NEWSLETTER
NDGS

A publication of the
North Dakota Geological Survey
University Station
Grand Forks, North Dakota 58202
Phone: (701)777-2231

CONTENTS

JUNE, 1978

CURRENT SURVEY ACTIVITIES--

Current Survey studies will require varying amounts of time to complete. Most of the county groundwater studies already underway should be finished in approximately five years. Coal evaluation studies are ongoing and may continue indefinitely, depending on funding and staff resources. Studies on surface mine reclamation procedures now underway will require several years to finish; we may go into greater detail on these studies.

This coming summer field season, Survey geologists expect to continue their geologic studies in several areas. We will continue our cooperative (with the State Water Commission and the U.S. Geological Survey) studies of the geology and groundwater resources of the state. Ken Harris expects to map Bottineau County. He is also drilling testholes in the glacial sediments in various parts of the state as he continues his work on the glacial stratigraphy of North Dakota. Alan Kehew may map parts of Ward and Renville Counties as well as study the geology of the Minot urban area in detail. John Bluemle plans to field check parts of Ransom, Sargent, McHenry, and Sheridan Counties this summer with the expectation of completing reports on these areas next winter.

We expect to continue our evaluation of existing sanitary landfills for the State Health Department and, depending on the availability of federal funding and time, we plan to begin a study of pits, ponds, and lagoons, also in cooperation with the State Health Department. Alan Kehew attended a three-day geophysical training session in Baraboo, Wisconsin, in May to learn more about operating a new earth resistivity meter being purchased for the NDGS by the Division of Solid Waste Management of the State Health Department. Alan will use the instrument in his investigation of waste disposal sites. Earth resistivity is a method of investigating subsurface materials. An electrical current is passed through the ground by means of electrodes. By measuring the voltage across two other electrodes, the resistivity (resistance to current flow) of the materials can be determined. In areas where some additional geologic information is available, the method can be quite useful to fill in gaps between existing drill holes. The method can also be used to detect contaminated groundwater, which usually has a lower resistivity than does the uncontaminated groundwater in an aquifer.

Our evaluation of lignite resources, conducted by Kelly Carlson with the cooperation of the U.S. Geological Survey, will continue in several counties, although approximately two-thirds of it will probably be concentrated in Burke and McLean counties.

We will begin compiling the Quaternary geology of the state at a 1:1,000,000-scale as part of the new U.S. Geological Survey Quaternary Map of the United States. This work is being done by Lee Clayton of the UND Geology Department, and by Alan Kehew, Ken Harris, and John Bluemle of the NDGS. We hope to have the first sheet, which includes the largest portion of glaciated North Dakota, compiled by the end of the year.

For the past several years, Gerald Groenewold has been conducting studies related to lignite mining, reclamation of spoils, etc. A grant for up to ten years from the Falkirk Mining Company will enable us to study groundwater recharge through reclaimed spoils. Another study, the second phase of a study of the Falkirk area dealing with the effects of strip mining on groundwater supplies, will begin on July 1 and last through 1981. The final report on the first phase of this study is nearing completion. A U.S. Bureau of Mines-funded project designed to determine the causes of instability in strip-mine spoils will be expanded from the existing site at the Indian Head Mine to include a test site at the Center Mine.

As coal mining increases, reclamation permitting activity will also increase. Although we are responsible only for permitting of coal exploration and not for reclamation activities, which are regulated by the Public Service Commission, considerable geological input will be required of the Survey by the Commission. In addition, increased exploration for other subsurface minerals will increase the Survey's activities correspondingly. The NDGS is responsible for the reclamation of lands mined for subsurface minerals other than coal.

Erling Brostuen continues his duties as Assistant to the State Geologist, handling much of the Survey's involvement with federal and other state agencies as well as representing the NDGS at Industrial Commission hearings and at Natural Resources Council meetings. Erling responds to many of the environmental impact statements that the Survey receives. He expects to spend several weeks in the field this summer investigating the uranium potential in western North Dakota.

Sid Anderson has co-authored several papers that will be presented later this summer in Billings at the Williston Basin Symposium. One dealing with the geology of the Glenburn Oil Field is co-authored with and will be presented by Lee Gerhard; another, on the Carrington shale, will be presented by Peter Bjorile (see the article in this Newsletter about recent UND geology theses). These reports will be published in the 1978 Montana Geological Society Guidebook. Sid is also finishing a paper on North Dakota and Montana potash potential, which will be published by the AIME in a special issue devoted to potash.

NEW PUBLICATIONS--

The last Newsletter in which I listed recent NDGS publications was a year ago. Since then we have published several more reports.

Three groundwater resources studies were published. These reports deal with Cavalier and Pembina Counties (Part III, Bulletin 62); Griggs and Steele Counties (Part III, Bulletin 64); and Emmons County (Part III, Bulletin 66). The reports describe the general availability of groundwater and provide information on quantity and quality with an emphasis on the major aquifers. Aquifer discussions include lithologic descriptions and areal extent. They also include information on present groundwater use.

Groundwater basic data reports were published for Dickey and LaMoure Counties (Part II, Bulletin 70) and Morton County (Part II, Bulletin 72). These reports include geologic and hydrologic data, water level measurements, lithologic and geophysical logs, chemical analyses, and particle-size analyses.

Report of Investigations 59, entitled "The Slope (Paleocene) and Bullion Creek (Paleocene) Formations of North Dakota," was written by Lee Clayton, C. G. Carlson, Walter L. Moore, Gerald H. Groenewold, F. D. Holland, Jr., and Stephen R. Moran. The authors discuss the problems involved in correlating the Ludlow and Tongue River Formations between North Dakota and adjacent areas. The report introduces and defines two new formation names, the Slope Formation and the Bullion Creek Formation. The Slope Formation (Paleocene) consists of strata that have been considered to be the upper part of the Ludlow Formation or part of the Tongue River Formation. The Bullion Creek Formation (Paleocene) consists of strata that have been considered to be equivalent to either the entire Tongue River Formation or to the lower, middle, or upper part of the Tongue River Formation.

Report of Investigations 63, entitled "Geologic, Hydrologic, and Geochemical Concepts and Techniques in Overburden Characterization for Mined-Land Reclamation," was written by Stephen R. Moran, Gerald H. Groenewold, and John A. Cherry. The authors discuss the distribution of geologic materials; some of the geochemical properties of these materials; groundwater-flow patterns; and chemistry of groundwater at five existing or proposed coal mine sites in west-central North Dakota. The data have been used to identify the factors that control the distribution of salinity in soil and water in the overburden. These factors have an important influence on soil development and plant growth and, thus, wide application design.

The Official Oil Production Statistics and Engineering Data for the Second Half of 1976 was published in July, 1977. This report contains the oil and water production by individual wells as well as other pertinent information.

Finally, the revised Rules and Regulations for the Conservation of Crude Oil and Natural Gas have been printed and are now available. These revised rules and regulations, recently adopted by the Industrial Commission, incorporate a number of changes, amendments, and additions.

