NEWSLETTER

NDGS

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North Dakota Geological Survey
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John P. Bluemle, Editor

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June, 1981

EDITOR'S NOTE

All of the articles not otherwise credited were written by the Newsletter Editor.

The recently completed Legislative Assembly of North Dakota provided for a number of substantial changes in the operation of the North Dakota Geological Survey. I have included an article on the new role of the Survey on page 2. An article by Erling Brostuen, Assistant State Geologist, reviews North Dakota's Oil and Gas Conservation Law (page 21). Since 1981 is North Dakota's 30th anniversary as an oil producer, I've written a brief outline of our oil and gas development history and resources (page 16) and one on some of the earlier efforts at finding oil in the state (page 27). In keeping with recent precedent, I am including an article of general interest on earthquakes in North Dakota (page 28). Finally, I think our readers will find the article on climate change (page 26), written by John Hoganson, Survey Geologist, especially interesting.

If you have questions about any of the articles, please write or give me a call.

John P. Bluemle
Newsletter Editor
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DR. LEE GERHARD LEAVES AS STATE GEOLOGIST

Dr. Lee C. Gerhard, State Geologist of North Dakota and UND Geology Department Chairman since September, 1977, will be leaving the Survey and the Department effective August 1, 1981. He will be taking a newly created position with Supron Energy Corporation as Rocky Mountain Region Regional Manager.

Prior to becoming State Geologist in 1977, Dr. Gerhard was Assistant State Geologist for two years. He came to North Dakota in 1975 from Fairleigh Dickinson University, St. Croix, Virgin Islands where he had directed the West Indies Laboratory. He has also taught at the University of Southern Colorado and at the University of Kansas and worked as a stratigrapher and geologist for Sinclair Oil & Gas Company.

During his tenure as State Geologist, Dr. Gerhard accomplished a great deal. He initiated the move for and oversaw the construction of the new Wilson M. Laird Core and Sample Library, which was dedicated last year. Dr. Gerhard's interest and expertise in carbonate geology led him to conduct a series of in-depth studies of Williston Basin carbonate rocks and of various modern sedimentological analogs. His interests are also reflected in his efforts toward establishing the Williston Basin Carbonate Core and Sample Laboratory, which has been operational since 1977. In this effort, and in others, Dr. Gerhard was notably successful, in his capacity as Department Chairman, in obtaining donated funding from both individuals and corporations for the purchase of equipment and to support scholarships.

Additional accomplishments--I can't begin to list them all--include the acquisition of a scanning electron microscope and microprobe for the Geology Department; the long-awaited Triceratops skull restoration (about time!); an extensive refurbishing of Leonard Hall (the Survey and Department office and classroom building on the University of North Dakota campus); the undertaking of an extensive geothermal program; and the computerization of much of the Survey's well data.

Perhaps Dr. Gerhard's most important contribution has been his dynamic attitude, which has shown us in the Survey that a great deal <u>can</u> be accomplished if we work at it. The Survey has come a long way in the last four years. Dr. Gerhard has helped show us how to get things done.

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 simply tabulating the names of companies that have applied for drilling permits.

Approximately 112 different companies applied for the 644 permits that were issued in 1979 and 156 companies applied for the 766 permits issued in 1980. As one might expect, some of the larger companies, a half dozen or so with over 20 permits each in 1980, accounted for about a quarter of the permits issued. The remainder of the permits went to companies applying for less than twenty permits each, and 62 companies received only one permit each in 1980.

At least 68 companies that were not active in North Dakota in 1979 applied for permits to drill in 1980. Conversely, 22 companies that had permitted in 1979 did not do so in 1980. A total of 136 different companies applied for the 529 drilling permits issued by the Survey during the first six months of 1981, through June 30. Of these 136 companies, 40 are new this year (did not apply for permits in 1980).

