

**OIL EXPLORATION AND DEVELOPMENT IN THE
NORTH DAKOTA WILLISTON BASIN**

by

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CONTENTS

	Page
INTRODUCTION	1
HISTORY OF DEVELOPMENT	1
PRODUCING HORIZONS	6
SIGNIFICANCE OF OIL AND GAS INDUSTRY IN NORTH DAKOTA	11
REGULATORY TRENDS	14
THE FUTURE	17
SUMMARY	19

ILLUSTRATIONS

Figure

1. Oil and gas, subsurface minerals, coal exploration activity in North Dakota, 1970-1978	2
2. County outline map of North Dakota	3
3. Oil field development, 1951 and 1952-1959	4
4. Oil field development, 1952-1959 compared to 1960-1969	5
5. Oil field development, 1960-1969 compared to 1970-1975	7
6. Oil field development, 1970-1975 compared to 1976-1977	8
7. Oil field development, 1976-1977 compared to 1978	9
8. General stratigraphic column, North Dakota	10
9. Number of holes drilled annually for oil and gas in North Dakota	12
10. Annual crude oil production (barrels) in North Dakota	13
11. Net oil and gas gross production tax collections and projections	15
12. Present fields--1978	18

Table

1. North Dakota oil and gas pool discoveries	6
2. Oil and gas lease bonus income from state lands	14

INTRODUCTION

Oil and gas exploratory activity in the North Dakota Williston basin has been increasing since 1972, reaching boom proportions in 1978 when an all-time record 57 drilling rigs were operating in North Dakota. A number of factors have contributed to the boom in North Dakota. Economic incentive stemming from the Arab oil embargo, use of computerized seismic data, chance encounter of unexpected shallower reservoirs in Red River Ordovician tests, and success of wildcat tests drilled on acreage acquired in response to the Red Wing Creek discovery in 1972 are probably most important. This boom is being fueled by an incredibly high 25 percent wildcat success ratio (first six months of 1978, second six months appears to be virtually the same).

The purpose of this paper is to briefly outline the exploration cycles the Williston basin of North Dakota has undergone, review development of significant reservoirs, and look ahead at some future possibilities. The data presented in this paper are from the files of the North Dakota Geological Survey, which operates as the permitting and compliance agency for the North Dakota Industrial Commission for oil and gas and subsurface minerals.

Oil was discovered in North Dakota in 1951; like the rest of the nation, North Dakota's production was declining by the early part of this decade. The low point in production for North Dakota occurred in 1974, but fortunately the downward trend has been reversed and production is now climbing in response to the drilling boom of the 1970's. Both the number of wells and the drilling footage are increasing dramatically (fig. 1).

HISTORY OF DEVELOPMENT

In 1951, the Amerada #1 Clarence Iverson opened oil development in North Dakota (discovery well of the Beaver Lodge Field). Subsequent drilling in 1952, from Croff Field in southeastern McKenzie County to Tioga in Williams County,

produced a 75-mile long string of successes for Amerada. Subsequent drilling outlined a broad area of western and west-central North Dakota that presently produces hydrocarbon (fig. 2). Initial development continued along the Nesson anticline, largely in Williams and McKenzie Counties. Several additional producing horizons were opened on the Nesson anticline so that today Ordovician (Red River), Silurian, Devonian, and Mississippian reservoirs are important, not only on the Nesson anticline, but also in other areas of the state. Significant discoveries between 1952 and 1959 included the Mississippian oil fields of Bottineau and Renville Counties and the Mississippian fields of Burke County. In addition, the discovery of the Dickinson Field in Stark County, in 1957, stimulated exploration in the southwestern part of North Dakota (fig. 3).

From 1960 to 1969 most drilling in North Dakota concentrated on development of existing pools and on drilling for pools in close proximity to the existing production, although discoveries in Divide and Williams Counties, such as Round Prairie in 1968, opened more remote production. The big exploration phase for that decade was the discovery and development of Red River oil in Bowman County. These Red River discoveries in southwestern North Dakota did spur a land-play that later became important in 1970's drilling (fig. 4).

The third cycle of exploration was stimulated by two factors. First, in 1973, the Arab oil embargo spurred interest in development of domestic sources of oil and gas across the continental United States. Second, in 1972, the Red Wing Creek Field was discovered in McKenzie County. This discovery of an extremely thick pay section (1 100 feet net pay) on a highly anomalous structure spurred major lease plays throughout the region. These five-year term leases would expire in 1977 and 1978. Drilling activity, as in the past decade, in Renville and Bottineau Counties continued with the discovery of several small fields, mostly of Mississippian age. Development of the Red River play in

ACTIVITIES OF GEOLOGICAL SURVEY / INDUSTRIAL COMMISSION

	YEAR								
	1970	1971	1972	1973	1974	1975	1976	1977	1978
OIL & GAS CASES HEARD/INDUSTRIAL COMMISSION	38	45	41	60	51	82	106	108	115
PERMITS ISSUED FOR									
OIL/GAS	171	134	103	129	174	264	246	351	400*
COAL						46	33	76	40*
POTASH							3	0	0
URANIUM							10	5	4
OIL & GAS WELLS COMPLETED	134	151	90	117	153	202	251	254	350
NUMBER OF FEET DRILLED/ OIL & GAS (1000's)	873	979	606	814	1,139	1,348	1,802	1,928	2,500*
COAL TESTHOLES DRILLED						4,613	2,319	4,800	2,800*
TEST HOLES FOR OTHER SUBSURFACE MINERALS:									
POTASH							3	0	0
URANIUM							91	620	320*

* - Estimated

Figure 1. Oil and gas, subsurface minerals, coal exploration activity in North Dakota, 1970-1978.

