NEWSLETTER
NDGS

A publication of the
North Dakota Geological Survey
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CONTENTS

December, 1980

EDITOR'S NOTE--

The first article in this newsletter is by State Geologist, Lee Gerhard. It examines some of our responses to the burgeoning energy development in North Dakota, our dealings with the federal government, and problems we face in the upcoming biennium. I've given considerable attention to the impact energy is having on North Dakota and on the Survey; to the unprecedented level of oil and gas development activity; and to the impact all of this is having on Survey programs.

This newsletter includes a short article on a newly discovered shale outcrop of the oldest rock exposed in the state, and an article on North Dakota's geologic history. I've also included three pertinent abstracts dealing with our work on waste disposal and other aspects of lignite mining.

I hope you will call or write if you have questions. We appreciate learning what you want to know.

THE STATE GEOLOGIST VIEWS SURVEY PROBLEMS AND ACTIVITIES (Lee Gerhard) --

Oil and gas development in North Dakota has reached levels of activity higher than it was possible for most people to imagine two years ago during the last legislative session. During that session, the Legislature adjusted the Survey budget for high levels of activity, around 60 drilling rigs. We originally projected 80 rigs, but over 100 rigs are now drilling in North Dakota. As I look back over this biennium, I see several topics I would like to discuss, most of which are related to oil and gas and other energy issues.

First, the Survey has responded to the greatly increased workload of oil and gas development by individual as well as group effort. All members of the Survey staff have spent a rigorous two years working under intense pressure and putting in many extra hours. I believe that North Dakota citizens should recognize with pride that our people have done such an excellent job under such high stress. I am proud of all the staff and their accomplishments and I appreciate this opportunity to publicly express my gratitude to them.

We have kept as much pressure on the federal establishment as possible over the last three years to strive for a balanced view of energy development as part of the federal land management policy in North Dakota. Even through we have been only partly successful in this area, several recent policy shifts in federal management of energy-producing lands have greatly eased our minds. In particular, the decision to allow continued development of discovered oil reserves in the Mondak Field area, rather than the arbitrary shutting off of drilling next April, is a major step forward. This move alleviated the need for immediate massive drilling efforts in the area, and it will allow development to proceed at a much more measured pace than it otherwise might. Environmental damage should be minimized as a result of this slower development. In return for the federal decision allowing continued development of the area, we would support restrictions on the use of lease roads by non-essential vehicles.

Our relationships with the Environmental Protection Agency and the Federal Energy Regulatory Commission have changed somewhat in recent months also. The Underground Injection Control program of the E.P.A. was looming as a major problem in oil field salt water injection. Recent changes in E.P.A. policy and congressional actions may allow the state of North Dakota to continue with its own existing program without becoming involved with the complicated E.P.A. rules. The E.P.A. seems to have adopted North Dakota's "Cessation or Restriction of Production" approach rather than applying its own administrative decisions as an enforcement tool. The Federal Energy Regulatory Commission recently told us that they will be receptive to outside ideas and be willing to work with us to solve mutual problems. This may put an end to our former "adversary" relationship. All of this is a healthy step toward actually solving problems rather than creating them.

The future is uncertain. As we go to press, the 1981 Legislative session is about to open. Oil and gas development now appears to be the largest single total revenue producer in the state, although agriculture is still the largest capital industry. Because of this, the Survey must assume a leadership stance in the regulatory aspects of its work. Rig counts are expected to continue to go up, and some degree of control may have to be exercised over production until transportation and refining facilities are improved. We do not yet know the role the federal government will play during the next four years, but in areas peripheral to energy development we expect increased activity. Coal reclamation, geohydrology and geochemistry, waste disposal, and geology of the urban environment are all of increasing importance.

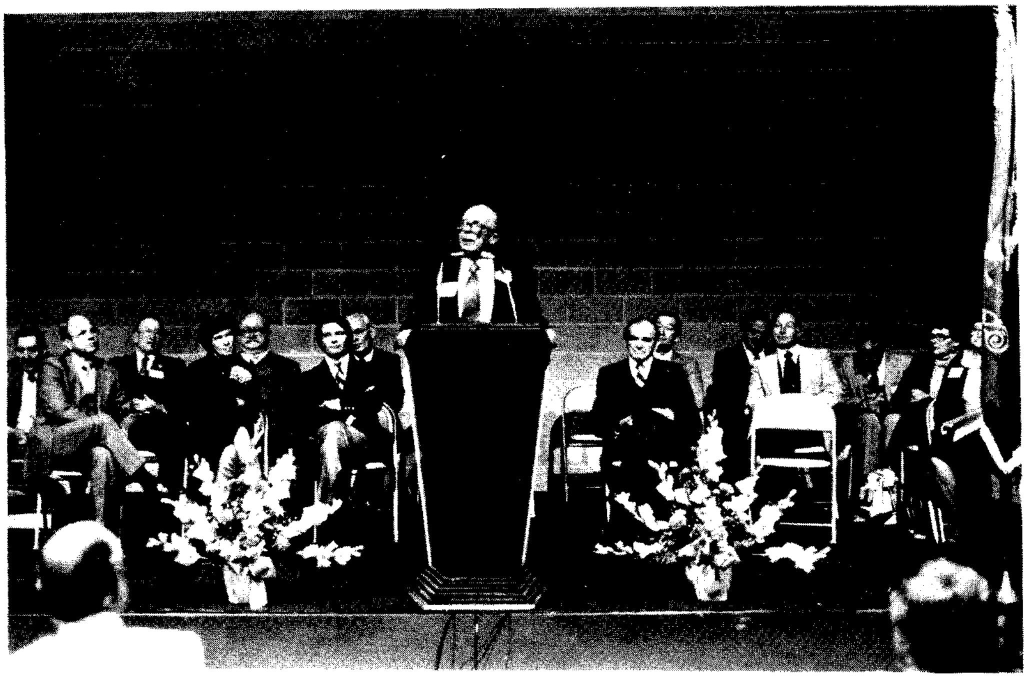
We expect that a variety of legislation will be introduced in the upcoming session that will affect the Survey in some degree. We already know that changes must be made in the expected budget recommendations if we are to do our regulatory work. It will be an exciting session.

WILSON M. LAIRD CORE AND SAMPLE LIBRARY DEDICATED--

In the last two issues of the NDGS Newsletter we have reported progress on the new core and sample storage facility that has been under construction on the University campus. The Wilson M. Laird Core & Sample Library was dedicated on October 3. It is appropriate that the new facility is named for Dr. Laird. Wilson Laird came to North Dakota in 1940 as Assistant Professor of Geology at the University. In 1941 he was named State Geologist and Chairman of the Geology Department. It was in 1941 too, that North Dakota's Oil and Gas Conservation Law was enacted by Legislature. The Law was based on the then Model Act drawn up by the Legal Committee of the Interstate Oil Compact Commission. This Law made the Industrial Commission the regulatory power and designated the State Geologist as the advisor and enforcer of the regulations promulgated by the Commission.

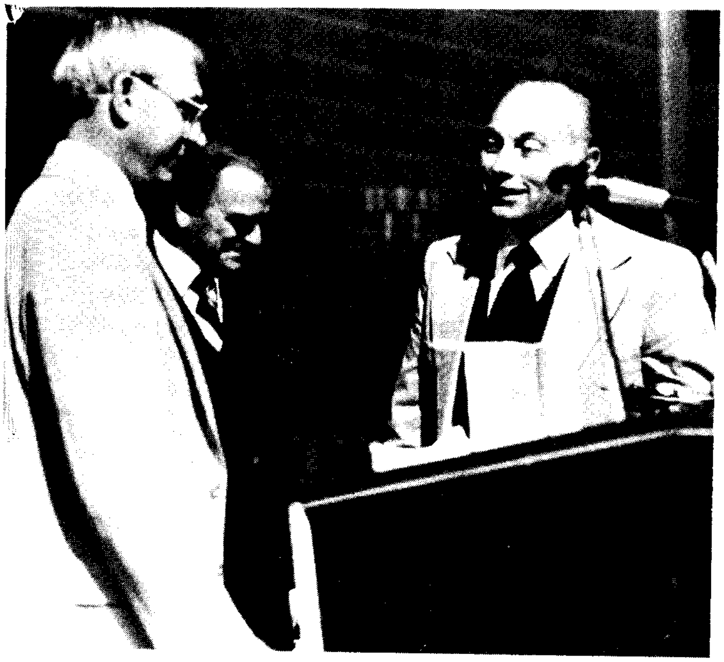
Dr. Laird served as Supervisor of Oil and Gas for the North Dakota Industrial Commission until 1969 when he accepted a position with the U.S. Department of Interior as Director of Oil and Gas. Dr. Laird was the architect of the Geological Survey as it exists today. It was due to his foresight that North Dakota had an oil and gas conservation statute in place prior to the discovery of oil in 1951; it was this fact that enabled an orderly development of the oil and gas industry in the state. His insistence on the preservation of data acquired during petroleum exploration and development resulted in the collection of core and samples maintained by the Survey today.