UNPUBLISHED INFORMATION--

Often, research of various types done by Survey geologists is, for one reason or another, not formally published. Some of this information will eventually be published, but, in other cases, it may represent the results of short-term projects that are not noteworthy enough or of sufficient general interest to warrant the expense of publication.

These unpublished materials may consist simply of a listing of data of some kind or they may have been compiled into a formal Open-File report.

Our Open-File Reports are listed in the NDGS List of Publications and they differ little from our regular publications except that, in our judgment, the potential readership is so limited that we decided not to go the expense of publishing them. We currently list three formal Open-File Reports:

OF-1 Groundwater Pollution Hazard Near Sanitary Landfills on the Glaciated Plains, North Dakota--A study of the Langdon, North Dakota sanitary landfill, by B. Michael Arndt. 1977

OF-76-869 Preliminary Report on 1975 Drilling of Lignites in Western North Dakota: Adams, Bowman, Dunn, Hettinger, McLean, Mercer, Oliver, Slope, and Williams Counties. 1977

OF-77-857 Preliminary Report of 1976 Drilling of Lignites in Western North Dakota: Adams, Billings, Dunn, Hettinger, McKenzie, Mercer, Morton, Oliver, Slope, and Stark Counties. 1978

The important thing to remember is that, with rare exceptions, the information contained in any unpublished materials is available in some form for inspection by anyone. We are attempting to somehow collect in one place or at least catalog as much of this information as possible so it will be more accessible to users. It may be possible to make photocopies of the information and provide it by mail for the cost of copying. Sometimes though, depending on the contents of the report--large, hand-colored maps for example--copying is impractical. In these cases, the materials may be examined in our offices.

To give a better idea of the type of unpublished information we have in our files, here is a partial listing of reports, studies, maps, etc., that I found during a quick survey. Some of these are the result of research by Survey geologists. Others were submitted to the Survey by geologists not with the Survey; still others are by geologists who were once with the Survey:

1. Report on oil found in a water well near Neche, North Dakota.
2. Geology of the Minto, North Dakota, area.
3. Map showing the thickness of the formations overlying the Pierre Formation in North Dakota.
4. Map showing the structure of the top of the Pierre Formation in North Dakota.
5. Geology of several state parks.
6. Geology and roadlogs of the International Peace Garden.
7. Assorted geologic roadlogs along various North Dakota highways.
8. Data on the thickness of glacial sediment in various parts of North Dakota.

9. Fortran IV Program to Sort and List the N-Numbered Data Set; a Manuscript that includes a description of the program function, a listing of the programs, a discussion of input parameters and forms, and operating instructions, by Ken Harris.

10. Geology of Adams and Bowman Counties, North Dakota.

11. Geology of Sheridan County, North Dakota.

12. Geology of Dickey and LaMoure Counties, North Dakota.

13. Geology of Ransom and Sargent Counties, North Dakota.

14. Geology of Ramsey County, North Dakota.

15. Precambrian Rocks of North Dakota, by E. G. Lidiak.

16. Alfalfa and the occurrence of fissures in North Dakota.

17. Surface study of the Pierre Formation of North Dakota, by John R. Bergstrom and Everett E. Wilson.

18. Results of Gypsum-Dolomite Exploratory Drilling Project, Pembina County, North Dakota.

19. A History of the North Dakota Geological Survey, by C. B. Folsom.

These studies are in all stages of completion. Some of them will eventually be completed and published while others will never progress beyond their present status.

RECENT UND THESES IN GEOLOGY--

In the first Newsletter, published in February, 1974, I included a list of geology-related theses prepared by University of North Dakota graduate students, and in this Newsletter I will include a selected listing of theses prepared since that time:

Frank P. Caramanica, 1973 (Ph.D) Ordovician corals of the Williston Basin periphery.

C. W. Cook, 1974 (M.S.) A mechanical well log study of the Poplar Interval of the Mississippian Madison Formation in North Dakota.

Bruce L. Ramsey, 1974 (M.S.) The physical and petrographic characteristics of formcoke produced experimentally from lignite and subbituminous coal.

Ronald E. Richardson, 1975 (M.S.) Petrography of the Precambrian Iron Formation, Pembina County, North Dakota.

James C. Grenda, 1977 (Ph.D.) Paleozoology of cores from the Tyler Formation (Pennsylvanian) in North Dakota.

Peter F. Bjorlie, 1978 (M.S.) Stratigraphy and depositional setting of the Carrington shale facies (Mississippian) of the Williston basin.

W. Kipp Carroll, 1978 (M.S.) Depositional and paragenetic controls on porosity development, Upper Red River Formation, North Dakota.

The titles listed above may contain valuable information of special interest to some of our readers. Master's theses (M.S.) are available for loan from: Interlibrary Loan Department, Chester Fritz Library, University of North Dakota, Grand Forks, ND 58202. Ph.D. dissertations pre-1966 are available for loan from the same address. Dissertations from 1966 to the present are available from: University Microfilm, Dissertation Copies, P.O. Box 1764, Ann Arbor, Michigan 48106. Also, in most instances, the theses or dissertations may be copied for a fee. The above listing of theses is incomplete; it does not include titles dealing with Tertiary or Quaternary geology, for example, or with the geology of areas outside of North Dakota even though a number of theses and dissertations have been written on these topics. If you want a complete listing of theses, or more information on those I have listed, let me know.

The abstracts for two theses completed just this spring are reprinted below:

Peter F. Bjorlie: Stratigraphy and depositional setting of the Carrington shale facies (Mississippian) of the Williston basin

ABSTRACT

The Carrington shale facies is a radioactive illitic lagoonal shale, apparently deposited behind lime mudstone banks (Waulsortian bioherms), along the eastern margin of the Williston basin during Early Mississippian time.

The Scallion subinterval, which is the basal subunit of the Bottineau interval of the Madison Formation in North Dakota, is divisible into six lithologic facies, one of which is the Carrington shale facies. West of the shale facies, on the basin-shelf hinge line, is the lime mudstone facies. Basinward of this facies is the interbedded shale-limestone facies. Stratigraphically above the latter two facies is the sand-silt-shale facies. Overlying a portion of this facies and the Carrington shale facies is the crinoid packstone-grainstone facies. Overlying the remaining portion of the sand-silt-shale facies is the wacke-packstone facies.

Following a period of erosion during the latest Devonian-earliest Mississippian time, Waulsortian mounds formed along the basin-shelf hinge line. These mounds and associated sediments (lime mudstone facies) created a barrier which allowed the deposition of the Carrington shale facies in a restricted environment. The source of the shale was the weathered Precambrian shield to the east. The sand-silt-shale facies was deposited on the basin slope during the deposition of the Carrington shale facies. After the deposition of these two clastic facies, carbonate deposition occurred on the basin shelf and slope in the form of the crinoid packstone-grainstone and wacke-packstone facies, respectively.

Possible petroleum traps exist where: the Carrington shale facies overlies erosionally truncated Devonian strata, abrupt facies changes occur within the Scallion subinterval, and along the pre-Mesozoic subcrop of the Scallion. Conditions necessary for the concentration of uranium beneath or within the Carrington shale facies may have occurred after the deposition of the shale facies.