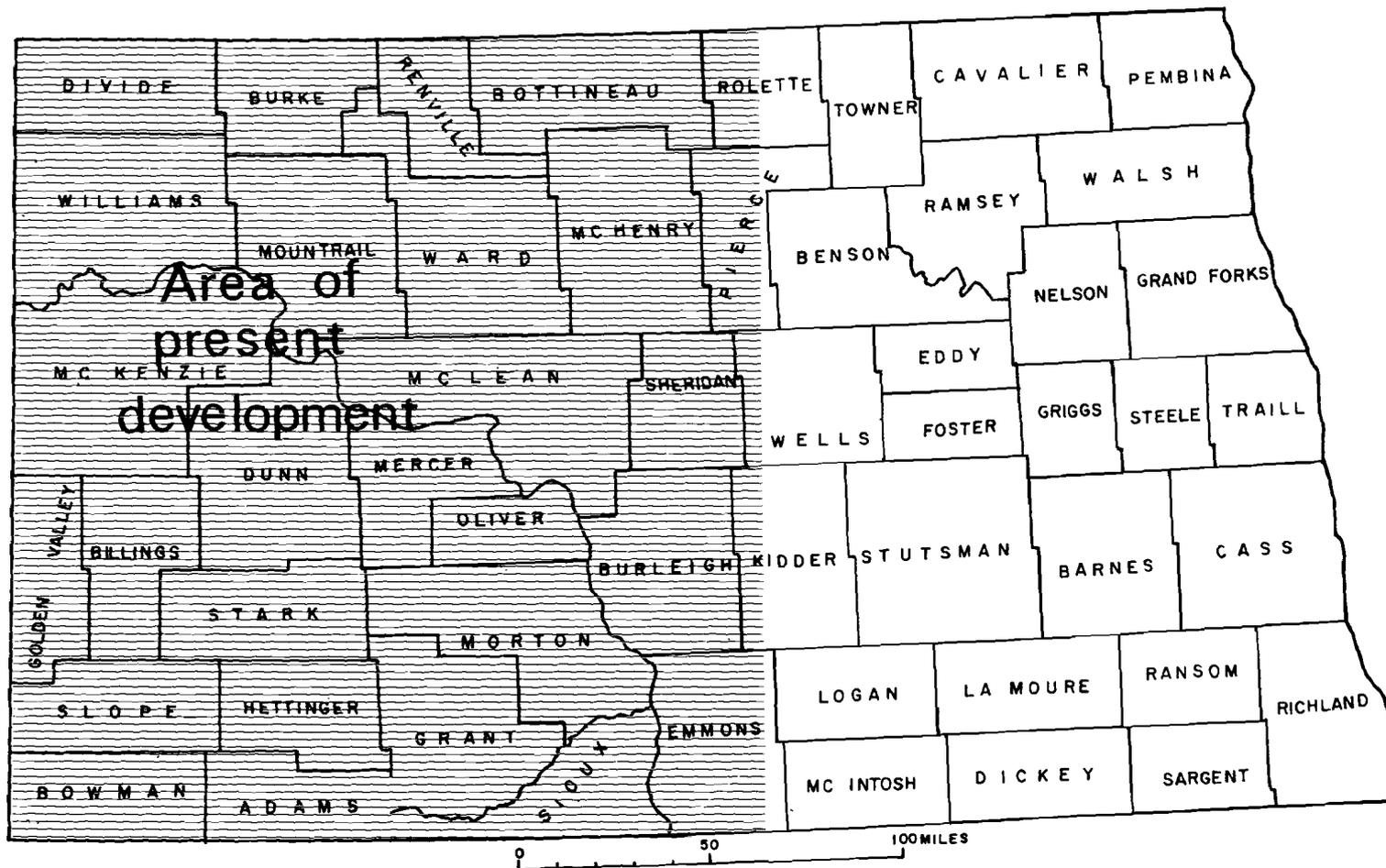
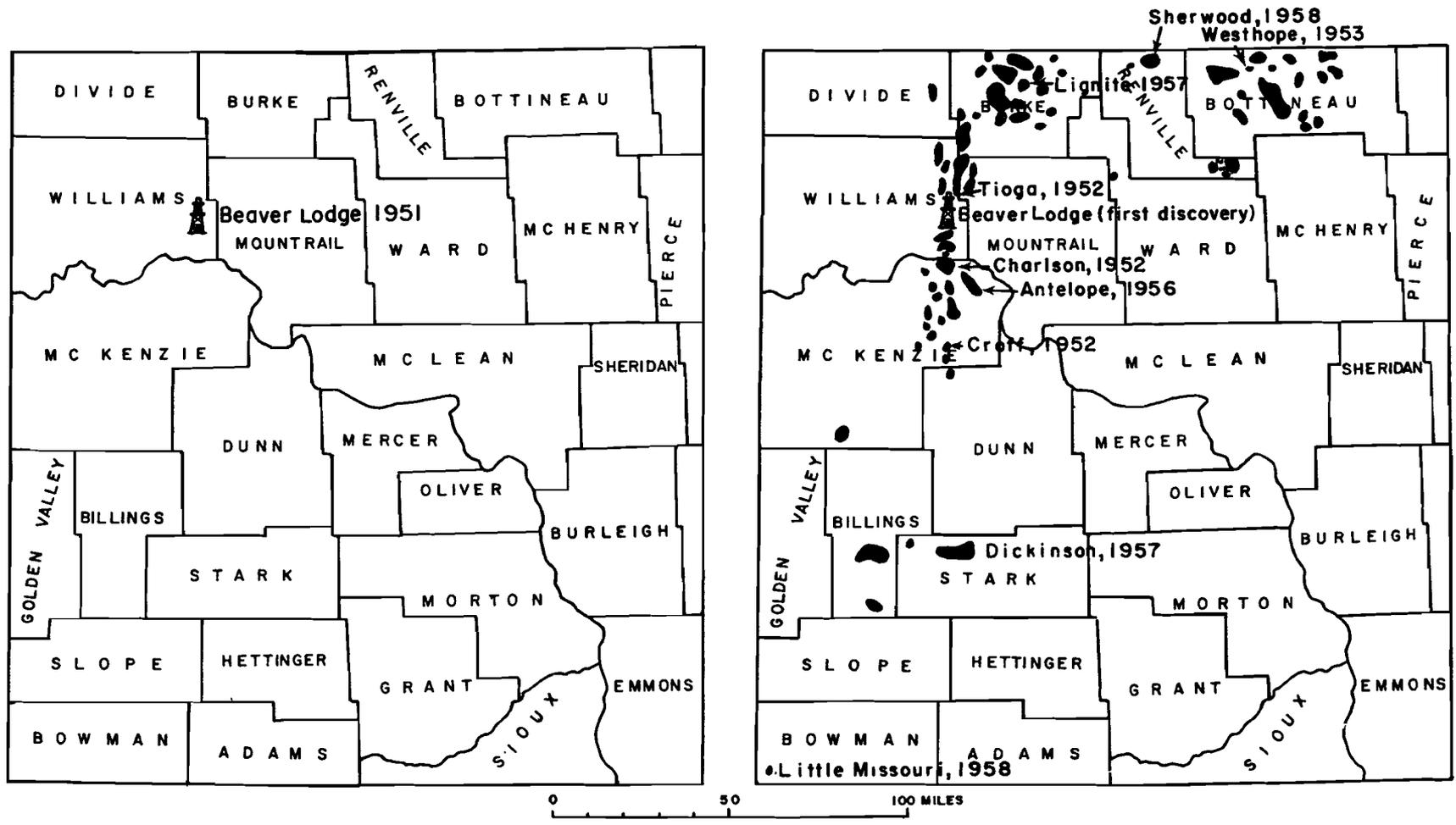


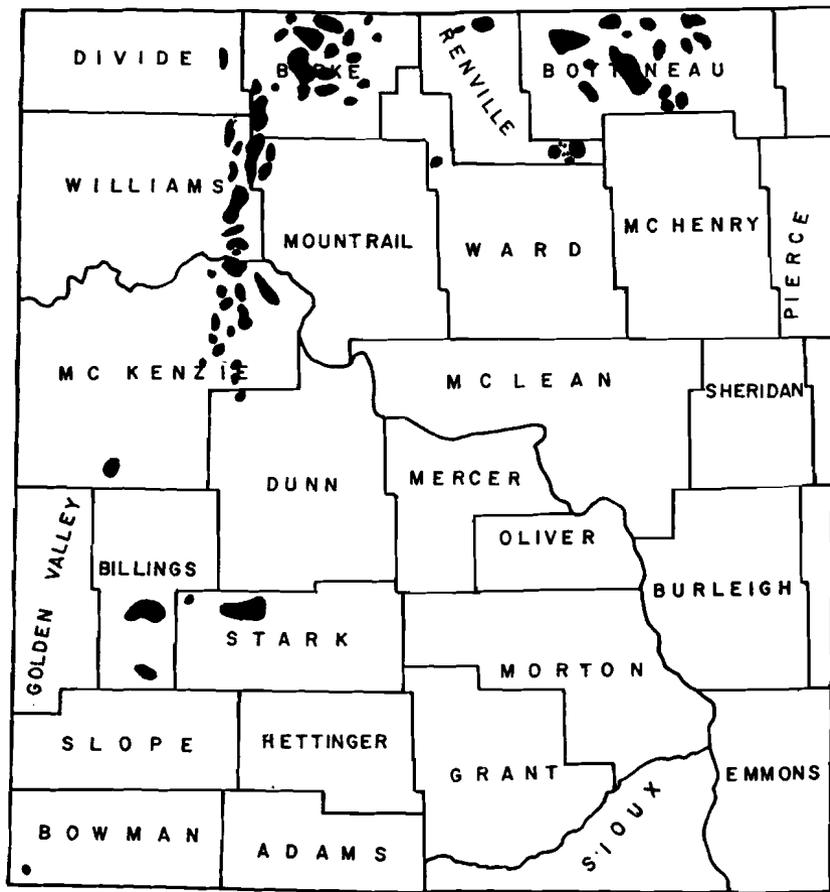
Figure 2. County outline map of North Dakota. Lined area is area of present oil and gas development and exploration.