Of the 529 drilling permits issued during the first half of 1981, a total of 239 were for development wells in existing oil fields; 178 were exploratory (wildcat) wells located more than a mile and a half from a producing well or an established field boundary; 72 were for extension wells drilled as offsets to producing wells or established field boundaries; 38 were for outpost wells located less than a mile and a half, but more than one location from a producing well or established field boundary (many states consider such wells to be wildcats); one replacement well was drilled; and one observation well was drilled. The observation well is part of a secondary recovery CO_2 flood experiment in Little Knife Field.

OVERLY OPTIMISTIC PREDICTIONS SHOULD BE TREATED CAUTIOUSLY

Recent oil production estimates of more than 50 million barrels a year for North Dakota may materialize, but many of the more optimistic forecasts that have been made in various places (newspapers such as the Wall Street Journal and others) project much more rapidly, continuing increases in production (and state tax revenues). Many of the discoveries of the past year or so are in Red River Formation rocks and other sub-Mississippian pools. These discoveries do tend to come in with exceptionally high initial production figures--some with a thousand barrels a day or more--but they often drop off dramatically, much faster than the smaller Madison producers. By contrast, many of the new Duperow discoveries that come in with very respectable initial production hold up quite well.

Given the "flash-in-the-pan" nature of so many of the new producers (on which many especially optimistic forecasts of 60, 80, or 100 million barrels of oil a year for North Dakota's Williston Basin are based), it will be necessary to have an exceptionally high, even accelerated, discovery rate in the next few years to reach, or even maintain, a 60-million barrel a year production figure (production during 1980 was 40 million barrels in North Dakota).

Even if the somewhat sobering viewpoint just stated is correct, one definite long-term plus of the current drilling boom (aside from the resources and revenues we are able to use today), is the fact that it has now been shown that oil can be found in areas far removed from existing production. The more widespread occurrence of hydrocarbons in the Williston Basin has been established and we can expect interest to continue, at some level at least, throughout the Williston Basin in areas that have historically been overlooked.

SURVEY'S ROLE CHANGED BY RECENT LEGISLATIVE SESSION

Easily the most significant event of the past six months for the North Dakota Geological Survey was the passage of House Bill No. 1536 by the Forty-Seventh Legislative Assembly of North Dakota. This bill, signed into law by Governor Allen I. Olson, amends sections of Chapter 38-08 of the North Dakota Century Code relating to the powers and duties of the Industrial Commission and the State Geologist. The bill amends sections 38-08-04, 38-08-05, and 38-08-07 of the Code to provide for the assumption of direct authority and responsibility for the enforcement of the provisions of Chapter 38-08 of the North Dakota Century Code by the Industrial Commission. Basically, the legislation reorganizes the State's natural resources agencies, transferring the Survey's role in oil and gas regulation directly to the State Industrial Commission. As a result, all NDGS personnel who in the past have been involved in oil and gas regulation, were transferred to a newly created Industrial Commission Oil and Gas Division. The changes involve a total of about 25 Survey employees, including all of our former Bismarck and Williston personnel as well as six Grand Forks positions.

The North Dakota Geological Survey now no longer maintains offices in either Bismarck or Williston. All field inspectors and support personnel in these offices were transferred, effective April 13 (North Dakota Industrial Commission emergency order No. 2364), to the North Dakota Industrial Commission. Wes Norton, formally the Survey's chief of oil and gas enforcement, was appointed Acting Chief of the Commission's new Oil and Gas Division.

Jack Wilborn, who has been in charge of Permitting and Compliance for the Survey; Sheila O'Shaughnessy, who has been the Survey's Permitting and Compliance Division Statistical Clerk; and C. G. Carlson, Senior Geologist with the Survey's Technical Services and Research Administration, are transferring to the Industrial Commission's Bismarck office. In addition, three Survey positions that have been transferred to the Industrial Commission in Bismarck will be filled there as the Grand Forks people involved have elected not to move. C. B. Folsom, the Survey's Chief Petroleum Engineer since 1953, will be involved in a special project assignment for his last year prior to retiring; Debbie Kroese, who has been employed as a Composer Technician, has taken a different position with the Survey; and Kathi Hjelmstad, Statistics Clerk, will hopefully be transferring to some other state employment in Grand Forks.