Kipp W. Carroll: Depositional and paragenetic controls on porosity development, Upper Red River Formation, North Dakota.

ABSTRACT

The upper Red River Formation in North Dakota comprises a subtidal/intertidal facies overlain by three evaporitic sequences of four lithologic units each, labeled "P," "R," and "F" in stratigraphic order. Four porosity zones are recognized in the upper Red River: the subtidal/intertidal facies forms one porosity zone, and each evaporitic sequence contains another. Each unit in a sequence, as well as the sequence itself, is thinner and less widespread than its preceding counterpart. All strata are laterally continuous across the main part of the Williston basin in North Dakota, but, the porosity zones eventually disappear to the east as they approach the basin margin. Porosity within any given zone varies from one part of the basin to another, often within relatively short distances.

The "D" porosity zone consists of two primary lithologic facies: a shallow subtidal burrowed mudstone and skeletal wackestone, and an impermeable, often laminated, black organic skeletal wackestone and packstone deposited in an intertidal or supratidal barred pond environment. Porosity in the subtidal burrowed facies is due to syndepositional dolomitization and later calcite solution and microfracturing. Maximum porosity values related to dolomitization and calcite dissolution occur in the burrowed horizons immediately above the impermeable organic units, which acted as barriers to interstitial fluid movement. Poor development of the organic units near the center of the basin perhaps accounts for sporadic porosity development in that area.

The basal unit of each of the sequences overlying the "D" zone consists of open-shelf bioturbated skeletal wackestone of characteristically low porosity. Porous, fine-grained, primary supratidal dolomite overlies the subtidal facies, and these units form the "C," "B," and "A" porosity zones. A very thin argillaceous marker bed of non-calcareous shale completes each sequence.

Porosity in the supratidal dolomite stems from intercrystalline voids and pinpoint porosity due to solution. Porosity in the upper three zones varies across the basin and is directly related to degree of exposure of the sediment in the supratidal environment, during which dolomitization occurred.

HISTORICAL NOTES ABOUT THE SURVEY--

C. B. Folsom provided the following items of historical interest that took place 25, 50, and 75 years ago:

25 years ago: The 1953 Legislature granted a request from the Survey for $20,000 for construction of a steel storage building in which to store the cores and samples from wells drilled in the state as required by the Oil and Gas Conservation statute. The Legislature also increased the Survey's appropriation to $155,000 for the following biennium to reflect the additional duties assigned to it under the new law. This allowed the State Geologist to increase his staff from 8 to 15 people.

The 1953 Legislature had revised the Oil and Gas Conservation Law to conform to a more recent version of the Model Act of the IOCC. They adopted all but the special provision for statutory unitization. The new act included Market Demand Proration. C. B. Folsom, from the New Mexico School of Mines, was appointed Chief Petroleum Engineer for the Survey in September, 1953. He immediately started to update the rules to reflect the new law. As might be expected, the new rules reflected the rules in effect in New Mexico to a great extent. Exceptions were to be found in the Proration Allocation Formula which included a factor for spacing and in the provision for a Temporary Spacing in a new pool which would allow time to collect reservoir data before establishing a "proper" spacing.

50 years ago: Due to the lack of funds, the only work carried out in 1928 was the inspection of artesian wells. This work was done with funds allocated to the State Water Geologist, Howard E. Simpson. Professor Simpson was assisted in this work by Robert E. Simpson and Herbert H. Sand.

75 years ago: Beginning with the 1903-04 fiscal year, the Legislature increased the Survey's appropriation to $1,000 per year and this remained fixed through fiscal year 1917-18.

Irrigation studies continued with studies on using lignite as a fuel to run pumps. Professor E. J. Babcock had previously demonstrated that a gaseous fuel could be derived from the coal.

During the field season, Dr. Frank Wilder led a party from the Montana state line to the mouth of the Little Missouri River and downstream from there to the mouth of the Cannonball River, using small boats. He followed the Cannonball, by wagon, upstream to its forks at Wade and then along Cedar Creek to the Standing Rock Indian Reservation. On the return trip, the party made observations along the Upper Heart River.

At the close of the field season, Dr. Wilder announced that he would be leaving the state and was resigning his post as State Geologist. Dr. A. G. Leonard was named to the vacant office and assumed his new duties with the beginning of the new school year. Arthur Gray Leonard came to the University from the Iowa Geological Survey.

ACTIVITIES OF THE NDGS ENGINEERING DIVISION--

The regulatory functions of our Engineering Division can be expected to continue at an accelerated pace with increased oil, gas, and coal exploration and production, and the inauguration of uranium and possibly potash mining (please refer to figure 1).

Figure 1. Minerals Statistics

	YEAR							
	1970	1971	1972	1973	1974	1975	1976	1977
OIL & GAS CASES HEARD/INDUSTRIAL COMMISSION	38	45	41	60	51	82	105	108
PERMITS ISSUED FOR:								
OIL/GAS	171	134	103	129	174	264	246	356*
COAL						46	33	76
POTASH							3	0
URANIUM							10	5
OIL & GAS WELLS COMPLETED	134	151	90	117	153	202	251	340*
NUMBER OF FEET DRILLED/ OIL & GAS (1000's)	873	979	606	814	1139	1348	1802	2720*
COAL TESTHOLES DRILLED						4613	2319	4800*
TEST HOLES FOR OTHER SUBSURFACE MINERALS:								
POTASH							3	0
URANIUM							91	620*

* - Estimated

Numerous revisions to the oil and gas conservation rules, proposed by the Survey and approved by the Industrial Commission, became effective April 1, 1978. The Survey is currently reviewing the regulations regarding the exploration, development, and production of subsurface minerals, and we will probably be proposing revisions and additions to the Industrial Commission later this year. Of particular concern to us is the regulation of in situ leaching of uranium. At the request of the Legislative Council, we have prepared a draft bill for a proposed measure to regulate the underground storage and retrieval of materials and the terminal disposal of wastes including spent nuclear fuel. The ultimate fate of the draft will not be known for some time as the North Dakota Legislature will not be in session until January, 1979.

OIL EXPLORATION, PRODUCTION, AND VALUATION--

A total of 105 wildcat oil wells were drilled in North Dakota during 1977. Of these, 29 produced oil and 77 were dry for a success ratio of 27.4 percent. No gas wells were completed. The average depth for all exploratory wells was 7,816 feet. The 27.4 percent successful ratio for oil well completions was higher than that for any other state. We also have a new depth record, 15,380 feet for the Gulf Oil-1-3-4A Zabolotny in the Little Knife Field in Billings County (NW¼SW¼3-144-98). At last report drilling was still underway. The Little Knife Field in Dunn, McKenzie, and Billings Counties is in the development process and additional wells are being drilled. The field's limits are not yet defined. The Mondak Field, on the North Dakota-Montana state line in west central McKenzie County, and the Charlson Field in northeastern McKenzie County also have the potential to significantly affect total crude oil production in North Dakota. An important discovery by Shell Oil Company of an oil pool in the Deadwood Formation, in Renville County, has spurred interest in the deeper horizons across the state.