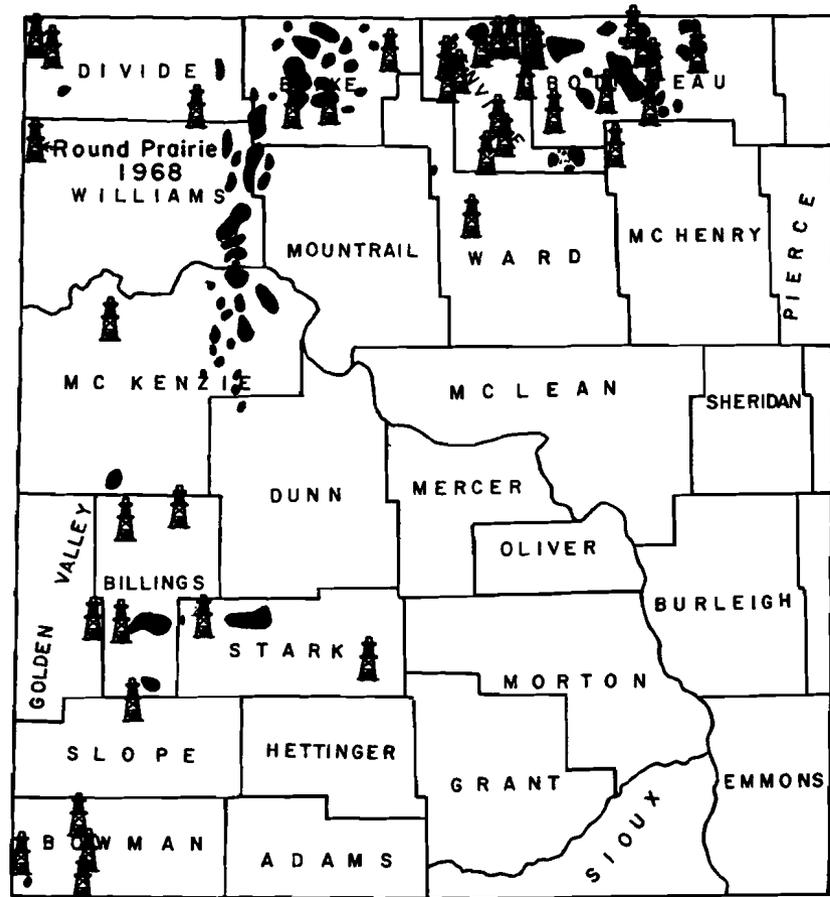
First oil discovery made in 1951.

New fields discovered from 1952-1959

Figure 3. Oil field development, 1951 and 1952-1959.



1952-1959
Oil Fields



🏠 - New field discoveries from 1960-1969

Figure 4. Oil field development, 1952-1959 compared to 1960-1969.

Bowman County produced several more fields from 1970 to 1975 (fig. 5).

Computerized seismic information, coupled with expiring lease dates from the 1972 lease activity and higher prices for crude oil engendered by the Arab oil embargo, spurred exploratory drilling activity from 1975 through 1977; 1976 and 1977 were banner years (fig. 6). Although activity in the Williston basin had been high, discovery of Mondak-Madison and Bicentennial-Red River pools in 1976 spurred much activity in McKenzie County; whereas Halliday, Killdeer, Rattlesnake Point, and Oakdale spurred activity in Dunn County, which had heretofore been essentially an undrilled and non-productive county.

In 1977, two additional significant discoveries were drilled. The first of these, the Charlson-Silurian pool, proved that production rates in excess of 2 000 barrels of oil per day were possible in North Dakota. Although the multiple-pay Mondak Field discovered in 1976 may turn out to be North Dakota's largest field in areal extent, it was the discovery of Little Knife Field in 1977 which drew national attention to North Dakota. Located at the junction of Billings, Dunn, and McKenzie Counties, Little Knife Field has demonstrated potential for at least two zones of production (Madison and Duperow), and is easily over a 100-million-barrel-reserve field.

Exploratory drilling success was also high in 1977, averaging about one success in five tries for a 20 percent success ratio.

Drilling continued to increase in 1978 and the wildcat success ratio also increased. Initial calculations for 1978 indicate a wildcat success ratio of 25 percent. 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. 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

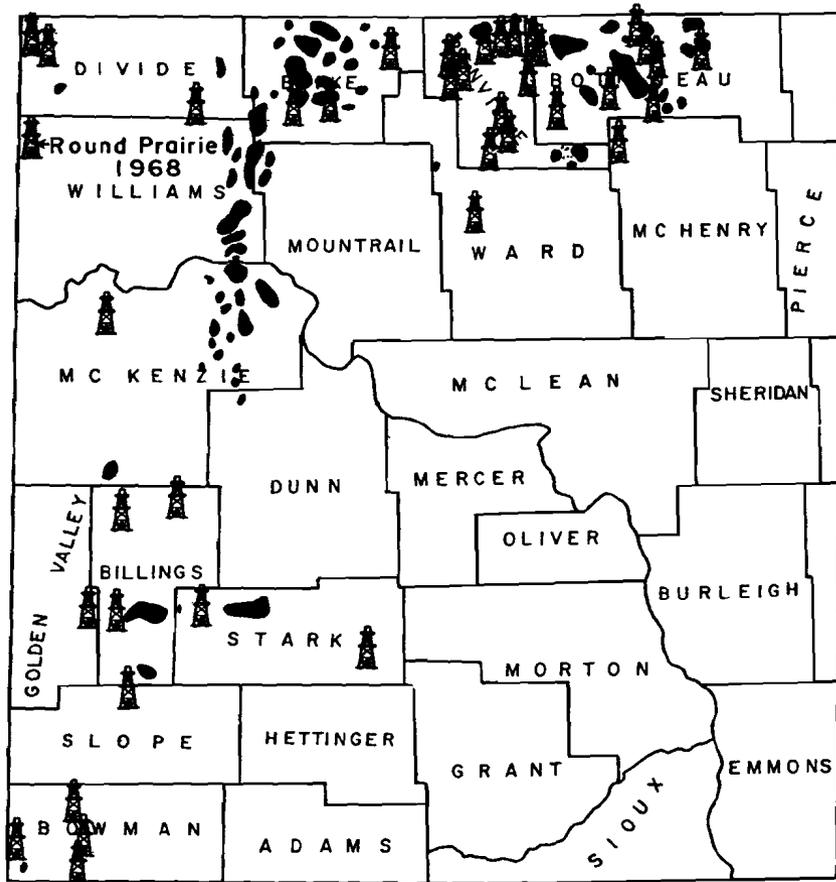
north of Williston and an as-yet unnamed Red River discovery south of Williston opened production in southern Williams County and northern McKenzie County. The north-south structural trend previously mapped as "the Billings Nose" finally became productive in a big way with the discovery of the TR, Four Eyes, and Bull Moose Fields, so that major production has now been established throughout the western Dunn County, Billings County, and McKenzie County regions (fig. 7). This third cycle of exploration in the North Dakota Williston basin is continuing in 1979.