The legislation includes the following stipulations:

> It amends all prior orders of the Industrial Commission to conform with amendments to Chapter 38-08 of the North Dakota Century Code as follows:
>
> 1) That wherever any order of the Commission provides for filing of logs, surveys, or reports with the State Geologist, such order is hereby amended to provide for such filings with the State Geologist, and with the Commission. Wherever any order of the Commission provides for the filing of samples, core chips, or cores with the State Geologist, the filings of such samples, core chips, or cores shall continue to be filed only with the State Geologist.
>
> 2) That wherever any order of the Commission otherwise mentions the State Geologist, substitute in lieu thereof the words "commission acting by and through the chief enforcement officer."

The legislation does not affect existing rules relating to oil and gas regulation. All oil field rules remain in effect, unchanged. All prior orders of the Industrial Commission, which had been implemented by the Geological Survey's Compliance Division, remain in effect, unchanged.

The law still provides for the conservation of the resource, for the protection of correlative rights and the environment, and it does so without unduly restricting the industry which it regulates. A new section (Section 5) was added to Chapter 38-08. Section 5 reads as follows:

> STATE GEOLOGIST TO ASSIST COMMISSION. The state geologist shall furnish the industrial commission with such technical services and assistance as the duties of the office permit.

Under the provisions of the new law, the State Geologist expects to continue to provide technical advice to the Industrial Commission from time to time, and we will, of course, continue conducting research into all aspects of the geology of hydrocarbon-bearing rocks.

CHANGES IN PERSONNEL

Apart from changes arising from the recent reorganization resulting from legislative action (see the previous article), the North Dakota Geological Survey has seen some other changes in personnel. Howard Umphrey, who was the Survey's Computer Programmer/Analyst, resigned in May to take a position with Petroleum Information (PI) in Denver. Kathy Miller, formerly a Composer Technician on our IBM System 6, was promoted to Howard's position as Computer Programmer. Debbie Kroese moved into Kathy's vacated position.

Our new Publications Clerk is Anne Behl, who began work with the Survey in February. Anne graduated from Apollo High School in St. Cloud, Minnesota and from the Area Vocational Technical Institute in East Grand Forks, where she completed a clerk-typists program. Prior to attending the AVTI, Anne worked at a resort in Battle Lake, Minnesota and for a time pinning and stretching mink at a mink ranch in Ottertail, Minnesota. Anne comes from a family of 7 girls and 5 boys.

John Hoganson recently joined the Survey as a geologist working on environmental problems. He holds a B.A. in geology from North Dakota State University and an M.S. from the University of Florida. John worked as a micropaleontologist with Union Oil Company of California from 1972 until 1975 in the Gulf Region. He lived in Houston at the time. He is currently completing his Ph.D. at the University of North Dakota on a study of the late Quaternary and Holocene climatic changes in southern Chile as deduced from changes in fossil beetle assemblages. John and his wife Carla, have two children, Kelly and Josh.