A total of 16 new oil pools were discovered during 1977 and 7 new pools have already been discovered in 1978.

Figure 2 illustrates annual crude oil production for the period 1970 through 1978. Production declined from 22 million barrels in 1970 to a low of 19.6 million barrels in 1974. Although eight new oil pools were discovered in 1974, their impact was not felt until 1975 due to the lag time between discovery, completion, and construction of surface facilities. An additional nine discoveries in 1975 added to the upswing in production, which increased to 21.7 million barrels in 1976. Seventeen new pool discoveries in 1976 resulted from the increasing level of drilling activity in North Dakota. Production increased to 23.3 million barrels, surpassing the 22 million barrel production of 1970.

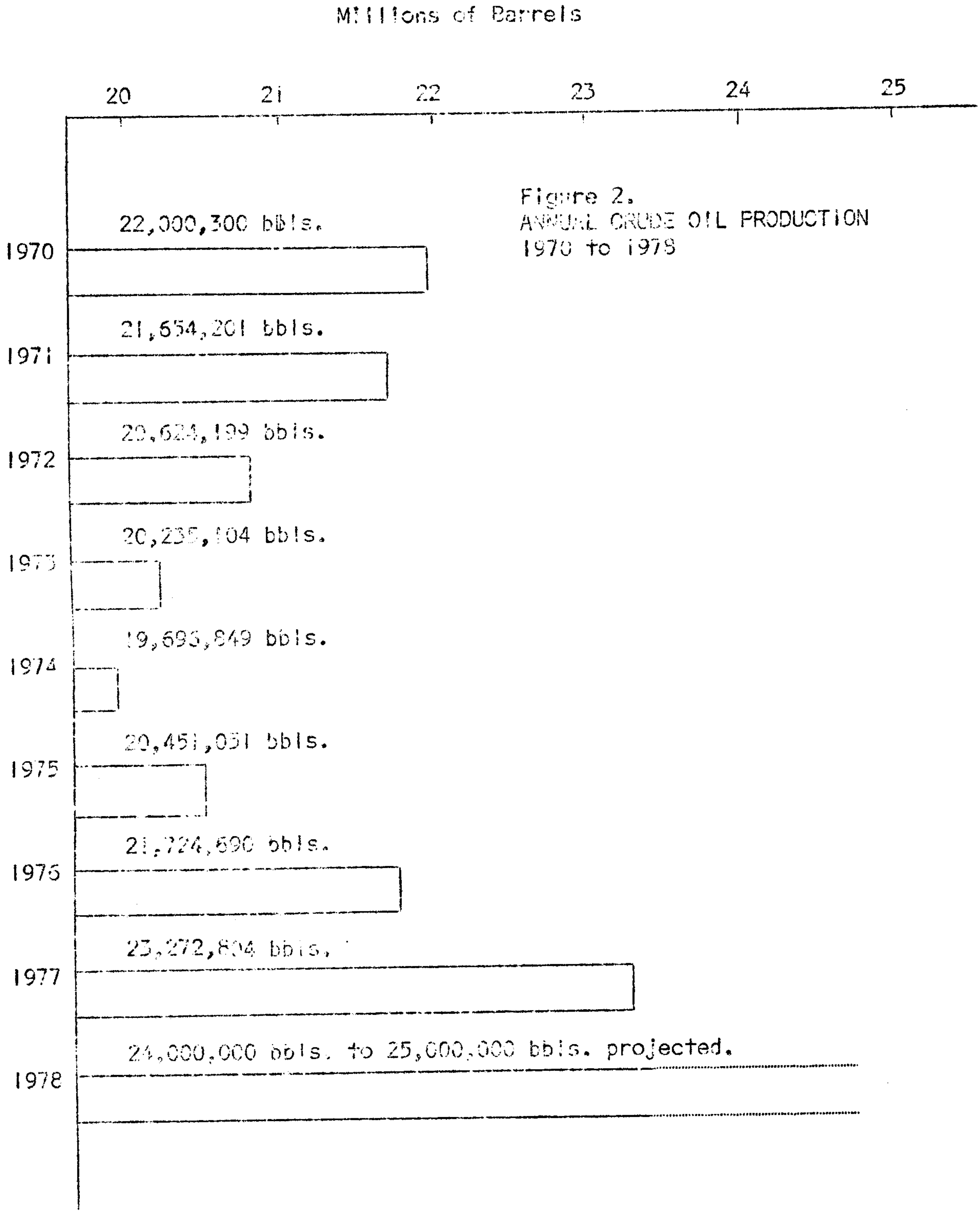

Figure 2.
ANNUAL CRUDE OIL PRODUCTION
1970 to 1978

The year 1977 was a banner year insofar as exploration success and production were concerned. The Charlson Silurian Pool, discovered by Tiger Oil Company, demonstrated the potential for finding new pools at greater depths in areas that have had shallower oil production for many years. The Charlson Silurian discovery well produced at rates exceeding 2,000 barrels a day and occasionally produced over 3,000 barrels a day. This field is also in the development stages and its ultimate potential may not be known for some time. The Mondak Field produces from fractured carbonate rock in the Madison Formation and appears to have other zones capable of production. Development continues in this field as well. The Mondak, Little Knife, and Charlson Fields all produce large volumes of natural gas. This gas is either collected and processed in existing plants, or it will be processed in plants now under construction. The North Dakota Industrial Commission has restricted production from wells in these fields, which are not yet connected to a gas processing facility.

The value of crude oil increased before the production increased in North Dakota. In 1970, the value of produced crude oil was 63.8 million dollars. By 1974, our poorest production year, the value was up to 87.2 million dollars, exceeding the 1970 value by 23.4 million dollars even though the production was 2.3 million barrels less. Figure 3 illustrates the valuation of crude oil production for the period from 1970 to 1978. The estimated value of crude oil that will be produced in 1978 is 239 million dollars, an increase of 275 percent over the value of the crude oil that was produced in 1970.

INCOME TO NORTH DAKOTA FROM OIL AND GAS--

Revenues to the State of North Dakota directly related to oil and gas exploration and development have increased rapidly in recent years. They include the gross production tax; lease sales, including bonus and rentals for lands administered by the State Land Department and the Bank of North Dakota; and royalties paid for production therefrom.

State Tax Department projections for 1978 indicate that the five percent gross production tax will provide $11,950,000 to be distributed to the general fund and to those counties that have oil production. This is in contrast with the 1970 tax of $3,191,717 and represents a 275 percent increase in gross production tax revenues from 1970 to 1978. Figure 4 illustrates the increase in these revenues for the period 1970 through 1978.

Income accruing to the State Land Department and to the Bank of North Dakota due to lease bonuses and royalty payments are as follows:

Lease Bonuses:

Bonuses for leases for the period July 1, 1970, to June 30, 1977, amounted to $7,123,020. Since July 1, 1977, the three lease sales that have taken place in North Dakota have brought in a total of $10,886,616, or nearly 1.5 times as much as for the prior seven years combined.