PRODUCING HORIZONS

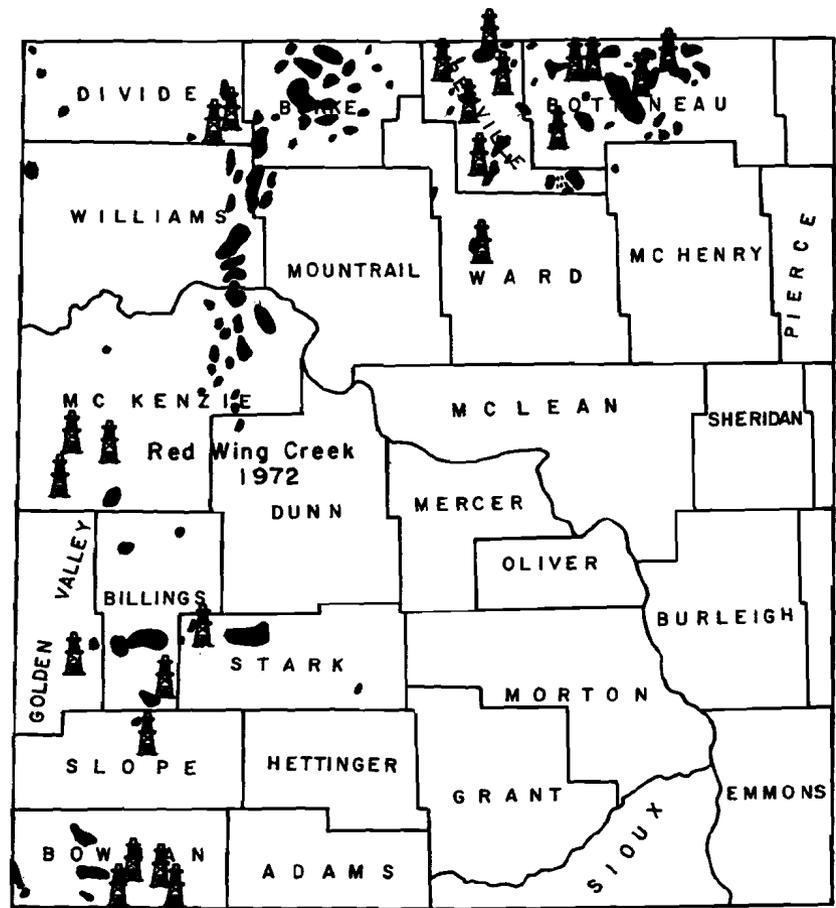
Seventeen stratigraphic horizons produce oil and/or gas in North Dakota (fig. 8, table 1). These range in age from the Cretaceous Eagle Sand, down to and including the Cambrian Deadwood. In addition, one well in the Newporte Field produces oil from the Precambrian. Of particular importance to North Dakota production are the Madison reservoirs of Mississippian age and

TABLE 1.--North Dakota oil and gas pool discoveries

<u>Horizon</u>	<u>1975-1978</u>	<u>1951-1974</u>
Cretaceous		1
Triassic		
Spearfish	1	3
Pennsylvanian		
Tyler	2	9
Madison	27	108
Devonian	1	12
Bakken	3	3
Sanish	0	1
Birdbear	1	1
Duperow	9	2
Winnipegosis	0	3
Silurian	3	4
Ordovician		
Red River	16	19
Winnipeg	0	1
Cambrian		
Deadwood	1	0

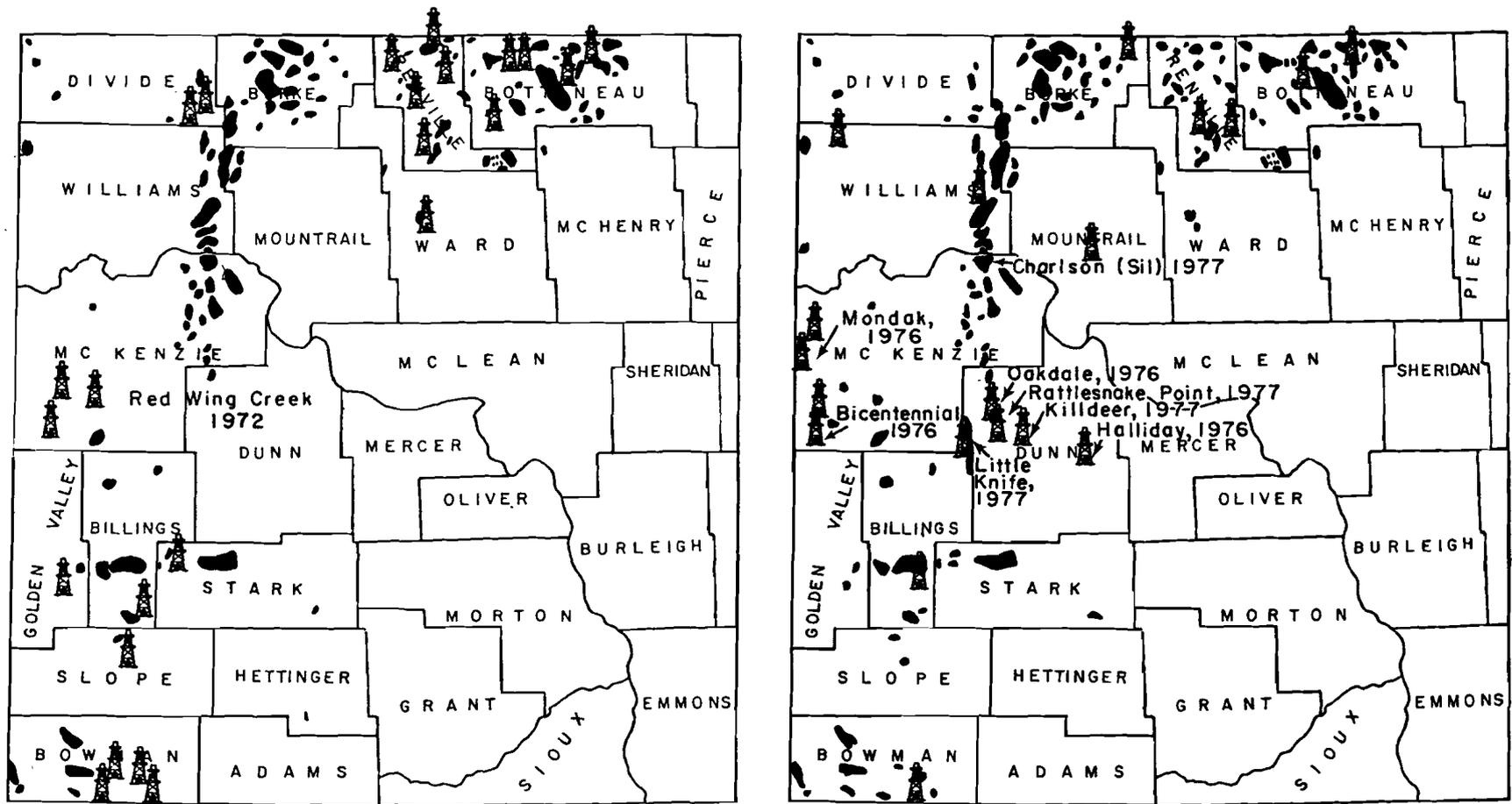


1960 - 1969
Oil Fields



— New field discoveries from 1970-1975

Figure 5. Oil field development, 1960-1969 compared to 1970-1975.



1970 - 1975
Oil Fields

 - New field discoveries from 1976 - 1977

Figure 6. Oil field development, 1970-1975 compared to 1976-1977.

