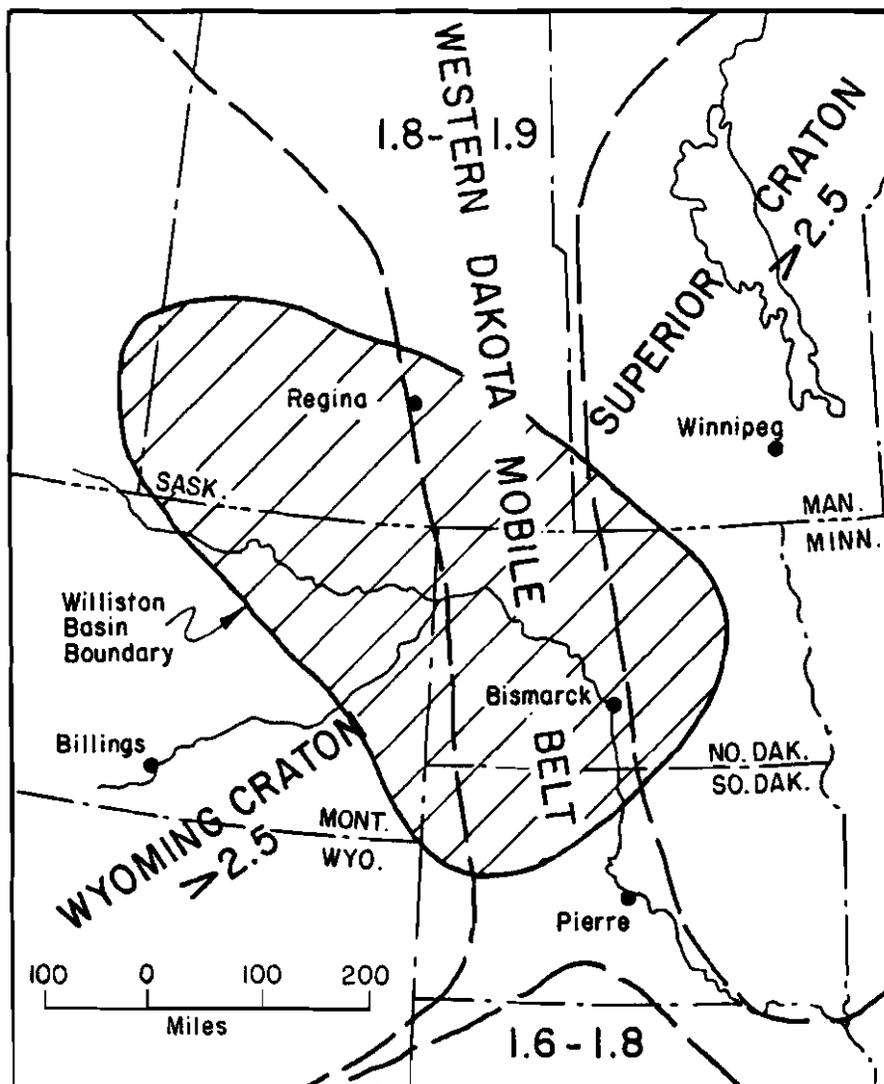


Figure 1. Map showing the extent of the Williston Basin. The major Precambrian structural provinces (Superior Craton, Western Dakota Mobile Belt, and Wyoming Craton) are shown along with the approximate ages of the basement rocks in each area; e.g., rocks of the Wyoming Craton are greater than 2.5 billion years old; rocks of the western Dakota Mobile Belt range in age from 1.8 to 1.9 billion years old.

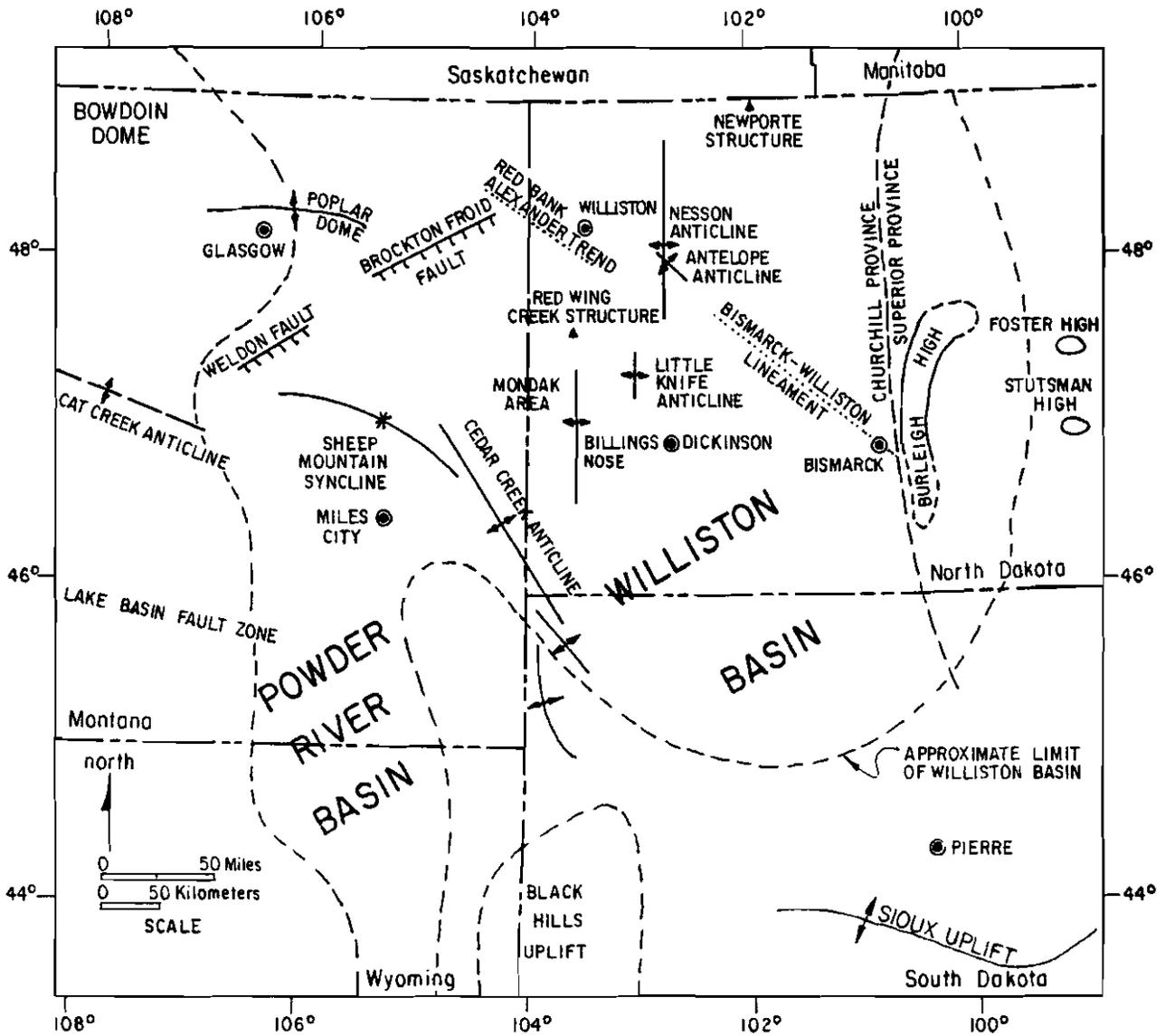


Figure 2. Map showing the major structural features in western North Dakota and South Dakota, eastern Montana, and northeastern Wyoming.