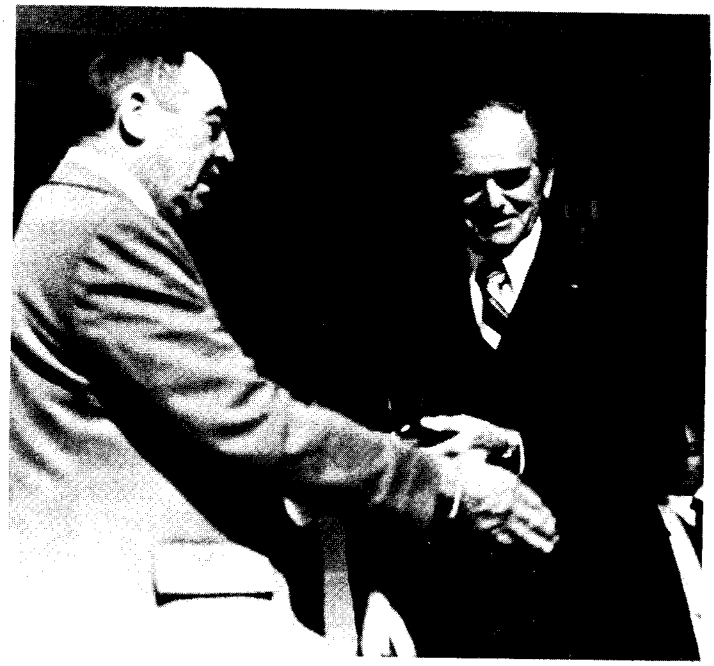
The dedication of the new building on October 3, Homecoming weekend at UND, was a memorable event for the large number of Dr. Laird's friends who attended. Both Governor Arthur A. Link and Attorney General Allen Olsen (now Governor-elect



Dr. Wilson M. Laird speaking at the dedication ceremony of the new Core and Sample Library on October 3, 1980.

Governor Arthur Link (second from left) shown with former State Geologist, Dr. E. A. Noble (left); Dr. Wilson M. Laird; and Dr. Lee C. Gerhard, current State Geologist (right). Photos on this page courtesy of University Relations.

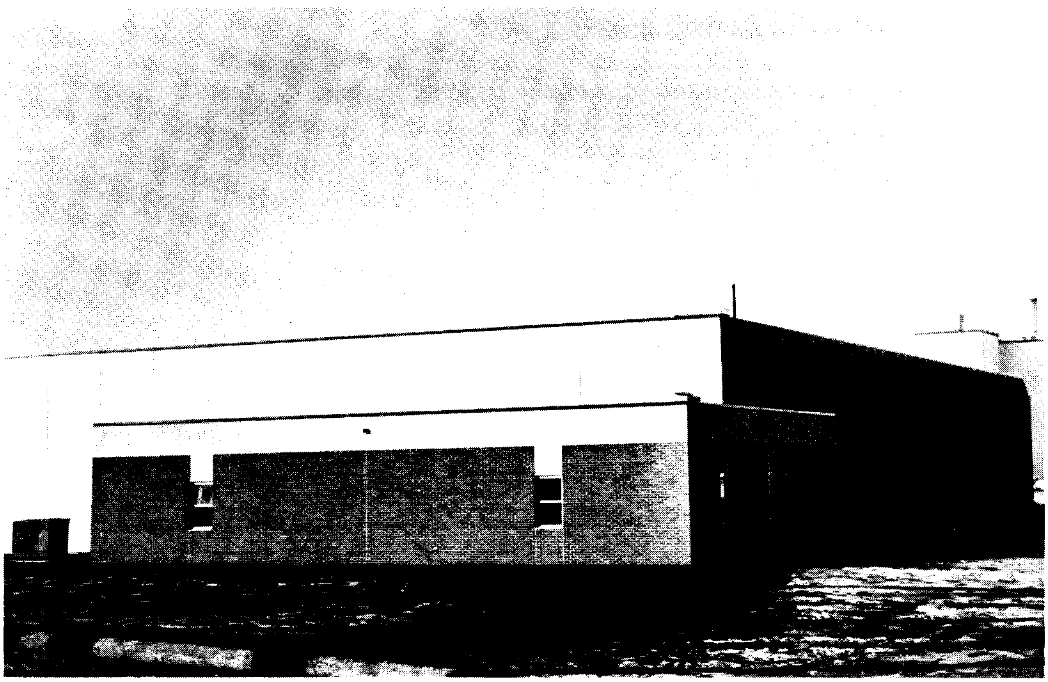




During the Dedication Ceremony, awards were presented to three NDGS staff members by Governor Art Link. Shown receiving the awards here are Sidney B. Anderson, Chief of the Subsurface Section of the Survey (28 years of service), upper left picture; C. B. Folsom, Jr., Chief Petroleum Engineer (27 years of service), upper right; and Clarence G. Carlson, Senior Geologist (26 years of service), left. Photos courtesy University Relations.

of North Dakota) spoke at the dedication ceremony. Other speakers included Mr. Hugh E. Palmer of Palmer Investments; Mr. J. R. Enloe of Amerada Hess Corporation; Mr. Bernold M. Hanson of Hanson Oil Corporation; and Dr. Norman J. Williams, State Geologist of Arkansas, representing the Association of American State Geologists.

The new building, located immediately south of Leonard Hall on the University campus, contains 20,482 square feet of total floor space to provide 18,432 square feet for core and sample storage and 2,050 square feet for laboratories and office space. The temperature in the storage area will be maintained above freezing during the winter to alleviate thermal shock to the building. The laboratories and office are both heated and air conditioned. This is welcome news to anyone who has had the opportunity to examine cores in the old facility during the winter months. The potential storage of the new facility is 200,000 boxes of core.



The new Wilson M. Laird Core and Sample Library. Some finishing work remains to be done on the building before it is officially accepted by the Survey. Shelving for the core has not yet been installed in the building, and the laboratories are not yet equipped.

NORTH DAKOTA OIL EXPLORATION AND PRODUCTION UP IN 1980--

The oil boom in North Dakota continues unabated. Through December 15, 1980, a total of 47 new pools have been discovered. In 1979, 40 pools were discovered. Discoveries this year have included 16 each from the Madison and Red River Formations, 9 from the Duperow, 3 from the Bakken, and 1 each from the Dawson Bay, Tyler (Heath), and Silurian (Interlake Formation).

As this is written, we project that a total of 760 drilling permits will be issued during 1980 (fig. 1). This is an 18 percent increase over last year. About 540 holes will be drilled this year, up from the 439 holes that were drilled last year (fig. 2). Just over 5 million feet (950 miles) of hole will be drilled this year in search of oil and gas (fig. 3).

Production figures also continue to climb. Oil production is now up to about 115,000 barrels daily and should reach nearly 40 million barrels of oil this year, compared with the 31 million barrels produced last year and the 25 million barrels of oil production in 1978 (fig. 4). Production has doubled since 1974, when we reached the recent low of 19½ million barrels, down from our previous high of 27 million barrels in 1966. Primarily as a result of production from Little Knife Field, Billings County now leads North Dakota in oil production, with over a million barrels a month. McKenzie County was the leading producer for many years.

It is interesting to compare North Dakota's recent oil production history with that of other states. Along with North Dakota, three other states are currently increasing their production: Alaska (up 12% in 1979 over 1978); Michigan (up 3%); and Ohio (up 6%). North Dakota's production was up 30% in the same period. Production in nearly all other states is declining (we don't have specific state data on Florida, New York, Pennsylvania, and West Virginia, but as a group, these states did increase their production about 4% in 1979 over 1978).

Looking at the decade of the 1970's, we find that production in 13 states peaked in 1970 and has been declining since then. Production peaked in three states in 1971, in another three states (including Texas) in 1972, another three states in 1974, and in one state in 1977. In all of these states, oil production is now on a declining curve.

As we travel around North Dakota, we sometimes hear people say things like "Well, of course the production is up, with the prices the oil companies are getting." But North Dakota, along with Alaska, is almost is a class by itself in performance. Prices are up everywhere, but production isn't. Maybe the unexplored Williston Basin has something to do with it.

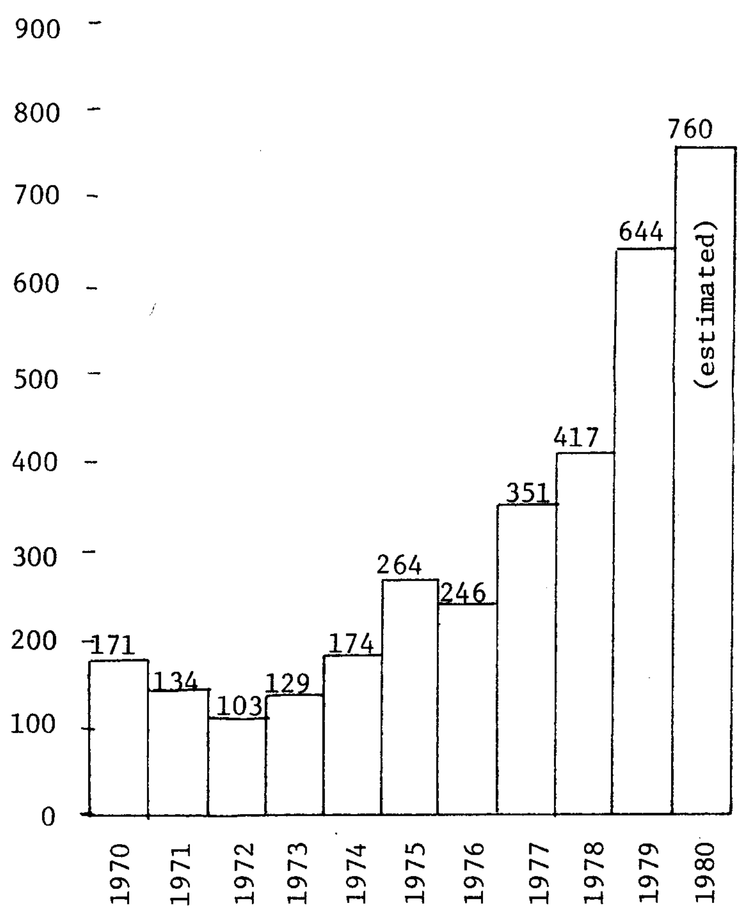


Figure 1. Number of permits issued annually to drill for oil and gas in North Dakota since 1970.