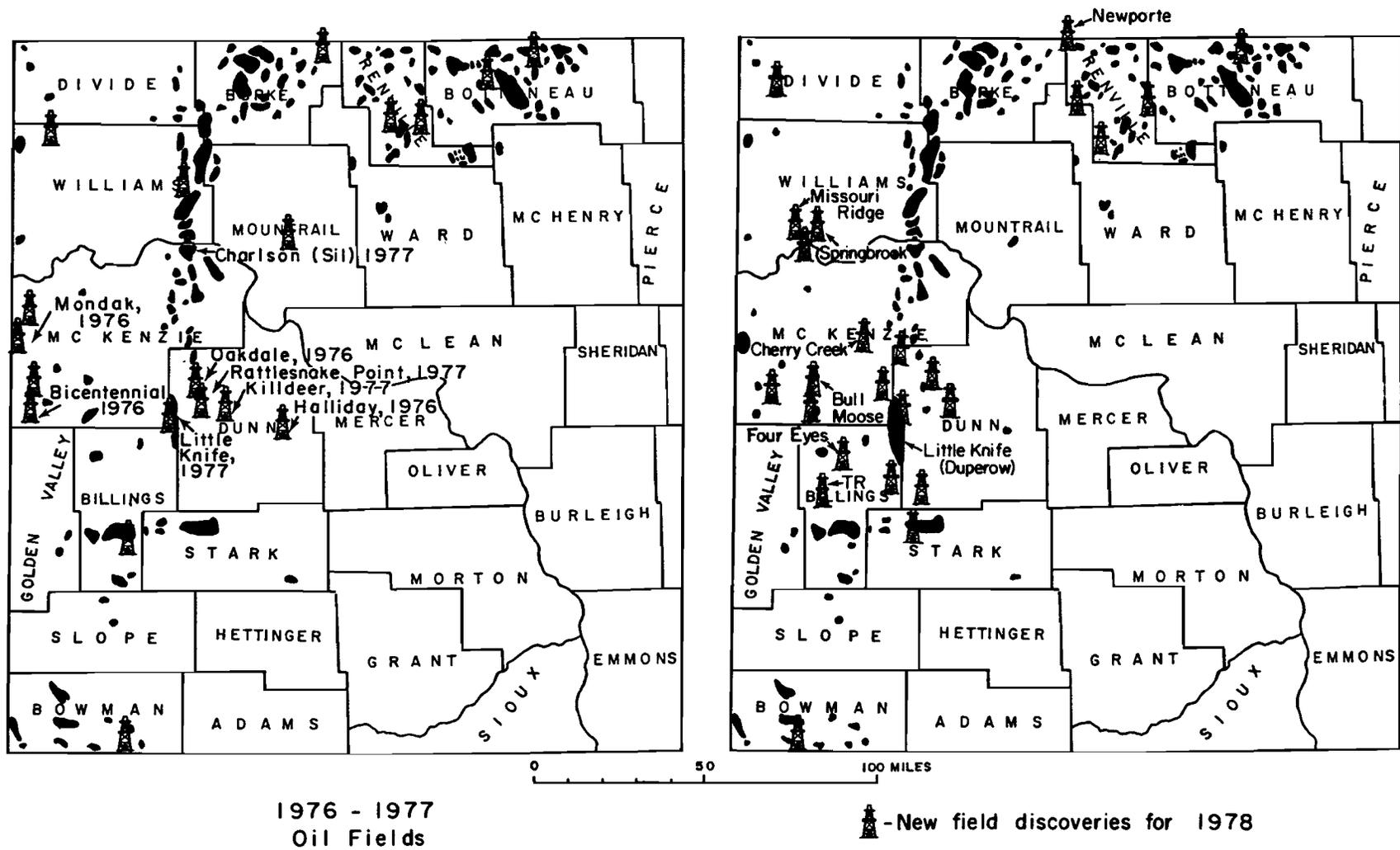


Figure 7. Oil field development, 1976-1977 compared to 1978.

NORTH DAKOTA STRATIGRAPHIC COLUMN

SYSTEMS	GROUPS	ROCK UNITS		
TERTIARY	FORT UNION GROUP	PLEISTOCENE	BIG SNOWY GROUP	MINNEKAHTA ●
		WHITE RIVER		OPECHE
		GOLDEN VALLEY		MINNELUSA
		SENTINEL BUTTE		AMSDEN
		BULLION CREEK		TYLER ●
		SLOPE		OTTER
		CANNONBALL		KIBBEY ●
CRETACEOUS	MONTANA GROUP	LUDLOW	MADISON	POPLAR INTERVAL
		HELLCREEK		RATCLIFFE INTERVAL ●
		FOX HILLS		FROBISHER ALIDA INTERVAL ●
		PIERRE		TILSTON INTERVAL ●
	JUDITH RIVER	BOTTINEAU INTERVAL ●		
	EAGLE ⚙	BAKKEN ●		
	COLORADO GROUP	NIOBRARARA		THREE FORKS ●
		CARLILE		BIRDBEAR ●
		GREENHORN		DUPEROW ●
		BELLE FOURCHE		SOURIS RIVER
		MOWRY		DAWSON BAY
	DAKOTA GROUP	NEWCASTLE ss		PRAIRIE
		SKULL CREEK		WINNIPEGOSIS ●
		FALL RIVER		ARBURN
LAKOTA		INTERLAKE ●		
JURASSIC	MORRISON	MORRISON	BIG HORN GROUP	STONEWALL
		SUNDANCE		STONY MTN.
		PIPER		RED RIVER ● ⚙
TRIASSIC	SPEARFISH ●	"UNRESTRICTED"	CAMBRO-ORD.	WINNIPEG ⚙
				DEADWOOD ⚙ ●
			PERMIAN	
			PENNSYLVANIAN	
			MISSISSIPPIAN	
			DEVONIAN	
			SILURIAN	
			SILURO-ORD.	
			ORDVICIAN	
			CAMBRO-ORD.	
			PRECAMBRIAN	

● OIL PRODUCTION
⚙ GAS PRODUCTION

Figure 8. General stratigraphic column, North Dakota.

the Ordovician Red River reservoirs. Recent exploration and development activity has demonstrated the significance of these reservoirs. Sixteen new pools were discovered in the Red River reservoirs between 1975 and 1978 compared to 19 pools from 1951 to 1974. This probably reflects the precision of new computerized seismic techniques, which permit drilling on small seismic "bumps." The development of the Madison reservoirs is of great significance to production and total reserves. The Madison reservoirs have been known and exploited since the early days of development in the Williston basin, but of the total 135 pools, 27 (20 percent), have been discovered since January 1, 1975. Included in the 27 new discoveries are the potentially giant Little Knife and Mondak-Madison pools. These two fields rank among the largest in the state in spaced area; Little Knife is the largest single spaced field in North Dakota. The number of multiple completions, or at least multiple pays, within individual fields is of great importance. Mondak Field, for instance, produces not only from the Madison, but also from the Red River, and other pays are also possible in the border area. Little Knife Field has established production from the Duperow as well as its better-known Madison pay and holds potential for additional pays. Two significant new discoveries, Bull Moose and Cherry Creek, also indicate multiple-pay potential. In each of these fields, Madison and Red River production are indicated; and, in both, considerable gas is associated with the oil. In fact, the Cherry Creek Field may be more accurately termed a gas reservoir.

The region's petroleum geologists were excited about the discovery of Cambrian production in Shell Oil Company's Newporte Field. Although subsequent development has not borne out the promise of early drill stem tests, this field is still significant in that it establishes production from Cambrian and Precambrian rocks and indicates clearly that structural and paleotopographical complexities remain to be explored along the boundaries of the northeastern Williston basin.

SIGNIFICANCE OF OIL AND GAS INDUSTRY IN NORTH DAKOTA

The recent low in drilling activity for oil and gas in North Dakota was reached in 1972 when 90 holes were drilled (fig. 9). Since 1972, increases have been the rule, although in 1976 and 1977 the numbers of oil and gas wells drilled were nearly the same. In 1978, a major jump occurred, in part due to expiring acreage drilling commitments and in part due to the large number of 1976, 1977, and early 1978 discoveries. Current projections of the North Dakota Geological Survey and Industrial Commission suggest that drilling activity will continue to increase, irrespective of whether significant new discoveries are made in the next few years. The rationale for this is that the discovery ratio of about 25 percent on wildcat wells has so committed drilling rigs to wildcat locations that very little development drilling has been done except that necessary to hold acreage. Since the discoveries of 1975, 1976, and 1977 set off large-scale land and lease plays, the expiration dates of these five-year term leases will be in the early 1980's. In consequence, drilling activity for the development of existing discoveries and development for discoveries to be made in the next several years will maintain or increase the level of oil and gas drilling in North Dakota.