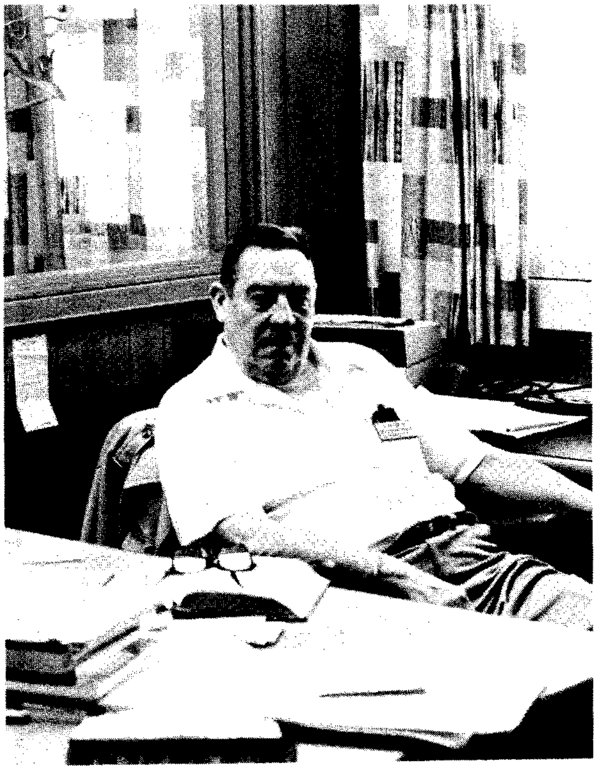
Gerald Groenewold is now the Associate Director of the Minerals and Mining Research Institute at the University of North Dakota. He continues half time with the Survey.

SURVEY PROFILES

Following are short profiles on three Survey staff members.

CLARENCE B. FOLSOM, Jr.

C. B. "Burt" Folsom has been Chief Petroleum Engineer for the Survey since 1953. Originally from Denver, Colorado, Burt attended the Colorado



School of Mines, receiving B.S. and M.S. degrees in Petroleum Engineering. He was employed by Phillips Petroleum Company prior to World War II, moving on to the position as Head of the Petroleum Engineering Department of the New Mexico School of Mines from 1947 until 1953.

When Burt was appointed Chief Petroleum Engineer for the Survey in 1953, he immediately began the process of writing and implementing rules to reflect North Dakota's new Oil and Gas Conservation Law, which was also enacted in 1953. These rules are essentially the ones in force today.

Burt was recognized for 27 years with the NDGS during the dedication ceremony for the new Wilson M. Laird Core and Samply Library last October.

Clarence B. Folsom, Jr.

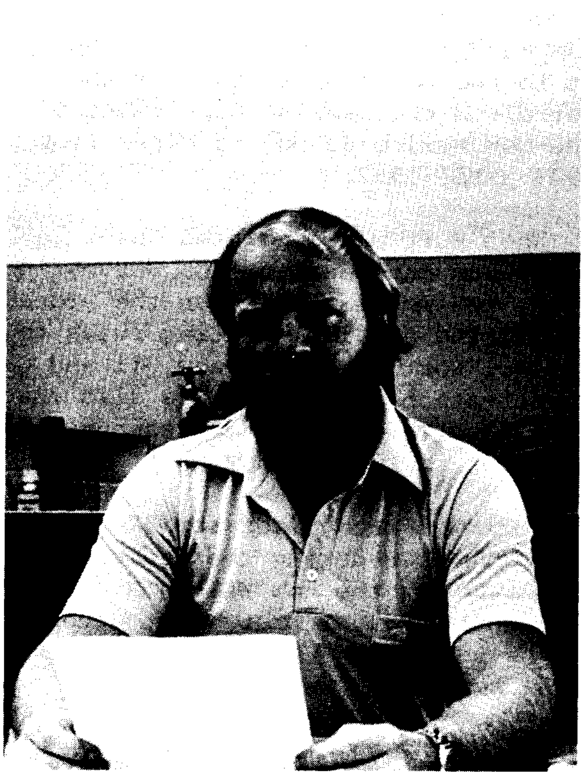
RANDOLPH B. BURKE

Randy has been with the Survey as a carbonate geologist since 1979. He has a B.S. degree from the University of Southern Colorado, an M.S. from the Marine Science Institute, University of South Florida, and he is currently completing a Ph.D. on the morphology, structure, and benthic communities of the Belize Barrier Reef, also from the University of South Florida. Prior to coming to the NDGS, Randy was employed as a Research Associate, and later as a Research Collaborator, at the U.S. National Museum, Washington, DC, working on marine geology. He has done considerable research on coralline algae and on reef structures in the Caribbean. Randy is involved in research on North Dakota's oil-producing carbonate formations.