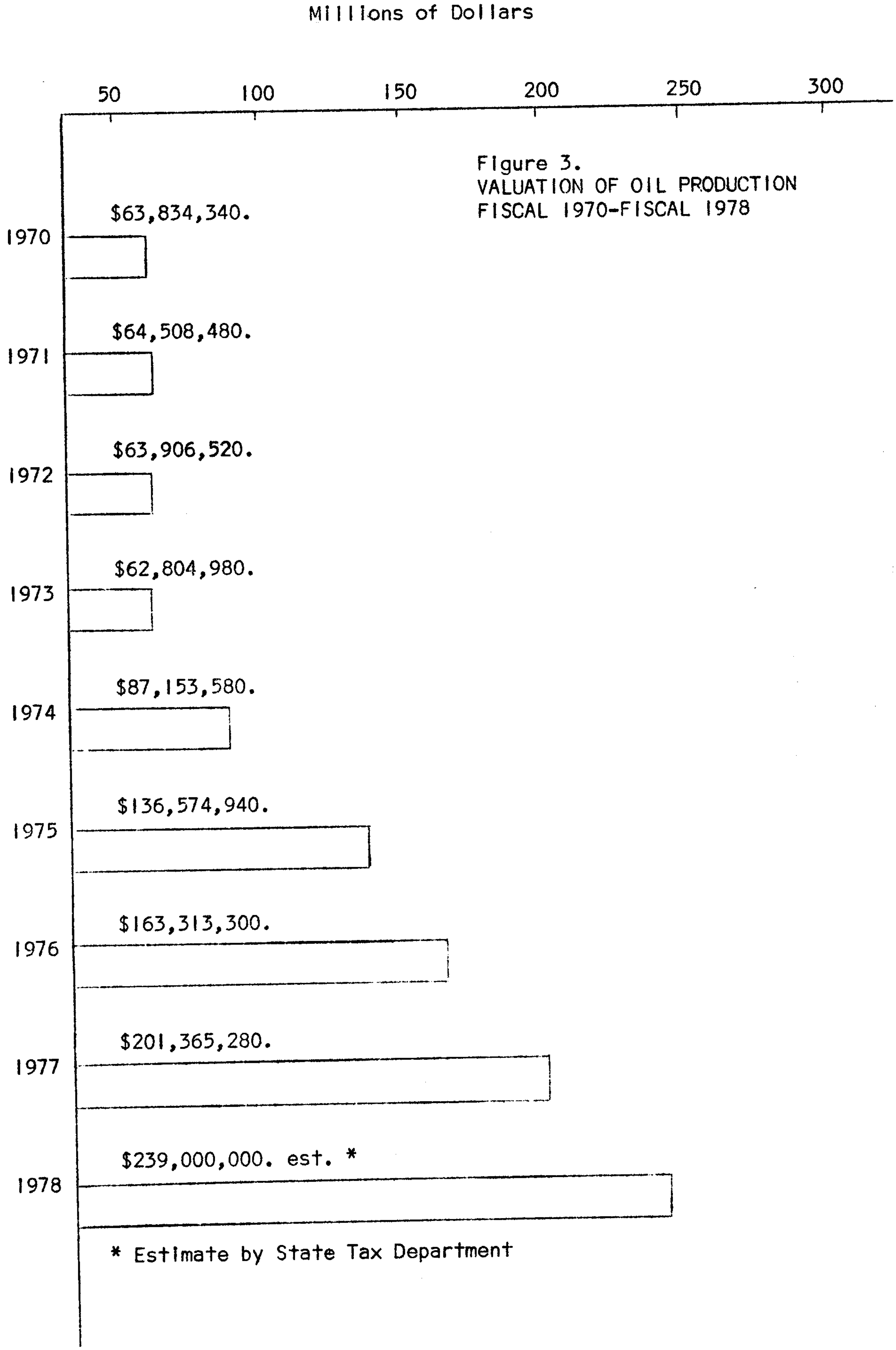

Figure 3.
VALUATION OF OIL PRODUCTION
FISCAL 1970-FISCAL 1978

* Estimate by State Tax Department

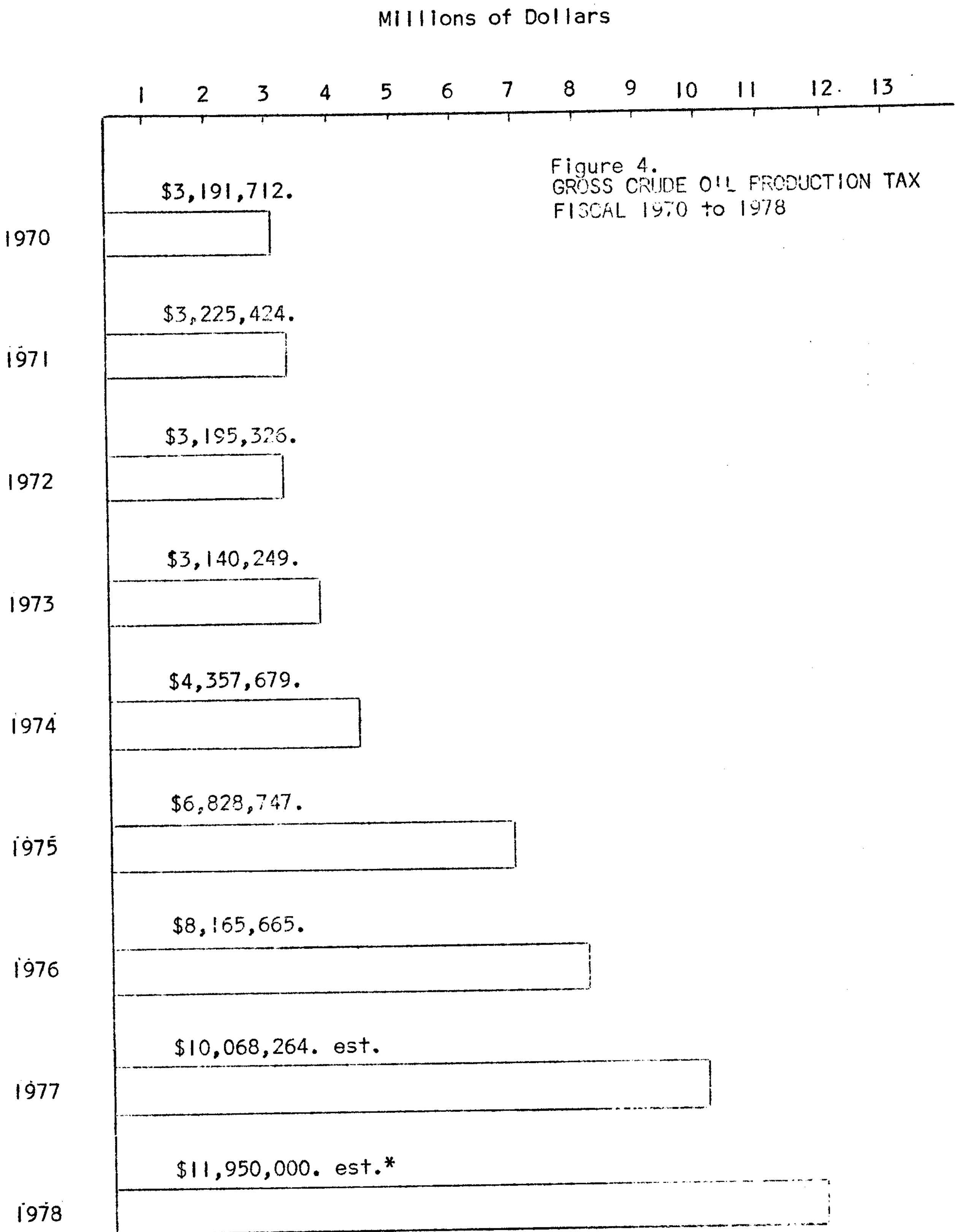

Figure 4.
GROSS CRUDE OIL PRODUCTION TAX
FISCAL 1970 to 1978

* The estimated tax receipts for 1978 are conservative and do not take into account increasing production from several recent discoveries.

Royalty Payments:

1973-1975 Biennium	
Land Dept.	$1,154,416
Bank of North Dakota	619,820
Total	$1,774,236
1975-1977 Biennium	
Land Dept.	$2,310,486
Bank of North Dakota	1,203,180
Total	$3,513,666

From the 1973-1975 biennium to the 1975-1977 biennium, there was a 98 percent increase in royalties paid to the state.

NORTH DAKOTA AMONG TOP FIVE STATES IN RESERVES ADDITIONS FOR 1977--

As a result of discoveries made during 1977, North Dakota now ranks 14th in proved crude oil reserves at 150,190,000 barrels, compared to its 15th-place ranking in 1976. Nearly 160 million barrels of oil were added to our nation's proved reserves by new field discoveries last year. Five states accounted for the bulk of the new discoveries. They include Louisiana, the leader with 43.4 million barrels, California 41.7 million barrels, Texas 15 million barrels, Wyoming 12.2 million barrels and North Dakota nearly 12.1 million barrels.

In addition to the 12.1 million barrels of new field discovery reserves, North Dakota had indicated added reserves of over 18 million barrels. Indicated added reserves are additional recoveries in known reservoirs, in excess of proven reserves, which engineering knowledge and judgment indicate will be economically available by application of enhanced recovery techniques.

Exploration and development drilling continues at an accelerated rate. Drilling rig availability appears to be the major factor limiting the number of tests being drilled.

Development drilling is still taking place in two of the major field discoveries for 1977. Little Knife Madison and Charlson Silurian continue to have their boundaries extended as the result of successful development drilling. Mondak Madison, discovered in 1976, is also being expanded in area and reserves as development drilling continues. Final reserve figures for these fields will not be known until they have been delineated and their reservoir data interpreted.

The picture is not so rosy insofar as the state's natural gas and gas liquids are concerned. Natural gas reserves declined nearly 14 billion cubic feet. As could be expected, gas liquids reserves also declined, down 1.7 million barrels from 1976. Most of the natural gas produced in the state is associated with crude oil production. An exception is the production from the Cretaceous Eagle Formation on the Cedar Creek Anticline in southwestern Bowman County. Exploration for gas has been at a virtual standstill for some time in North Dakota. Hopefully, the recent interest being shown in shallow gas exploration in Colorado, Nebraska, and South Dakota will expand into North Dakota.

NATURAL SCIENCE SOCIETY WILL MEET--

Some of our readers may be interested in attending an early autumn field trip currently being planned by the North Dakota Natural Science Society. The Society will meet in eastern McLean County to observe sandhill cranes and the glacial geology of that area. During September and October of each year, approximately twenty thousand sandhill cranes gather in the Lake Williams area near Turtle Lake. These birds enroute from Arctic nesting grounds in Siberia, Alaska, and northern Canada pause several weeks to feed and rest before continuing southward to wintering grounds located primarily in Texas and New Mexico. The cranes roost on alkali flats bordering the lake and spend the daytime in nearby fields. Excellent opportunities exist for viewing the cranes while in the fields and during morning and evening flights. This field trip will provide participants an opportunity to become more familiar with the flora and fauna of saline lakes, a unique habitat utilized by many species of shorebirds and waterfowl during the fall migration.