Crude oil production in North Dakota peaked in 1966 at 27 126 243 barrels, with a steady decline from 1966 to 1974. The increased drilling activity since 1972, coupled with the production from Red Wing Creek Field, which was discovered in 1972, has produced a reversal of the production decline. In 1974 production had declined to under 20 million barrels of oil (19 696 849), but recovered in 1975 to over 20 million barrels and is projected for 1978 at approximately 25 million barrels of oil (fig. 10). The production figures for 1976 through 1978 are deflated by action of the North Dakota Industrial Commission to restrict production in oil wells where flared gas would be significant. Therefore, it is likely that production increases will be seen in the North Dakota Williston

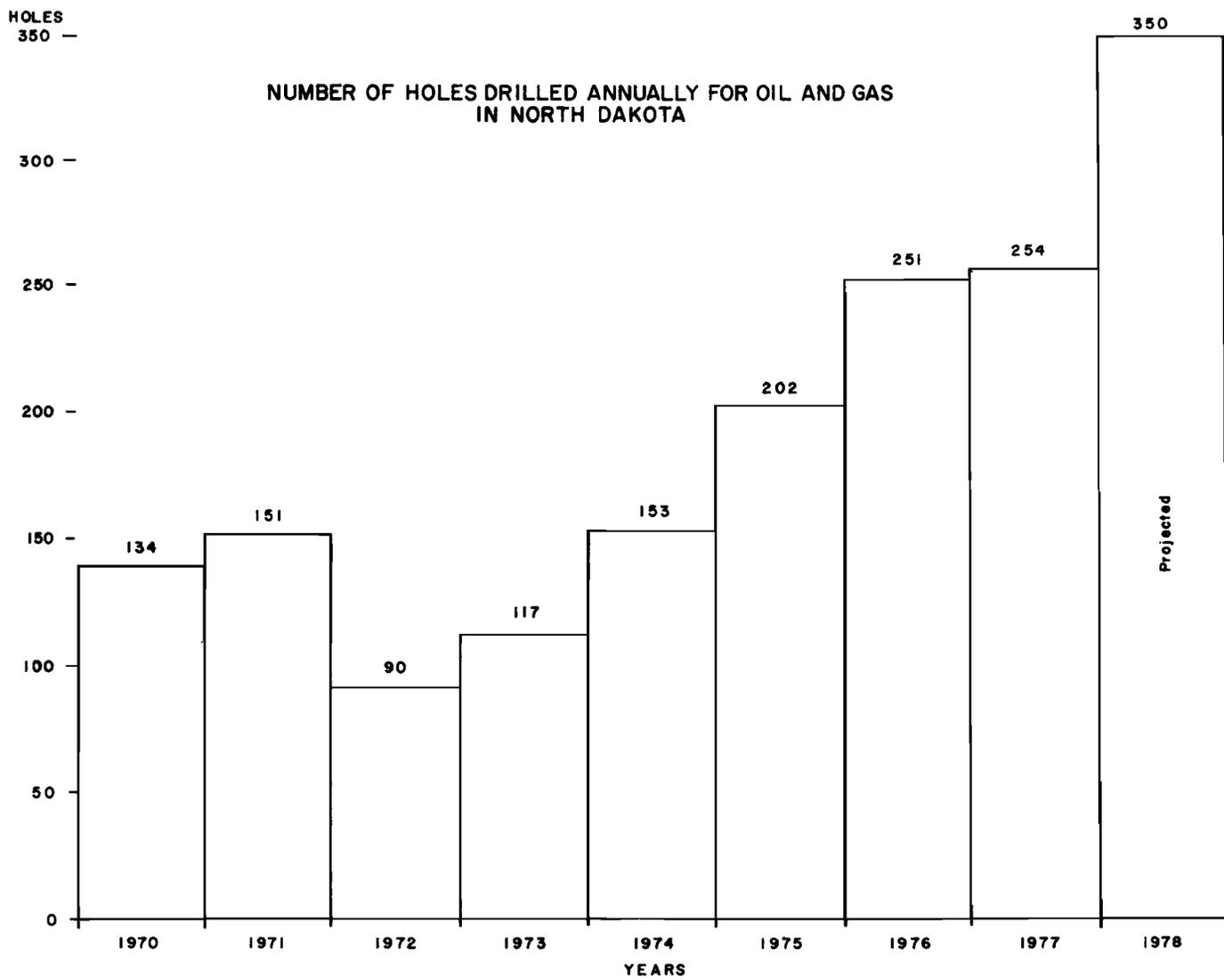


Figure 9. Number of holes drilled annually for oil and gas in North Dakota.