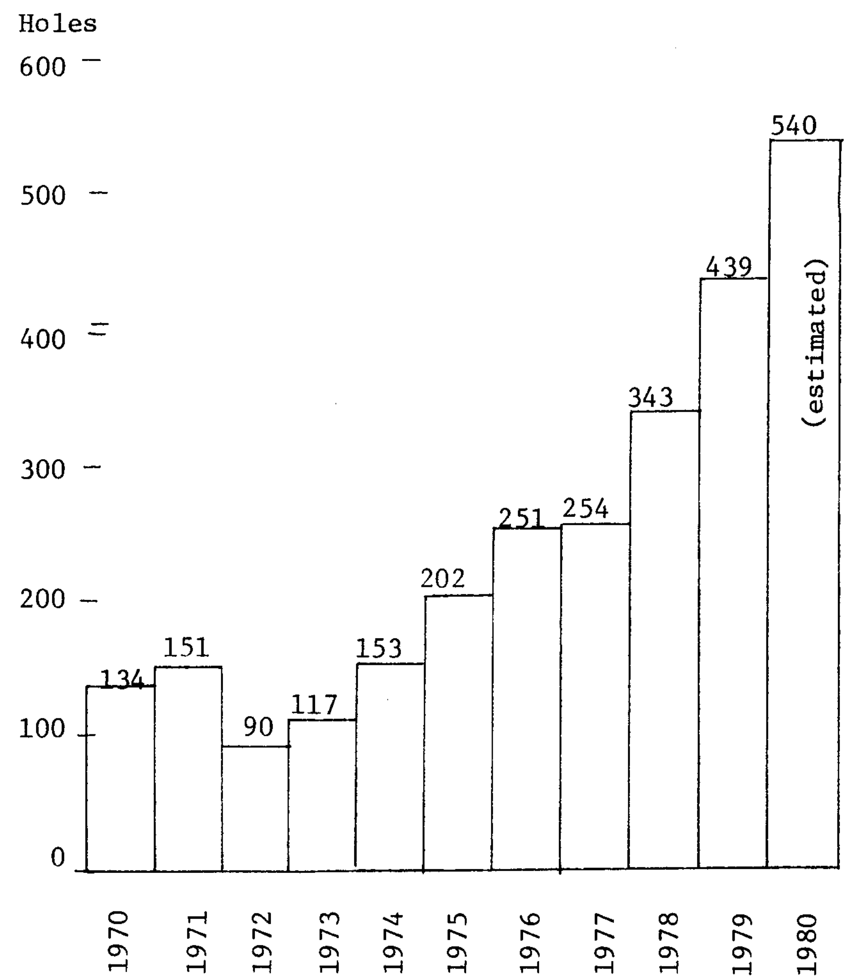


Figure 2. Number of holes drilled annually for oil and gas in North Dakota since 1970.

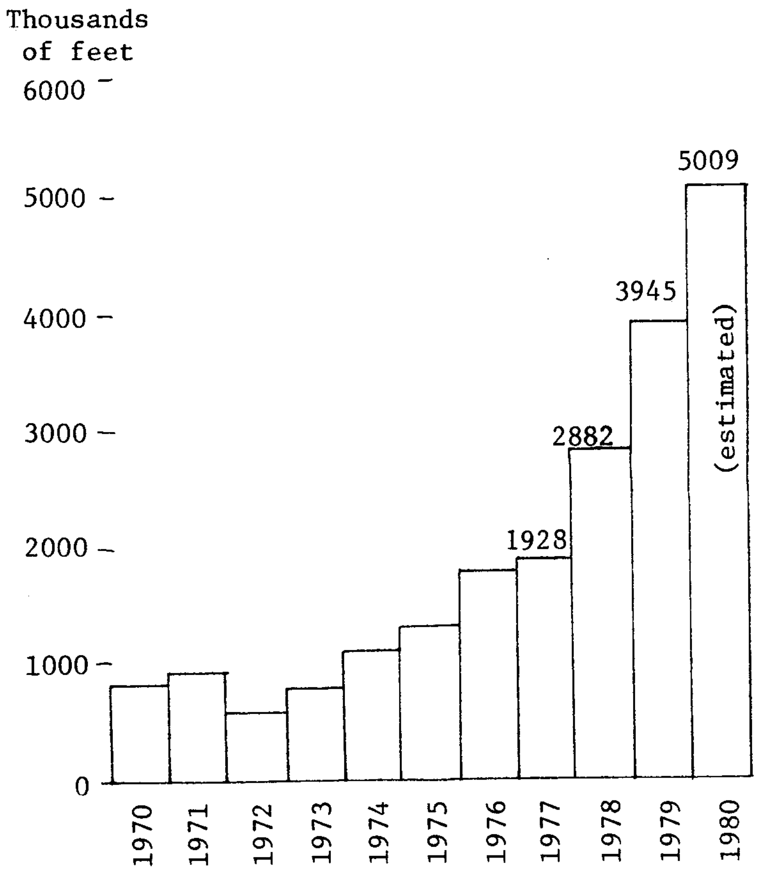


Figure 3. Number of feet drilled for oil and gas in North Dakota since 1970.

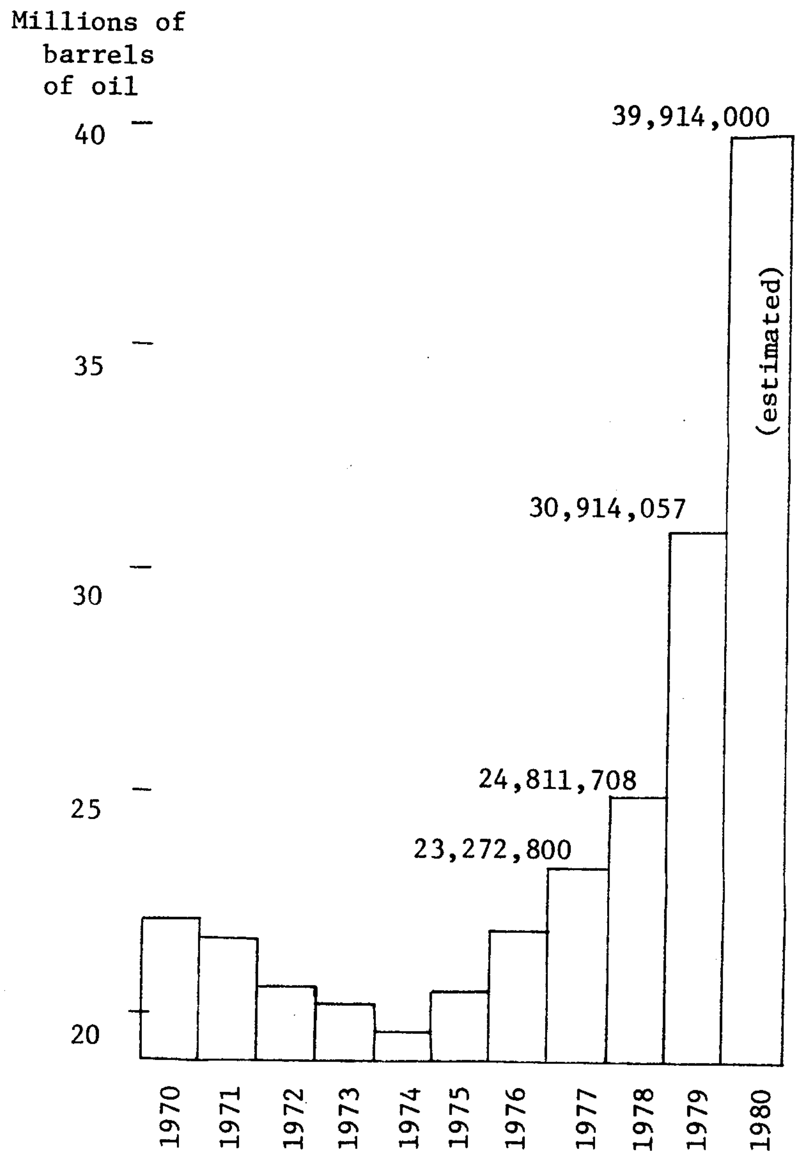


Figure 4. Annual crude oil production (barrels) in North Dakota.

LIGNITE PRODUCTION CONTINUES TO CLIMB--

North Dakota lignite coal production continues to rise steadily, although not at the rapid rate of oil and gas. During fiscal 1980 (July 1, 1979 to June 30, 1980), coal production by the ten companies now operating in the state was 16.8 million tons. These ten companies operate a total of 14 mines. The table on page 11 lists lignite coal production by county and company. Tonnage figures were supplied by the Office of the Tax Commissioner.