The area we will visit is on the Missouri Coteau, and it has an unusually diverse suite of landforms that developed as a result of large-scale glacial stagnation. Our trip will be conducted by Gary Krapu, of the Northern Prairie Wildlife Research Center in Jamestown, and John Bluemle of the North Dakota Geological Survey in Grand Forks.

We have not yet set a definite date for the field trip, although the weekend of September 23-24 is a likely possibility. We also haven't arranged a specific meeting place yet. Any readers interested in the trip can contact me (John Bluemle) here at the NDGS and I'll see that you get the final announcement when all the plans are complete.

I'll also take this opportunity to say a little about the North Dakota Natural Science Society. We now have about 250 members, mostly from North Dakota. Our membership includes all types of people, all of us interested in the natural environment of our state; every one of the readers of this Newsletter is eligible for membership in the Society. In general, we encourage the recording and preservation of observations of nature, and the Society serves as a means of communication among those of us concerned about enjoying and conserving the natural world around us.

The North Dakota Natural Science Society publishes the Prairie Naturalist four times a year. This periodical deals with the environment and the natural history of North Dakota. We are fortunate in having increasing numbers of interesting manuscripts dealing with a wide range of natural science topics being submitted for publication in the Prairie Naturalist.

Individual memberships in the Society cost only $3.00, and family memberships are $4.00. If you would like more information about the Society, or if you want to join, please let me know.

FEDERAL WITHDRAWAL OF LANDS FROM MINERAL EXPLORATION AND DEVELOPMENT--

Through frequent items in the press and other news media, the public is becoming aware of conflicts within the federal government regarding the withdrawal of federal lands from exploration and development for mineral and energy resources. The U.S. Department of the Interior is Currently wrestling with the problem of finding a way to develop the petroleum potential of the Overthrust Belt in the Rocky Mountains without violating the wilderness concept. Many of the federal lands located within the Overthrust Belt would qualify as wilderness under the criteria for such designation within the Wilderness Act. At the same time, the Department of Energy has reported that there are 156 high-energy tracts within the Overthrust Belt and that all lands in the area have high-energy potential and should be omitted from wilderness proposals because of the importance of the development of their energy resources.

The three principal statutes authorizing and regulating the disposition of federal mineral resources are: the Mining Law of 1872; the Mineral Leasing Act of 1920; and the Mineral Leasing Act for Acquired Lands of 1947. The Mining Law allows claimants to acquire fee title to the claimed land. A prospector may enter public land and search for minerals and, if he finds a valuable mineral deposit, he may file a claim and begin mining. The prospector will have an exclusive right to possess the land for mining purposes as long as $100 worth of development work is done each year. If the claimant can show that a valuable mineral has been found and that at least $500 has been spent on improvements, he is entitled to obtain a patent granting him fee title to the claim. The mineral leasing acts control disposition of coal, oil, oil shale, gas, phosphate, potassium, sodium, and certain other materials. The Secretary of the Interior has the authority to decide whether to lease or not to lease land or deposits or to issue prospecting permits.