ANNUAL CRUDE OIL PRODUCTION (1,000'S BARRELS) IN NORTH DAKOTA

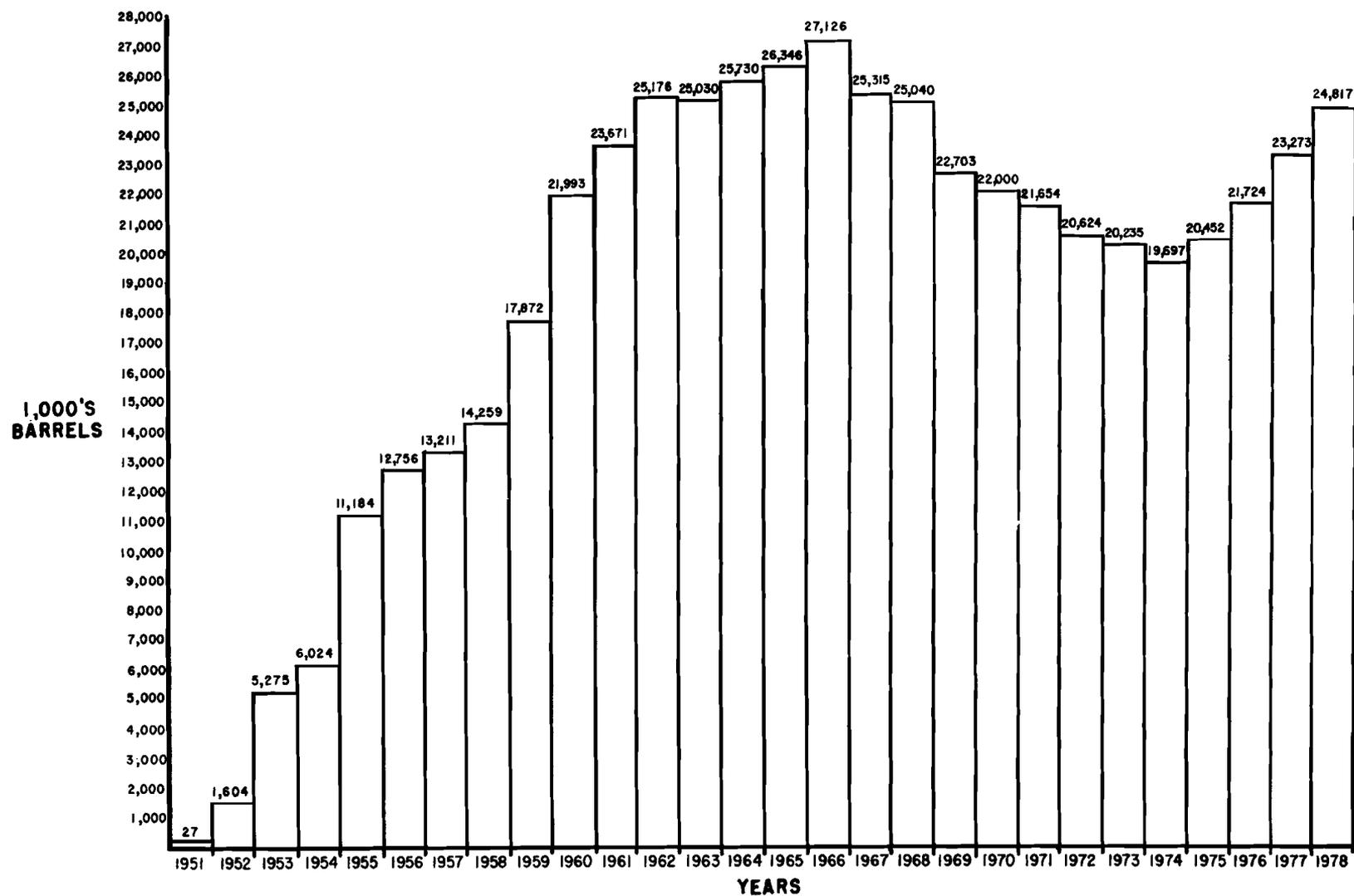


Figure 10. Annual crude oil production (barrels) in North Dakota.

basin for a number of years to come as both new discoveries and their developments are put on line and as the associated gas is captured for consumer use.

The net effects of the increase in production and increase in drilling activity in North Dakota can be seen in several areas. One area is the increase in income to the State Land Board from oil and gas lease activity on state lands and on net production royalties on state lands. Since 1974, there have been dramatic jumps in the bid levels for lease bonuses on state land, and increased oil prices have added to the royalty income for both present production and for newly established production. The sharp jumps in bonus bids has certainly been one of the early and obvious manifestations of increased interest in the North Dakota Williston basin (table 2). The other areas of obvious effect are in the net oil and gas gross production tax collection and in the total dollar value of oil and gas exploration and development activity in the state.

TABLE 2.--Oil and gas lease bonus income from state lands

1970-1976 include estimates of Bank of North Dakota bonus income. 1977 and 1978 actual income.

<u>Year</u>	<u>Bonus Total</u>
1970	\$ 293,826
1971	218,638
1972	1,083,686 ⁽¹⁾
1973	436,342 ⁽²⁾
1974	3,582,558 ⁽²⁾
1975	851,896
1976	666,792 ⁽³⁾
1977	9,925,749 ⁽³⁾
1978	19,666,496

- (1) Red Wing Creek discovery
 (2) Boxcar Butte discovery
 (3) Little Knife, Mondak, others, discovered; Bank of North Dakota lease sales transferred to State Land Department

A recent study (Thor Hertsgaard) of the role of oil and gas exploration and development in

North Dakota, as separate from refining, transportation, and sales, has shown that this industry is a major factor in the North Dakota economy. Estimates of the valuation of oil and gas exploration and development in North Dakota in 1978 dollars is 800 million dollars (.8 billion) for 1978 with an increase of approximately 5 percent per year over the next several years, in 1978 dollars. The level of activity indicated by this study places the oil and gas exploration and development business as approximately the number three industry in North Dakota, outranked only by crops and by total governmental activities.

The last obvious effect of increased oil and gas exploration and development in North Dakota is the net oil and gas gross production tax collection rates. North Dakota levys a 5 percent gross production tax on oil and gas production which is distributed in part to the counties of origin and in part to the general fund of the state of North Dakota. Since this is a percentage tax, the price of the product is as determinative of the amount of tax collected as is the amount of production. Thus, tax collections from 1970 to 1973 were very close to level, although production was declining. In 1974, when production was lowest, gross production tax collection jumped from a little over 3 million (in 1973) to over 4 million dollars, a reflection of the jump in price of oil due to the Arab embargo. As the world market price has increased, so the net oil and gas gross production tax collections increase in North Dakota. Coupled with the annual crude oil production increases (fig. 10), the increase in price has jumped the annual collections from the 3 million dollar level of 1970 to 1973 to nearly 11 million dollars in fiscal 1978. The estimate for total gross production tax collection during 1977-1979 biennium is approximately \$23 900 000 (fig. 11).

REGULATORY TRENDS

Oil and gas exploration and development regulation in the state of North Dakota is a responsibility of

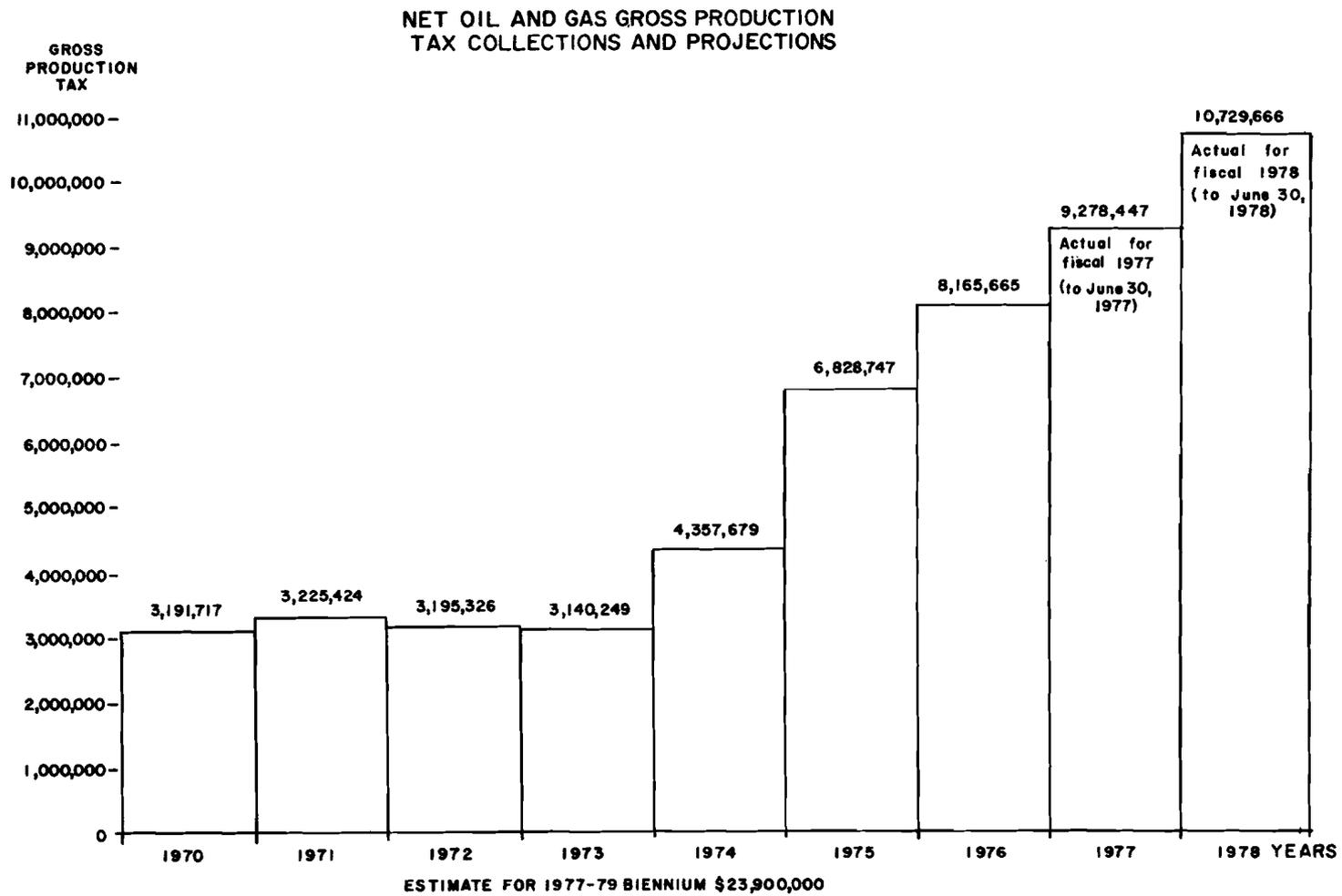


Figure 11. Net oil and gas gross production tax collections and projections.

the North Dakota Industrial Commission, which is comprised of the Governor, the Attorney General, and the Commissioner of Agriculture. By statutory authority, the Commission delegates certain responsibilities to the Office of the State Geologist, including field inspection and compliance provisions of rules, permitting, and various other administrative decisions. Several changes in direction or trend or regulation philosophy have been apparent over the last several years. These changes have occurred because of the increasing workload of the Industrial Commission due to the increased oil and gas activity and other activities which are also the responsibility of the Commission. Increased federal involvement in oil and gas affairs is also a parameter that has forced some change.