The editors of the Keystone Coal Industry Manual project an increase of 4.3 million tons in North Dakota's lignite coal production in 1981 (calendar year), so annual production should soon reach 20 million tons. Currently, about 12 states produce more coal than North Dakota. Kentucky led the nation in coal production in 1979 with about 140 million tons. That is nearly ten times North Dakota's production. In the Great Plains area, Montana has recently been producing about twice as much coal as North Dakota and Wyoming nearly 5 times as much. Much of Montana's and Wyoming's coal is bituminous and subbituminous coal, which has a somewhat higher BTU output and therefore commands a higher price than North Dakota's lignite. Cost per ton values are not entirely relevent for North Dakota's lignite coal because very little of it is shipped away from the mine site; nearly all of the state's lignite production is consumed by mine-mouth operations, and the coal is not marketed, except as a "finiahed product," electricity.

Although the steady rise in lignite production should continue in the years to come, the dramatic jump in production that has been projected for the mid 1980's is somewhat clouded with the future of the Great Plains Coal Gasification Plant in doubt. The gasification plant, which would produce about 125 million cubic feet of synthetic natural gas a day, was dealt a setback when a federal appeals court ruled recently that the Federal Energy Regulatory Commission acted illegally in authorizing shipment of SNG through regulated pipelines. The gasification plant will consume about 10 million tons of lignite annually if it is built.

TONS OF COAL SEVERED — FISCAL YEAR ENDED JUNE 30, 1980

COMPANY	ADAMS	BOWMAN	BURKE	GRANT	McLEAN	MERCER	OLIVER	STARK	WARD	WILLIAMS	TOTAL
Baroid Division NL Industries, Inc.	43,106.56										43,106.56
Baukol-Noonan			453,626				3,847,247				4,300,873
Consolidation Coal Co.						2,222,365	1,252,755		335,361		3,810,481
Coteau Properties						-0-					-0-
Falkirk Mining Company					2,591,854						2,591,854
Geo Resources, Inc.										87,803*	87,803*
Husky Industries								223,900			223,900
Knife River Coal Mining Company		2,936,996				1,081,104	538,735				4,556,835
North American Coal Corporation						1,209,359					1,209,359
Sprecher Coal Mine				4,690.7							4,690.7
TOTALS	43,106.56	2,936,996	453,626	4,690.7	2,591,854	4,512,828	5,638,737	223,900	335,361	87,803	16,828,902.26

*Covers quarters ended September 30, 1975, through June 30, 1980.

Source of information: Office of the North Dakota State Tax Commissioner

NORTH DAKOTA MINERAL TAX REVENUES--

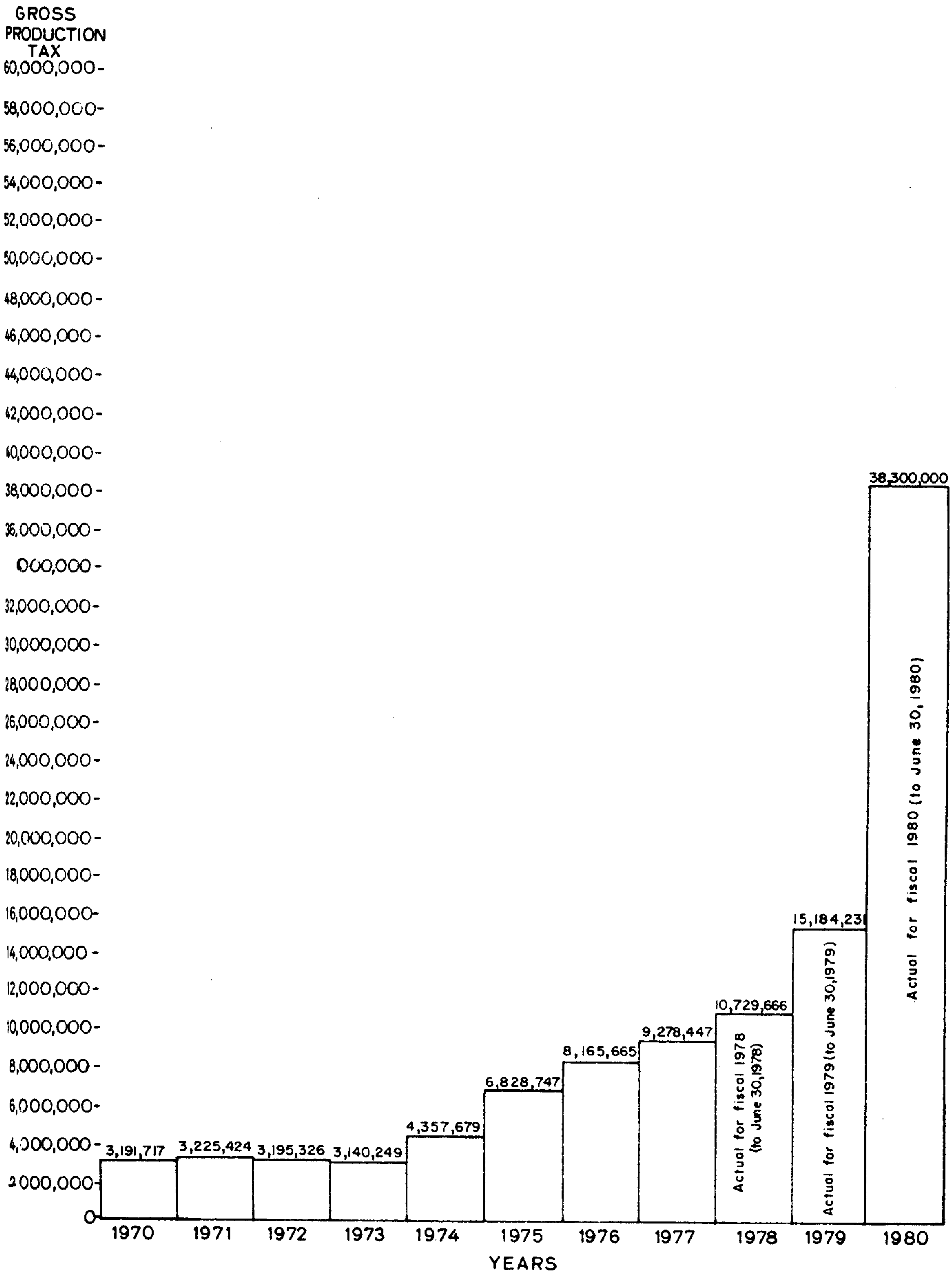
The impact that mineral revenues are having on North Dakota's economy is substantial. During fiscal year 1980 (July 1, 1979 through June 30, 1980), oil and gas gross production taxes totaled $38,300,000, up 152 percent over the previous fiscal year total of $15,184,231 (see the chart on page 13). The tax represents 5 percent of the value of crude oil and natural gas produced. Thus, the total value of oil and gas produced in fiscal 1980 on non-federal land was $766,000,000. The recently initiated 6½ percent extraction tax will result in a sizeable increase in tax revenues when it takes effect.

Oil and gas lease bonuses received by the State Land Department for the same period (fiscal 1980) totaled $46,176,465. This again is a 120 percent increase over bonuses received in fiscal 1979 in which $20,937,812 were realized in lease bonuses (I have not calculated rentals). The August and November lease sales have already brought in $34,195,149 in bonuses for fiscal year 1981 ($3,635,957 in August, 1980, and $30,559,192 in November). One more lease sale will take place in fiscal year 1981, that in May, 1981. There will be no sale in February due to the fact that North Dakota Legislature will be in session.

Similarly, the state's coal severance tax, which is currently $0.93 a ton, is contributing a substantial amount of revenue to the state. During the fiscal year 1980, for example, coal severance tax revenue was 14.6 million dollars.

Total income to the state from gross production taxes, lease bonuses and rentals, and coal severance taxes amount to well over a hundred million dollars for fiscal 1980, a significant contribution to the economic stabilty of the state and local governments. The total impact on state and local governments from the tax revenues related to oil, gas, and coal exploration and development is even greater when state taxes paid on royalties on production and mineral industry related salaries are included. Tax revenues derived from related activities (motel and restaurant receipts; construction; machinery repairs; etc.) result in a huge total tax impact from mineral industry related activities.

NET OIL AND GAS GROSS PRODUCTION TAX COLLECTIONS AND PROJECTIONS



SURVEY PROGRAMS--

The major current impacts on the Survey are energy-related, especially the recently expanded oil and gas exploration and development activities in the state. Energy-related stress also results from the renewed emphasis on developing the state's lignite resources, and to a lesser extent, exploring for nuclear fuels. The increasing impact of mined lands reclamation and associated producing facilities is also placing additional demands upon the Survey. Population growth and urban expansion resulting from energy development require new and more detailed geologic studies in areas such as construction conditions, aggregate mineral resources, groundwater resources, and waste disposal.

I recently tried to compile a listing of research programs and other projects on which Survey staff members are working. It wasn't an easy thing to do, I found, because everyone is involved in several separate projects, all of which are in varying stages of completion. Even though each of us is responsible for completing certain projects within specified time limits, we seldom dedicate all of our attention toward any one project for a prolonged period of time. The fact that we are a small organization enables us to operate in a reasonably "unstructured" manner, moving from one project to another as it becomes necessary.