Approximately 742 million acres of federal lands are subject to the Mining Law of 1872. In 1968, 17 percent of these lands were excluded from exploration and development. By 1974, excluded or withdrawn lands had increased to 67 percent. Lands subject to the mineral leasing acts were similarly affected. Approximately 824 million acres of federal lands are subject to the mineral leasing acts. In 1968, 17 percent of this 824 million acre area was excluded from exploration and development and this had increased to 64 percent by 1974. As a result of these withdrawals, an area larger than that encompassing 25 of the 27 states east of the Mississippi River has been withdrawn from exploration and development.

In North Dakota, the National Grasslands constitutes the largest area of federal lands. The Grasslands are divided into two planning units and are managed by the U.S. Department of Agriculture under the Management prescription for the Badlands Unit, adopted September 1974 and the Management Plan for the Rolling Prairie Unit, adopted August 1975. The plans, which were adopted following considerable public involvement, provide for multiple use of the natural resources. They also provide for areas designated as "essentially roadless" with numerous restrictions and eventual exclusion of mineral exploration and development sometime in 1981.

At the present time, the areas designated as "essentially roadless" under the existing management plans are being considered for "wilderness" designation through a recently initiated evaluation program known as RARE II. Lands designated as "wilderness" would be immediately withdrawn from mineral exploration and development. Such designation would also place severe restrictions on the livestock industry in those areas. For example, only primitive methods would be allowed in the improvement and maintenance of stockwatering facilities and fences.

Even though federal wilderness area regulations will apply only to federally owned lands within an area so designated, they also affect privately owned surface and minerals within the area. As an example, two areas now being considered for "wilderness" designation were examined with respect to the privately owned minerals lying within them. Federal and non-federal mineral ownership was determined from maps published by the Bureau of Land Management.

In one area of 18,440 acres, approximately 4,480 mineral acres, or 24 percent, are privately owned. Another area of 21,120 acres includes approximately 7,410 privately owned areas (35 percent) of minerals. As these areas are withdrawn from leasing and surface exploration and development, the non-federal mineral rights will be adversely affected. Even though they may be leased and are open for exploration, it is unlikely that they will be explored or developed due to the inability of an operator to assemble a block of acreage sufficiently large to satisfy the economic requirements of an exploration and development program.

Most of the federally owned lands lie in the western states. These states contain most of the important sedimentary basins and mountain ranges with the greatest potential for energy and other mineral resources. While we recognize the importance of preserving wildnerness and other unique areas, their designation and ultimate withdrawal from mineral exploration and development has got to be considered in the light of the effect of such actions on the nation's economic and defense requirements. The nation finds itself on the horns of a dilemma which will require sound reasoning and judgment for its solution.

NDGS CORE AND SAMPLE LIBRARY FILLED TO CAPACITY--

North Dakota law requires that all requested core and samples and all geophysical logs acquired from exploration and development of oil and gas, lignite, and subsurface minerals be furnished to the State Geologist. We have accumulated and maintained these materials since the discovery of oil in the state in 1951. As a result, the North Dakota Geological Survey possesses what is considered to be the nation's most complete and accessible collection of subsurface geologic and engineering data obtained from exploratory and development drilling.

In addition to oil exploratory well cores and samples, the library is the repository for all cores and samples collected by the State Water Commission, and it also contains cores resulting from the U.S. Air Force missile-site evaluation program.

The core and sample library has proven to be a valuable source of information for Survey and industry geologists, and faculty and students in the Geology Department at the University of North Dakota. Its existence and use is a factor in the current acceleration of exploration activities for oil and gas and subsurface minerals in the state. The library is vital to the performance of the Survey's statutory responsibilities.

The core and sample library is currently housed in a metal building on the east side of the University campus. The building contains 9,600 square feet (80' x 120') of floor space and, except for a small examination room, it is unheated. No laboratory or washroom facilities are provided in the building. For this reason, core and samples must be transported between the library and Leonard Hall for study by Survey geologists, students and faculty, and industry representatives. The facility is nearly filled to capacity.

Although the percentage of wells cored has remained essentially constant at 27 percent over the years, there has been a dramatic increase in the footage of core from these wells. Footage of core per cored well in 1976 averaged 65 feet. During 1977 the average cored interval was 101 feet per well, an increase of 55 percent. At this increased rate, we expect the core library to be filled by the end of this year.

To alleviate current conditions and provide for future needs, the State Geological Survey is requesting an appropriation for a new core and sample library and equipment-storage facility to be constructed in the vicinity of Leonard Hall. The proposed new facility would include 22,000 square feet of floor area to provide 19,000 square feet for core and sample storage, 1,000 square feet for laboratory, office, and washroom space, and 2,000 square feet for equipment storage.

POTASH RESOURCES--

We last commented on potash in North Dakota in the December 1976 Newsletter. Since then, Sid Anderson has continued to study the North Dakota potash resources and we have learned much more about them.

The North Dakota potash deposits are extensions of rich deposits now being mined in Saskatchewan. They underlie 11,000 square miles in northwestern North Dakota and 3,000 square miles in northeastern Montana. They are of Middle Devonian age and occur in beds within the Prairie Formation, an evaporitic sequence composed mainly of halite, but also of potash and anhydrite.

The limits of the Prairie salt in the United States are from western Bottineau County in north-central North Dakota to Daniels County in eastern Montana and as far south as northern Dunn County in west-central North Dakota. Evidence of solution is found along both the eastern and western margins as well as in eastern Montana. Thickness of the salt ranges up to over 500 feet in Burke County, North Dakota.

On the United States side of the international boundary, as in Saskatchewan, three potash beds occur. The Esterhazy and Belle Plaine Members, the lower beds, are present in both North Dakota and Canada. The upper bed, the Patience Lake Member in Saskatchewan and the Mountrail Member in North Dakota, is discontinuous and cannot be traced across the international boundary; however, the Patience Lake and Mountrail Members are probably correlative.

The North Dakota and Montana potash deposits occur at depths below 3,500 feet so coventional shaft-mining would be impractical; solution-mining appears to be the only way to mine the resource. In North Dakota, depths range from 5,600 feet near the eastern limit in northwestern Bottineau County to over 12,000 feet in southern McKenzie and northern Dunn Counties.

The Esterhazy Member is the most extensive potash bed in the United States portion of the Williston basin, extending westward from western Bottineau County, North Dakota to Daniels County, Montana, and south from the Canadian boundary to northeastern Dunn County, North Dakota. This member is also the lowest stratigraphically and the shallowest. It occurs at a depth of 5,632 feet in northwestern Bottineau County, which is the shallowest known occurrence of potash in the United States portion of the basin. In North Dakota, the Esterhazy Member has a maximum gross thickness of 44 feet at a depth of 11,800 feet in west-central Mountrail County. The maximum net thickness known is 32 feet in north-central Burke County (net thickness equals gross thickness of the potash member minus the thickness of the interfingering halite beds). Other areas in North Dakota with substantial net thicknesses are: central Divide County with 29 feet; northeastern Burke County, 28 feet; and southwestern Bottineau County, 27 feet.