Generally, the changes and adoption of new rules have been centered around relatively few areas. These areas can be categorized as conservation of associated gas, protection of subsurface aquifers, data retention, and safety provisions for both personnel and environment.

Two areas of major change have been groundwater protection and gas flaring. The most important rule change relating to water protection has been the requirement that surface casing be set through the Fox Hills aquifer, which is the lowest freshwater aquifer in western North Dakota. The Industrial Commission and the Geological Survey both recognize the increase in drilling costs engendered by this requirement; in some cases, this requires 2 000 feet of surface casing. Yet, it is apparent to today's world of environmental concern, concern for future resources, and the increasing role of federal regulation in environmental affairs and mineral resource extraction, make this step necessary to assure that no damage to freshwater aquifers could occur as a result of oil and gas drilling activity. It must be emphasized that this rule was promulgated despite absolutely no evidence being presented that any damage to freshwater aquifers had occurred. Thus, it is an expensive protection measure designed to

insure that no future damage could occur, and not as a mitigation measure for existing problems. In addition, most salt water disposal pits have been eliminated; existing pits are lined. Surface drilling is now done with fresh water, except in extremely cold weather.

The North Dakota Industrial Commission recognized early that flaring of associated gas is a waste of a nonrenewable natural resource. Accordingly, since August 12, 1975, the Commission has put pressure upon oil operators in North Dakota to eliminate gas flaring. In some instances, it was easy to convince operators to connect to existing pipeline systems. In other areas the cost of processing and collection systems has been excessively high as compared to valuation of associated gas reserves, so that it has been quite difficult to effect collection and utilization of that gas.

The Commission has evolved an unwritten policy of restricting oil production in new fields, on an incremental basis, until such time as these wells or fields are connected to a gathering system and the gas is utilized. In most instances, new wells are allowed to operate at an unrestricted production rate for 60 days to allow testing and proper completion. At the end of the 60 days, production is restricted to 200 barrels a day per well; after an additional 60 days, to 150 barrels a day; and after another 60 days, a final restriction to 100 barrels a day per well is imposed. Furthermore, the Commission regularly reviews gas flaring in older fields to determine whether additional drilling has created the potential for economic collection of the associated gas. The net result is that North Dakota has only one major area left where significant associated gas is flared, and it is hoped that that area will soon have an available pipeline. The Industrial Commission has been giving careful consideration to the problems of industry, of cash flow, and of the increasing amounts of money invested in drilling in recent years. Major problems of capturing associated gas are not only economic, but are related also to reticence of

federal agencies, such as the U.S. Forest Service, to allow entry to federal lands.

Conflicts between air quality standards, entry restrictions to federal lands, and the real need for conservation and development of gas resources appear to be continuing with little hope of immediate relief. A lack of meaningful communication between federal land managers and federal energy administrators complicates the role of individual states and of operators in providing an adequate oil and gas supply for the United States.

THE FUTURE

The North Dakota Geological Survey does not perform an exploration function or predict the location of new fields; however, there are certain trends and exploration areas that should be recognized as being generally significant for future exploration. The majority of the state of North Dakota has not been adequately tested even in counties such as McKenzie, which is currently our largest producer. Of the 75 total townships in McKenzie County, 25 have had no tests at all. Many of the untested townships in McKenzie County are surrounded on all sides by production. Even many of the townships that have been tested have only one or two test holes and many of these have not gone deeper than Mississippian. Production has been established in a relatively few counties concentrated in the western third of the state and in the northwestern tier of counties (fig. 12). The deep part of the basin in Dunn County, in particular, has yet to be systematically drilled and has the potential for production down to and including the Deadwood. The possibility of stratigraphic traps based on lower Devonian pinchouts in the southwestern part of North Dakota is an attractive target for a major exploration program. It is quite unlikely that all of the potential Tyler sandstone channels, strandlines, or deltaic deposits have been identified and explored, particularly in the area of Stark and Billings

Counties. A possibility also exists for similar accumulations to the northeast of the Stark County fields.

Continued exploration for small-scale Red River structural features should bring major new discoveries throughout the western half of North Dakota. As drilling progresses for deeper horizons, testing of shallower horizons, especially Madison, will probably provide some unanticipated bonuses. Certainly, Mississippian exploration following trends established across the border in Canada in Tilston and in Lodgepole rocks have possibilities in North Dakota. Work done by the North Dakota Geological Survey has indicated that Mississippian strandline accumulation may extend southward along the periphery of the basin. A few wells drilled in Burleigh County have not yet been completed, so no data is yet available on the results of those Mississippian tests. Although a number of Winnipegosis reef mounds have been drilled and found to be water wet, the potential for finding oil associated with these mounds still exists. Continued study of the depositional facies of many of the carbonate units of lower Paleozoic age should assist industry in increasing the number of discoveries outside of the main "fairways" now being tested by the drill.

Eastern North Dakota has no established production, but it is also largely untested. The potential for oil accumulation at stratigraphic pinchouts with structural assists along the eastern periphery of the basin remains a strong possibility for future exploration programs. One drilling success along this margin would probably spur another major cycle of basin exploration activity. The other area of major possible recoveries is in the Niobrara Formation and other shallow Cretaceous rocks in eastern North Dakota. The success of similar drilling programs in other states suggests possibilities for shallow gas occurrences in North Dakota. Drilling technology for this type of exploration and development program will be different from that normally used in North Dakota drilling; that is, air drilling or light-weight fluid

drilling appears to be necessary in order to avoid masking the relatively low pressure gas.

SUMMARY

Three major exploration cycles have occurred in North Dakota. The first two of these have been completed. The first included the initial discoveries on the Nesson anticline, their development, and the discovery and development of the Mississippian oil fields of Burke, Renville, and Bottineau Counties. The second was the discovery and exploitation of the Red River structures in southwestern North Dakota.

Drilling activity in North Dakota continues in the third cycle of exploration, which began in 1973. The present cycle has developed a variety of reservoirs in new areas remote from most of the old structures. This third phase of exploration will probably develop fields and reserves comparable to those found during the first cycle of exploration. Future possibilities in other areas of the state are good and probably will

eventually be tested.

The oil and gas exploration and development business in the state of North Dakota is a significant factor in the state's economy, both as a direct contributor in tax revenues, lease bonuses, and royalty payments and as a generator of income to the state through the cycling of revenues in the private sector. The North Dakota Industrial Commission and the North Dakota Geological Survey, as regulators of the oil and gas industry, have consistently attempted to exercise a regulatory philosophy balancing the needs of industry for economic incentive and the needs of the people of North Dakota for protection of correlative rights and conservation of natural resources. The jump in the price of oil due to the Arab oil embargo and the new increase in gas prices due to the National Gas Policy Act, along with technical advances, have stimulated the third exploration boom in North Dakota. When gas flaring problems are eliminated in North Dakota, the state will establish a new record for daily production.