The listing of specific research projects that follows should serve to give an idea of the type of studies in which our geologists and engineers are involved. Formal research projects include:

1. Studies of oil and gas carbonate reservoir origin and geology
2. Studies on the depositional systems of Paleozoic basin rocks
3. County groundwater studies
4. Geohydrologic studies of the effects of coal mining
5. An evaluation of geothermal resources
6. Studies of the environmental effects of geologic settings of various North Dakota communities
7. Studies of the stability of sanitary landfill systems
8. Correlation, geochemistry, and resource potential of Cenozoic rocks in North Dakota and adjacent areas
9. Compilation of stratigraphic correlation charts for the Committee on Correlation of Stratigraphic Units of North America
10. Development of computer-assisted data retrieval systems

Currently, our regulatory responsibilities include the following:

1. Regulation of oil and gas exploration, development, and production
2. Regulation of subsurface mineral exploration, development, and production
3. Regulation of coal exploration
4. Regulation of subsurface disposal and storage of materials including nuclear wastes.

The research and regulatory programs of the North Dakota Geological Survey revolve around our central goals--the acquisition of sufficient geological knowledge and data to assure the proper performance of our regulatory and advisory functions. Our activities are subject to constantly changing state, national, and international economic, social, and environmental events or concerns. For

ACTIVITIES OF GEOLOGICAL SURVEY/INDUSTRIAL COMMISSION

	YEAR										
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
OIL & GAS CASES HEARD / INDUSTRIAL COMMISSION	38	45	41	60	51	82	106	108	115	164	250
NEW PERMITS ISSUED FOR:											
OIL/GAS	171	134	103	129	174	264	246	351	417	644	760*
COAL						46	33	76	37	33	37
SALT							3	0	0	0	1
URANIUM							10	5	4	0	2
OIL & GAS WELLS COMPLETED	134	151	90	117	153	202	251	254	343	439	540*
NUMBER OF FEET DRILLED/ OIL & GAS (1000's)	873	979	606	814	1,139	1,348	1,802	1,928	2,882	3945	5009*
COAL TESTHOLES DRILLED						3,761	2,139	3,817	2,483	2,300*	2,200*
TEST HOLES FOR OTHER SUBSURFACE MINERALS:											
SALT							3	0	0	0	1
URANIUM							91	620	640	0	18

Estimated*

this reason, we must be a flexible organization, capable of moving quickly in response to these impacts to provide accurate geologic and engineering expertise.

A thorough understanding of subsurface geology, geohydrology, and geochemistry are vital to the proper discharge of our regulatory, compliance, and research responsibilities. Our on-going research programs assure an adequate understanding of the geologic factors affecting the activities we regulate.

GEOLOGICAL DEVELOPMENT AND ENERGY AND MINERAL RESOURCES OF THE WILLISTON BASIN (Lee Gerhard) --

(Editor's Note: The following abstract summarizes a speech by Dr. Lee C. Gerhard at the V. H. McNutt Colloquium on October 29, 1980 at Rolla, Missouri.)

The Williston Basin of North Dakota, Montana, South Dakota, and south-central Canada (Manitoba and Saskatchewan) is a major producer of oil and gas, lignite, and potash. Located on the western periphery of the Phanerozoic North American craton, the Williston Basin has undergone only relatively mild tectonic distortion during Phanerozoic time. This distortion is largely related to movement of Precambrian basement blocks.

Sedimentary rocks of cratonic sequences Sauk through Tejas are present in the basin. Sauk, Tippecanoe, and Kaskaskia Sequence rocks are largely carbonate, as are the major oil and gas producing formations. Absaroka and Zuni rocks have more clastic content, but carbonates are locally important. Clastics of the Zuni Sequence (Fort Union Group) contain abundant lignite. Tejas Sequence rocks are not significant in the production of minerals and energy, although glacial sediments cover much of the region.

Oil exploration and development in the United States portion of the Williston Basin in the time period 1972 to present has given impetus to restudy of basin evolution and geologic controls for energy resource locations. In consequence, oil production in North Dakota, for instance, has jumped from a nadir 19 million barrels in 1974 (compared to a previous zenith of 27 million in 1966) to 32 million barrels in 1979 and an estimated 38 million barrels in 1980. Geologic knowledge of carbonate reservoirs has expanded accordingly

Depositional environments throughout Sauk, Tippecanoe, and Kaskaskia time were largely shallow marine. Subtidal and even basinal environments were developed in the basin center, but sabkha deposits were abundant near the basin periphery. Evidence of subaerial weathering was commonly preserved in structurally high areas and on the basin periphery, especially in late Kaskaskia rocks. Some pinnacle reefs were developed in Kaskaskia time, morphologically similar to the Silurian pinnacle reefs of the Michigan Basin.

Clastic sediments were transported into the southern (U.S.) part of the basin during Absaroka time, a product of erosion of ancestral Rocky Mountain orogenic structures. Continental and shallow marine clastic sediments were deposited until deeper Cretaceous marine environments were established. Laramide orogenesis to the west provided detritus that was deposited in fluvial, deltaic, and marginal marine environments, regressing to the east. Major lignite deposits are part of this post-orogenic regressive rock body.

Major structures in the basin have ancient histories, many of them probably pre-Phanerozoic in origin. Reversals of structural movement on faults occur during Paleozoic events. Meteorite impact structures have been hypothesized in the basin, and some early Saukian structural complexity is seen.

A rapidly accumulating computerized data base in the North Dakota part of the basin is serving to establish the Williston Basin as a model for study of cratonic basin structural grain and evolution.

A POSSIBLE SOLUTION TO RECTANGULAR SPACING UNITS (Erling Brostuen) --

The designation of spacing units in the case of rectangular spacing such as 80-acre and 320-acre spacing, has been a source of contention in North Dakota since Beaver Lodge Field was spaced at 80 acres in the early 1950's. The problem does not exist in the case of square spacing such as 40, 160, and 640 acre spacing.

In some spacing and field rules' orders issued by the North Dakota Industrial Commission, spacing units were designated as running east-west, or north-south with well locations designated in the center of specific quarter quarter sections. This did not prove to be a solution as leaseholders and royalty owners alike frequently objected to the designated spacing unit, depending upon its effect on their participation in the production from the unit. In some cases, the Commission left the designation of the spacing unit to the operator drilling the well. This again was frequently objected to by adjacent leaseholders and royalty owners. In addition, the pooling statute placed the responsibility and authority with the Commission to pool all interests within a spacing unit in the event that voluntary pooling could not be achieved. Thus, numerous cases have been heard by the Commission to "force pool" all interests within a spacing unit.

Flexible well locations were first permitted by the Commission in some spacing and field rules' orders in the mid-1960's. The flexible well location provision allowed an operator to locate a well anywhere within a spacing unit, but with specific tolerances from the spacing unit boundary and minimum distances between wells permitted to, or producing from, the pool. The flexible well location provision was partly due to necessity as in the case of difficult terrain such as in the "badlands," and partly due to the reality that specific quarter quarter well locations did not take into account the geology of the area and the target formation. In most cases, the designation of the spacing unit was left to the operator of the well. The Commission, however, retained jurisdiction to designate spacing units in the interest of the protection of correlative rights if the unit did not coincide with the geological and physical nature of the pool, upon application by any interested party, after due notice and hearing. The problem of spacing unit designation continued to persist and interested parties would petition for a change in spacing unit designation.

Recently, the Commission has developed a system for the designation of spacing units while still retaining the flexible well location provision in the event of 80- and 320-acre spacing. The system provides that such spacing units shall be determined by the location of the well. The spacing units shall be in a direction so as to allow the first well in the section, in the case of 320-acre spacing, or in the quarter section, in the case of 80-acre spacing, to be nearest to the center of the spacing unit. Spacing units for wells being equi-distant from mid-section lines (320-acre spacing) or from mid-quarter section lines (80-acre spacing) shall be designated by the operator. The Commission, however, retains continuing jurisdiction, and in the event that spacing units formed by this system do not coincide with the geological and physical nature of the reservoir, the Commission may alter specific spacing units upon application by any interested party, after due notice and hearing.

The system is not expected to be a panacea for every problem related to 80-acre and 320-acre spacing, but hopefully, it will serve to diminish some of the controversy and the frequency of spacing unit related cases on the Industrial Commission dockets. It also demonstrates the Commission's continuing concern for the protection of correlative rights and the conservation of the crude oil and natrual gas resource.

RECENTLY RELEASED PUBLICATIONS--

Since our last Newsletter in June, the Survey has published the following reports:

Bulletin 70, Part III -- "Ground-water Resources of Dickey and LaMoure Counties, North Dakota" was prepared by C. A. Armstrong. The report is one of four parts dealing with the geology and groundwater flow systems in the two counties. It is a result of an investigation to determine the quantity and quality of groundwater available in Dickey and LaMoure Counties. Groundwater is available from glacial-drift and bedrock aquifers. The major glacial-drift aquifers, which range in depth from 0 to 300 feet, may yield as much as 1,500 gallons of good-quality water per minute. Groundwater is available from bedrock aquifers in generally smaller amounts than from the glacial-drift aquifers and this water is more highly mineralized than is the water from the glacial-drift aquifers. However, aquifers in the preglacial (bedrock) materials have a greater areal distribution than do those in the glacial drift. The report is 61 pages long and includes a map showing groundwater availability in the two counties. A geohydrologic cross section through LaMoure County is also included with the report. This report is available free of charge from the North Dakota Geological Survey.