The Belle Plaine and Mountrail Members are not as extensive as the Esterhazy Member. The Belle Plaine Member is up to 45 feet thick in parts of Burke County and has a maximum net thickness of 29 feet in Divide County. The Mountrail Member is 8 feet thick in south-central Mountrail County. It occurs near the top of the Prairie salt section, but it probably has no economic value because of vertical separation from the Belle Plaine and Esterhazy Members and because it is so thin.

In North Dakota, the most favorable areas for potash development appear to be: central Burke County where the depth to potash is 8,300 to 9,000 feet; western Divide County, where the depth is from about 8,900 to 9,200 feet; and western Bottineau, eastern Renville, and central Ward Counties, where depths are from 6,000 to 7,500 feet.

The total potash resources in the United States portion of the Williston basin are estimated to be approximately 60 billion tons. North Dakota has an estimated 50 billion tons and Montana has 10 billion tons. We do not yet have an estimate of recoverable resources.

THE LITTLE MISSOURI RIVER BADLANDS--

Many people would argue that the most scenic part of North Dakota is the badlands along the Little Missouri River. On first viewing the scenery there, a visitor might conclude that some great natural catastrophe has torn the earth apart, ripping it open and exposing its interior. But the hills and valleys of the badlands were formed by agents more relentless than earthquakes or volcanoes. This land, which Theodore Roosevelt found "fantastically beautiful," was carved by running water from rain and melting snow, by wind, by frost, and by other processes of erosion.

The Sioux Indians called the badlands "mako sika" ("land bad"), and early French explorers translated this to "les mauvais terres a' traverser" ("bad land to travel across" or, more simply, "badlands"). Today, modern roads make access to the area easy and the name "badlands" may not be as applicable as it once was.

The Little Missouri River Badlands are a product of the action of rivers and streams, both the modern ones that are eroding the area today and ancient rivers that delivered sediments to western North Dakota about 65 million years ago. During Paleocene time, layers of sediment exposed today in the badlands, mainly sandstone, siltstone, and claystone (geologists refer to these layers as the Bullion Creek and Sentinel Butte Formations) were deposited in lakes, ponds, and swamps along streams flowing east from the newly-formed Rocky Mountains to the sea in eastern North Dakota. In and near the rising mountains in Wyoming and Montana, the Paleocene rivers and streams flowed swiftly and carried large amounts of coarse materials such as gravel. At the point where the rivers flowed from the mountains out onto the plain, they lost much of their carrying power as their velocity dereased and, as a result, they deposited the coarser gravel and sand near the mountains. The streams carried the finer meterials, such as clay, silt, and fine sand, farther eastward to the Dakotas, depositing them at the edge of a large, inland sea that covered the eastern parts of the Dakotas. The deposition of the sediment was not uniform and blanket-like, but rather, as the rivers and streams meandered from side to side, they deposited materials over one area for a few years and over another one a few years later. During Paleocene time, while the Rocky Mountains were still forming, volcanoes were erupting in western Montana and Wyoming. These volcanoes produced large amounts of ash, which the wind carried eastward to the Dakotas. The ash collected in ponds and lagoons and, with the passage of time, it was transformed to clay that can be seen exposed as bluish layers in many places in the badlands.

The badlands are a hilly land, but when you approach them, you look down on the hills, not up at them. From the rim of the "breaks," as the drop into the badlands is called, an observer can see the strip of bare ridges, bluffs, buttes, mesas, and pinnacles along the river. Behind you, an unbroken, rolling plain stretches away to the horizon.

The erosion of the badlands began soon after the beginning of the Ice Age, probably about three million years ago. Before the Ice Age, the Little Missouri River flowed northward in a smooth, gentle valley, joining a larger river, the early Yellowstone River, near the Canadian boundary in northwestern North Dakota. These combined rivers flowed north from there into Canada and on to Hudson Bay. When glaciers first moved southward into North Dakota, they blocked the north-flowing rivers and diverted many of them, including the Little Missouri River, which was forced to flow eastward along the margin of the ice. After its diversion by the glacier, the Little Missouri River continued to flow over the new shorter, steeper route and because it did so, it cut rapidly downward, eroding its valley and carving the badlands.

Badlands erosion in western North Dakota has not been at a constant rate. Erosion tends to be most intense during times when the climate is drier and the covering of vegetation is too sparse to protect the soil; the occasional, heavy rains that do take place during these dry periods are thus able to remove large amounts of the loose, unprotected soil. During the past few hundred years, the Little Missouri Badlands have undergone four separate periods of erosion and three periods of deposition. New gullies have been cut to their present depth since about 1936. Since the badlands started to form about three million years ago, the Little Missouri and Missouri Rivers have carried about 40 cubic miles of sediment from western North Dakota downstream to the Gulf of Mexico.

Unusual shapes that result from uneven erosion of the layers of sediment enhance the natural beauty of the area. Such things as hard sandstone beds and sandstone concretions, beds of lignite coal, petrified wood, and scoria are all more resistant to erosion than are the softer silt and clay layers found in most places. Orange and reddish-hued scoria beds formed when veins of lignite coal burned, baking the nearby sediment to a hard, erosion-resistant, natural brick that has fused to a clinker-like material in places (the formation of scoria was discussed in more detail in a previous newsletter).

Petrified wood is found in many places in the badlands. Although the whole area that is now badlands was probably forested during Paleocene time, the preservation of wood and stumps required that the trees be rapidly buried by sediments so that they escaped decay. This might have happened when streams changed course or flooded their banks depositing sand or silt on the trees. After a tree was buried, groundwater began to circulate through it. With the help of bacterial action, the water dissolved out the softer cellulose material of the wood. The water also carried dissolved minerals, among them silica (SiO_2). The silica was deposited in the spaces left by the dissolving out of the plant tissue. This went on for a long time so that the replacement was gradual, a molecule of plant tissue being simultaneously replaced by a molecule of silica. In this way, the original cellular structure of the wood was preserved so that, in many cases, the petrified stumps look exactly like old wood stumps except that they are stone. The petrified wood found in the Little Missouri Badlands is mostly very light brown or cream colored and it is abundant in places.

It has often seemed to me that our North Dakota badlands are especially beautiful because wooded areas occur in many of the draws and on the north-facing slopes. Evergreens, such as the Rocky Mountain juniper, limber pine, and creeping red cedar are interspersed with trembling aspen, cottonwood, and poplar. Near Amidon, fumes from a burning vein of coal have altered the growth habits of the juniper, causing it to grow in a tall, columnar shape. When the fire eventually goes out, the descendents of these shapely trees will revert to the typical juniper shape, common elsewhere in the badlands.