Bulletin 76, Part II -- "Ground-water data for Billings, Golden Valley, and Slope Counties, North Dakota" was prepared by Lawrence O. Anna. The report is a compilation of groundwater data and it makes available the geologic and hydrologic data that were collected during the three-county investigation. It functions as a reference for the other reports, which deal with geology and hydrology. The report includes records of selected wells and test holes. Many of the test holes drilled by the North Dakota State Water Commission were converted to observation wells for periodic water-level measurements and water-quality sampling. The results of these measurements and sampling are included in the report. Also included in the report are water-level readings for a large number of selected wells that tap the major aquifers in the three counties. Most of the test holes drilled during the study have geophysical logs in addition to a description of the materials penetrated. The geophysical logs are extremely useful for geologic correlation purposes. This report is 241 pages long and includes one plate which shows the locations of wells and test holes in the three counties. It is available free of charge from the North Dakota Geological Survey.

Report of Investigation 70 -- "Geologic and Hydrogeologic Conditions Affecting Land Use in the Bismarck-Mandan Area," was written by Gerald H. Groenewold. As defined in this report, the Bismarck-Mandan area includes about 350 square miles, along both sides of the Missouri River. The report supplies detailed geologic materials maps and a series of land-capability maps to aid in future planning in the area.

All geologic materials were evaluated in terms of their engineering and hydrologic properties and mineral-resource potential. Hydrologic properties were obtained from well records and previous studies, engineering properties from foundation test borings. Flooding hazards, slumping hazards, river-bank instability, topography, glacial-boulder density, and soil characteristics were all considered. Based on the evaluations, maps delineating conditions affecting construction, waste disposal, and maps of groundwater resources were constructed for the Bismarck-Mandan area.

The report is 42 pages long, includes 5 figures, 2 tables, and 30 plates. It is available for $2.00 from the North Dakota Geological Survey.

Miscellaneous Series 58 -- "A History of the North Dakota Geological Survey," was written by C. B. Folsom, Jr. It provides a history of the development of the North Dakota Geological Survey from its inception in 1895 through 1978. For its first 58 years, the Survey operated with a shortage of funds. From 1923 to 1935, the State Legislature made no appropriations at all for the Survey. However, Dr. A. G. Leonard managed to keep it operating with funds he was able to obtain from other sources. After oil was discovered in 1951, the Survey expanded rapidly. The report consists of 51 pages of text and numerous pictures. It is available from the North Dakota Geological Survey for $1.25.

Educational Series 13 -- "Petroleum--A Primer For North Dakota," was written by Erling A. Brostuen. This publication, which should be released early in 1981, is a nontechnical discussion of the origin, exploration for, and production of crude oil and natural gas in North Dakota. The publication was prepared especially for the layman and includes a discussion of the regulation of the petroleum exploration and producing industry in the State.

Educational Series 8 -- "Guide to the Geology of Northwest North Dakota"
Educational Series 9 -- "Guide to the Geology of Southwest North Dakota"

These two reports, both by John P. Bluemle, were published in 1975, but because we had run out of copies and demand has continued, we have revised and reissued both reports. Originally prepared for the North Dakota Department of Public Instruction, these publications provide a summary of the general geology and roadlogs for field trips. Each report includes a colored geologic map of the area it describes. Ed 8: 38 pages; Ed 9: 37 pages. Both reports are available free of charge from the Survey.

The Official Oil Production Statistics and Engineering Data for the Second Half of 1979 contains the oil and water production by individual wells along with other pertinent information. This report is 338 pages long and is available for $5.00.

Open-File Report 80-867 -- "Lignite Drilling During 1979 in Ward, Mountrail, and Divide Counties, Western North Dakota." This report includes maps showing locations, logs (gamma ray, density, self-potential, and resistivity) and sample descriptions for test holes at 118 sites. Total drilling was 46,251 feet with 17 sites in Ward County, 32 sites in Mountrail County, and 69 sites in Divide County.

The report can be obtained from the North Dakota Geological Survey for $25.00.

PAMPHLET OF SEISMIC EXPLORATION AVAILABLE--

The North Dakota Natural Resources Council has published a pamphlet containing professional and legal information on seismic operations. The pamphlet, which was prepared by NDGS geologist Erling Brostuen, is entitled "Ever Wonder About Seismic Exploration?" It is intended to facilitate understanding on procedural matters regarding proper seismic operations.

A nontechnical explanation of mineral rights, the methods of seismic exploration commonly used, and the regulation of seismic exploration are all included in the booklet. The booklet notes that one of the reasons the Williston Basin is such an active petroleum region is because large areas of relatively unexplored land still remain. North Dakota's 30 percent success ratio for exploratory wells compares to a national success ration of 10 percent in 1979. The high success ratio in the Williston Basin can be attributed largely to the advancement in geophysical exploration technology.

The pamphlet should be useful to surface owners. It was paid for by the International Association of Geophysical Contractors and the North Dakota Division of the Rocky Mountain Oil and Gas Association. It can be obtained from our office free of charge or from the Natural Resources Council.

PERMITTING ACTIVITY IS INTENSE--

It is difficult to be certain exactly how many different oil companies are operating in North Dakota because some companies are subsidiaries or spin-offs of other, larger operators. Even so, it is possible to get a good idea of the level of interest by tabulating the names of companies that have applied for drilling permits.

Approximately 110 different companies applied for the 644 permits that were issued in 1979. As you might expect, some of the larger companies, a half dozen or so with over 30 permits each, accounted for about a third of the permits issued. The remainder of the permits went to companies applying for less than fifteen permits each, and 43 companies received only one permit each.

Through December 10, 1980, at least 56 companies that were not active in North Dakota last year have applied for permits to drill this year. Conversely, 41 companies that permitted in 1979 have not yet done so in 1980. As of December 10, a total of 133 different companies have applied for drilling permits in North Dakota this year.

GREENHORN EXPOSURE FOUND IN NORTH DAKOTA--

Survey geologists recently identified a small exposure of Cretaceous Greenhorn Formation shale along the Pembina River in Pembina County. Prior to the discovery of this outcrop, the Cretaceous Carlile Formation shale had been considered to be the stratigraphically lowest geologic formation exposed in North Dakota.

The Greenhorn shale exposure was first noted by Mr. Robert Wortman, a Corps of Engineers geologist, who contacted Survey geologists to verify its age. The exposure is located along the north (left) bank of the Pembina River (SW¼ SW¼ NW¼ Sec. 3, T163N, R56W) at an elevation between 960 and 980 feet. It occurs at the location of the proposed Pembilier Dam site, which is planned to dam the Pembina River forming a reservoir upstream from that point.

SURVEY PROFILES--

In this issue of the Newsletter, I've included short profiles of three key people who have been with the Survey for a long time. These are some of the people who "make things work."

CLARA LAUGHLIN

Clara Laughlin is the Survey's Administrative Officer. Her responsibilities include management of the Administrative Division, budget preparation, and she has had charge of implementing and coordinating the System 6 hookup with the University Computer Center. This is enabling the new Data Processing Analyst to computerize geological and engineering data, a long-time goal of the Survey. Clara provides a central focus of coordination and policy leadership which supports the two technical divisions, Engineering and Geology, and makes it possible for them to accomplish their objectives economically and efficiently.

Clara has over 30 years of experience in North Dakota State service. Prior to coming to the Survey in 1965, she was employed by the Registrar's Office at the University of North Dakota.

Clara graduated from Grand Forks Central High School and she has a B.A. and an M.A. From UND in Business Education. She and her husband Joe have one son, two daughters, and two grandchildren.

SHEILA O'SHAUGHNESSY

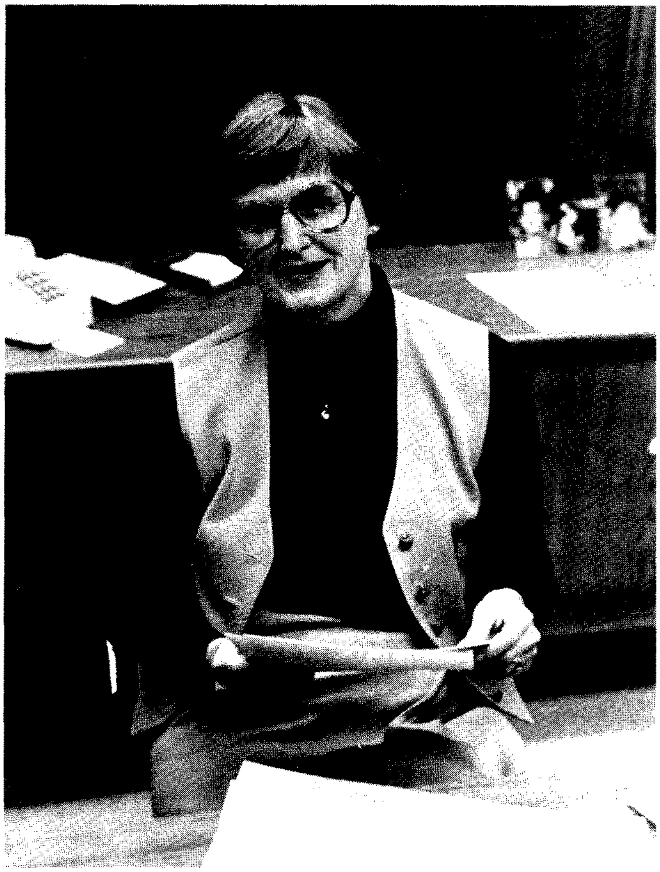
Sheila O'Shaughnessy has been the Engineering Division's Statistical Clerk since 1974. Prior to that time (from 1969 to 1974) she was employed by the Survey as a Secretary in the Engineering Division, then as a Bookkeeper. Sheila is the vital source of information for production statistics and data in the Engineering Division. She is responsible for the preparation of the monthly production and the six-months production report, and she is also working on the implementation of computerizing this data.

Sheila and her husband Robert have three children, a married daughter living in Hazen, North Dakota, a single daughter attending UND, and a son attending Grand Forks Red River High School.

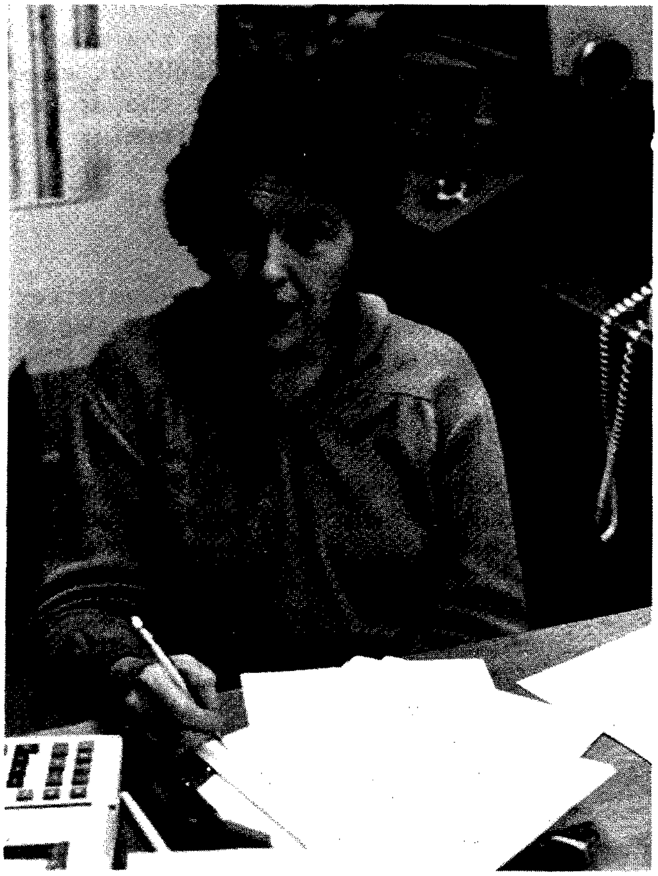
KATHY MILLER

Our Composer Technician, Kathy Miller has been with the Survey since 1970, except for a brief period in 1972 when she resigned to travel in Europe. Kathy works with our IBM Office System 6. She is currently working with our Data Processing Analyst in implementing the computerization of production statistics and supervising the operation of the System 6 in preparing NDGS publications for printing.

Kathy graduated from Larimore High School and from Wahpeton State School of Science in Computer Programming.



Clara Laughlin



Sheila O'Shaughnessy

Kathy Miller

CARBONATE STUDIES--

Our carbonate core and sample study laboratory, established in 1976, is seeing increasing use and results. Projects underway by Survey staff and University faculty and students include studies of many aspects of carbonate geology. Survey geologist Randy Burke is conducting a study of spheroidal sedimentary structures; Duperow Formation carbonates from the Tree Top, Big Stick, TR, Four Eyes, Whiskey Joe, White Tail, Fairfield, and Elkhorn Ranch Fields; and ancillary Holocene studies of bank barrier reef development in the Virgin Islands, hurricane development of a barrier island of Florida, and the effects of Hurricane Greta on the Belize Barrier Reef communities.

UND graduate students are studying a variety of carbonate units in the Williston Basin. Tom Obelenus is working on the Frobisher-Alida and also studying pisolites in Carlsbad and their relevance to Mississippian porosity formation in North Dakota. Nancy Perrin is studying Winnipegosis carbonates; Diane Catt is studying the Ratcliffe; Fred Lobdell the Ashern; Peter Loeffler the Birdbear; and Chuck Labue the Interlake.

One of the main objectives of our Carbonate Studies program is to arrive at a better understanding of modern carbonate-forming environments. This should enable us to better interpret comparable ancient environments; understand their lithology, geometry, etc.; and thereby more accurately predict the occurrence of hydrocarbons in the Williston Basin.

(Editor's Note: The three abstracts that follow summarize some of our studies on geohydrologic and hydrogeochemical properties of Great Plains coal, groundwater, overburden materials, power plant waste products, and the effects of surface mining. References to the entire articles are included at the end of each abstract).

POTENTIAL EFFECTS ON GROUNDWATER OF FLY ASH AND FGD WASTE DISPOSAL IN LIGNITE SURFACE MINE PITS IN NORTH DAKOTA (Gerald Groenewold and others) --

Increased reliance upon coal-burning power plants is resulting in the generation of large quantities of waste products. Fly ash and flue-gas-desulfurization (FGD) waste constitute the two major by-products of coal-burning power plants in the U.S. and at mine-mouth power stations a common method of disposal of these wastes operations is by emplacement in surface mine pits.

In this study, initially funded by EPA and presently by DOE, the potential impacts of surface mine pit disposal of fly ash and FGD waste at the Center Mine near Center, North Dakota, are being evaluated. The FGD waste at the Center site is generated by using the highly-alkaline fly ash as the SO_2 sorbent. The research involves field studies, laboratory studies, and computational geochemical studies to determine the potential for FGD waste and fly ash to affect groundwater quality.

FGD waste from North Dakota lignite, when placed in contact with water in various types of laboratory experiments, produces leach fluids with high SO_4, Mg and Na concentrations and pH values in the range of 7.0 to 8.5. Toxic metal and non-metal concentrations are generally not significantly in excess of drinking water standards. The concentrations of SO_4 and Ca are limited by the solubility of gypsum in conjunction with the degree of ion pairing between the major cations and sulfate. Highest total dissolved solids occur when Na and Mg are present as soluble salts.

In contrast, North Dakota lignite fly ash produces leach water that is potentially toxic because it has a pH commonly between 11 and 13 and contains concentrations of As and Se which exceed Primary Drinking Water Standards by a maximum factor of 15 and 35, respectively. Analyses of groundwater samples from piezometers in unmined areas, in spoil with no buried waste and in spoil with waste have provided confirmation of the expectations of groundwater quality degradation based on the laboratory experiments. Piezometers in and very near zones of buried fly ash yielded severely contaminated waters with high-pH and high concentrations of As, Se and Mo, whereas water from piezometers in spoil with FGD waste contained high SO_4 and cation concentrations but showed no significant quality deterioration due to As, Se, Mo or other toxic metals. Groundwater influenced by FGD waste is similar to groundwater in some areas of spoil without waste, where SO_4 and total dissolved solids concentrations are high. At present the areal extent of groundwater contaminated by FGD waste or fly ash at the Center site is small, but will increase gradually as a result of groundwater flow and as a result of continued waste disposal.

Environmentally safe disposal of fly ash and FGD waste in surface mine pits will require careful site selection and selective placement of wastes and the various overburden materials.

The complete paper dealing with fly ash and FGD waste disposal is published in the Proceedings FGD Symposium, held in Houston, Texas from October 28-31, 1980. Authors: Gerald H. Groenewold, John A. Cherry, Oscar E. Manz, Harvey A. Gillicks, David J. Hassett, and Bernd W. Rehm.

HYDRAULIC PROPERTIES OF COAL AND RELATED MATERIALS, NORTHERN GREAT PLAINS (Bernd Rehm, Gerald Groenewold, and Kevin Morin)--

The hydraulic properties (hydraulic conductivity, specific storage and porosity) of coal and the sediments that surround the coal must be known or estimated to properly evaluate the environmental impact of coal strip mining on groundwater flow systems. Published and unpublished data have been summarized from five study areas in North Dakota, three areas in Wyoming, two areas in Montana and two study sites in Alberta. Coal and sand beds form important aquifers in the region. Both materials have hydraulic conductivities of about 2×10^{-6} $m \cdot s^{-1}$ and specific storage values on the order of 5×10^{-6} m^{-1}. Aquitards in the region consist of clayey silt to clay bedrock and pebble-loam (in parts of the region). The aquitards are fractured to varying degrees resulting in a wide range of measured hydraulic conductivity values. The aquitards are, in general, 100 to 1,000 times less permeable than the aquifers. Specific storage values of the aquitard material is on the order of 3×10^{-4} m^{-1}. The hydraulic conductivity of strip mine spoils has a six order of magnitude range with a mean of 8×10^{-7} $m \cdot s^{-1}$. Variability is due to a number of factors including spatial variation of overburden lithology, method of spoil handling and contouring and time of year during which the spoil is handled. The hydraulic conductivity of the coal shows wide spatial variability within a given mine site. Variability of coal hydraulic conductivity between mines within North Dakota is less than within a given mine. Within the Northern Great Plains the permeability of coal may increase slightly from east to west.

The complete paper dealing with hydraulic properties of coal is published in the November-December, 1980 issue of Ground Water (vol. 18, no. 6), pages 551-562. Authors: Bernd W. Rehm, Gerald H. Groenewold, and Kevin A. Morin.

POTENTIAL HYDROGEOCHEMICAL IMPACTS OF SURFACE MINING IN THE NORTHERN GREAT PLAINS (Gerald Groenewold and others)--

Hydrochemical data from proposed surface mining sites in North Dakota, Montana, Wyoming, and Alberta indicate much regional similarity in chemical characteristics of shallow groundwater. $SO_4^{=}$ and HCO_3^- are commonly dominant anions. Na^+ and Ca^{++} are generally the dominant cations. The pH of the groundwater normally ranges from 7 to 9. The electrical conductance of the shallow groundwater typically ranges from 500 to 4500 μS. Groundwater at depth is generally of the Na-HCO_3 type. A hydrogeochemical model based upon mineralogical data and unsaturated and saturated-zone hydrochemical characteristics has been developed for this region. Critical hydrogeochemical processes include: oxidation of organic matter, pyrite oxidation, carbonate-mineral dissolution (mainly calcite), gypsum precipitation and dissolution, cation exchange, and sulfate reduction. Mineralogical variability results in significant differences in groundwater quality within and between proposed mining sites. Mineralogical variability is largely dependent upon the original depositional setting of the overburden sediments.

The hydrogeochemical model suggests that the potential for chemical degradation of groundwater is severe in certain mine settings in the Northern Great Plains. The potential for generation of highly mineralized groundwater in postmining landscapes is particularly great in areas where unoxidized pyritic and sodium montmorillonitic overburden is emplaced in the near-surface weathering zone.

Sulfate concentrations in spoils in the Northern Great Plains range as high as 10,000 mg/L in areas of sodic-pyritic overburden. Sodium concentrations in these settings range as high as 3500 mg/L. Degradation of groundwater quality in post-mining settings can be minimized if key mineralogical variables, as a function of the original depositional settings of the sediments, are understood and integrated within the framework of mine design.

The complete paper dealing with hydrogeochemical impacts of surface mining is published in the Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, University of Kentucky, Lexington, Kentucky (December 1-5, 1980), pages 465-474 of the volume. Authors: G. H. Groenewold, B. W. Rehm, J. A. Cherry, R. L. Koob, S. R. Moran, C. D. Palmer, and W. M. Peterson.

A SHORT SKETCH OF NORTH DAKOTA'S GEOLOGIC HISTORY--

(Editor's note: This article is adapted from a talk I gave last summer to a group of high school teachers. The talk was illustrated with slides, which aren't included here, of course. I intended that the material should not be technical, but even so, I had a lot of explaining to do afterwards. Readers who prefer a more concise summary of the evolution of the Williston Basin should read the article by Dr. Lee C. Gerhard that I have included on page 16 of this Newsletter.)

This place we now call North Dakota has been around for many millions of years, but it was not always the way it is today. Throughout most of our earth's history, even the most astute observer could not have detected so much as a glimmer of resemblance between our Flickertail State and the small portion of the earth that underwent uncounted geologic changes over the millenia to evolve into the land we know today.

For almost a quarter of its history, over a billion years, the earth's surface was probably molten rock, shrouded in a volcanic atmosphere of steam and assorted noxious gases such as methane, ammonia, and carbon monoxide, fit for nothing you or I can even imagine. Then, a few billion years ago, things started to cool off and settle down a little, even though the solid crust of land floated around over the surface of the globe for another three billion years or so, and it still does. The part of the crust that was to become North Dakota ranged at times from the poles to the equator.

About a half billion years ago--geologists have settled on a figure of something like 550 million years--North Dakota was part of a vast sea, a warm, tropical ocean, that supported some primitive life--microbes, some worms perhaps, and a little later, trilobites and their cousins--nothing really exciting or very advanced. If there was any land here, nothing lived on it.

About the same time, a sort of imbalance developed in the earth's crust over the area which is North Dakota, and the floor of the sea began to sink in places. It sank especially in western North Dakota and, as it did so, sediment from nearby upland areas was washed into the water by streams; lime deposits and coral reefs built up in the water; and layers of shale, sandstone, and limestone formed at the bottom of the sea.

This imbalance produced the depression that geologists call the "Williston Basin." The sinking was an "on-again/off-again" thing. At times the land would rise a little so that the sea drained from the area for a few tens of millions of years. During such unflooded intervals, different kinds of sediments were deposited; potash and salt for example, or else the areas were eroded and sediments washed to the seas in other places, just as today they wash from North Dakota to the ocean down the Missouri and Red Rivers.

All of this time, life evolved slowly, becoming more complex and diverse. Descendants of fish living 400 million years ago crawled out onto the land to become amphibians. Reptiles and dinosaurs developed about 200 million years ago and mammals and birds 100 million years ago. Ferns evolved into conifers, then came the deciduous trees, and finally the grasses.

Many of the plants and animals that evolved and grew in the water and on the swampy lands around the Williston Basin for much of the last 500 million years, grew, died, and sank to the bottom in the mud. They were covered by more mud; by more organic debris.

The weight of the great thicknesses of sediment--mud, sand, and limestone that built up on top of the organic-rich sediments--literally "squeezed" the material (petroleum or "rock oil") into more porous rocks nearby so that it collected in the more open-spaced (permeable) sandstone and limestone beds. It is from these layers that we pump oil in western North Dakota today.

The layers of strata in the Williston Basin became warped and folded in places. One such upfolding of rocks is known as the Nesson Anticline. The oil, being lighter than the salt water that occurs with it, tended to rise to the top of the anticline. In this way oil became concentrated in certain places. It is places such as these that petroleum geologists hunt for; places where oil and gas may be found.

Climates changed repeatedly through time as the continents, pieces of the earth's crust, "floated" over the surface of the globe. Geologists refer to this movement of land masses as "continental drift." Whenever the part of the North American continent we call North Dakota drifted over an equatorial region, tropical or near-tropical climates resulted. When it drifted to cooler regions of the globe, the climate was, accordingly, cooler.

The entire earth today is considerably cooler than it was during most of its history. Our modern, worldwide cooler climate (we may now be enjoying an interlude in a prolonged "Ice Age") is apparently being caused by the fact that the Antarctic continent, a large piece of the earth's crust and one of its major "plates," has drifted over the south polar region. The location of this large land mass over a cold region has affected world climates, causing a kind of "super-cooling." We can probably expect recurrences of the glaciations that have characterized our climate for the past three million years until the Antarctic continental plate "floats" away from the south pole.

But let's go back about 100 million years again, to a geologic time known as the Cretaceous Period. During Cretaceous time, much of North Dakota was still covered by a warm, shallow sea. In the western part of the state, this sea was gradually becoming filled with sediment carried by rivers and streams flowing from the "brand new and rising" Rocky Mountains. The sediment built up on floodplains and deltas in the Cretaceous seas, and it continued to accumulate during Tertiary time until about 50 million years ago. Lush vegetation growing on the deltas was repeatedly buried by sediment as the streams shifted course, covering the thick accumulations of dead plants with layers of silt and sand.

In some places, whole trees were buried by the sediment. Some of these trees later became petrified as mineralized groundwater circulated through them replacing the woody cellulose with mineral crystals. We see these petrified stumps and logs in many places in western North Dakota today, especially in the badlands.

In other places, the layers of buried plant debris were transformed to lignite coal. The coal didn't form overnight. It may have taken several thousand years to build up a ten-foot layer of plant debris, and then even this layer was compacted into a one- or two-foot-thick seam of coal as more sediments were piled on top of it. Some western North Dakota coal seams are over 30 feet thick, so it is easy to see that long periods of time were required to build up the coal resources we are mining today. North Dakota's lignite resource amounts to about 350 billion tons. Of this, perhaps 15 billion tons are economically mineable, using strip mining techniques.

Since the time the lignite was deposited, we have seen a gradual cooling of our climate as well as a long period of erosion. The cool climate and the erosion both continue today. Throughout most of this long period of cooling, rivers and streams flowing eastward from the rising Rocky Mountains eroded material from the area east of the mountains and gradually formed a broad east- to northeast-sloping plain. Over much of eastern Montana and the Dakotas, this plain had a thin covering of gravel.

The prolonged cooling spell that began about 40 million years ago, at the end of the Eocene Epoch, eventually led to the beginning of the Ice Age about 2½ to 3 million years ago. By the time the Ice Age began, North Dakota was a gently rolling plain with a few scattered buttes and drainage dominated by several north- and northeast-flowing streams and rivers. The whole state drained toward Hudson Bay.

Our modern North Dakota landscape was shaped by glacial processes and by processes indirectly related to glaciation. Nearly all of the hills and valleys northeast of the Missouri River were built by glaciers and by meltwater flowing from the glaciers or ponded in huge lakes. Although most of the landforms southwest of the river were not formed by the ice itself, they were strongly influenced by events that occurred during the Ice Age, especially by the increased precipitation and erosion. The Badlands are located in an area that was never glaciated, but they were eroded after the Ice Age began, in response to drainage changes wrought by glaciation. The Missouri River valley is also a product of glaciation.

I have touched on only a few aspects of our geology. The reddish layers of scoria, so apparent throughout western North Dakota; the incredibly flat and fertile Red River Valley in the east; the eskers, the drumlins, and all the other glacial landforms; all of these deserve explanation, but space and time are short. North Dakota's geology is as diverse as the geology of any mountain range, any sea floor. It is the product of several billion years of geologic processes that continue today and will continue, regardless of man's actions.