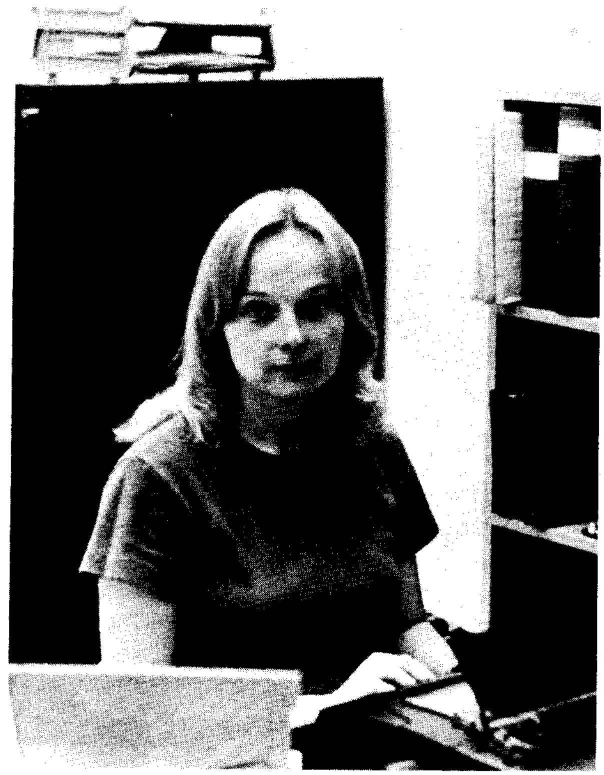
CONNIE BORBOA

Connie began work with the Survey as a Stenographer in the Publications Department in 1972. Originally from Overly, she graduated from the University of North Dakota with an AA in Business Education. Connie is one of those secretaries who can do anything and everything, and generally does. She manages to keep track of an on-the-go State Geologist, distributes all the mail to the appropriate people, assists in supervising the Publications Department, and keeps her dictating machine going, all at the same time.

Connie lives in Larimore with her husband Mario and two children, Kayne and Stacey.



Randolph B. Burke



Connie Borboa

RECENTLY RELEASED PUBLICATIONS

Since our last Newsletter was published last December, the Survey has released several new publications.

Miscellaneous Series 59 -- "Oil Exploration and Development in the North Dakota Williston Basin: 1980 Update" was co-authored by Lee C. Gerhard and Sidney B. Anderson. This nontechnical report provides general background on oil development in North Dakota from the discovery in 1951 through 1980. The 20-page booklet contains a wealth of information including statistics such as annual crude oil production in North Dakota since 1970, annual oil and gas production tax collections, and oil and gas lease bonus income figures. It summarizes annual crude oil production, new pool discoveries, total wells drilled, and wildcats attempted, all since oil production began in North Dakota in 1951. By means of a series of maps, the pattern of oil development in the North Dakota Williston Basin is clearly traced over the years. The report is available from the North Dakota Geological Survey for 50¢.

Educational Series 13 -- "Petroleum, a Primer for North Dakota" was written by Erling A. Brostuen. It is a non-technical discussion of the origin, exploration, and production of crude oil and natural gas in North Dakota. The publication was prepared especially for laymen and it includes a discussion of the regulation of the petroleum exploration and producing industry in the state. It is available free of charge from the North Dakota Geological Survey.

A supplement updating the Survey's 1973 Drill Stem Test Catalog was published recently. The Drill Stem Test Catalog provides a compilation of test data and log characteristics of the test interval for wells that are located one half mile or more from producing wells. The new supplement provides an update for the period August 1, 1973 through December 15, 1978. It provides additional information for 37 exploratory wells in eleven counties. The Supplement is punched for easy insertion into the original catalog. It is priced at $2.00. Copies of the 1973 catalog are also available for $5.00. The pair can be purchased for the price of $6.00.

Bulletin 74, Part II -- "Ground-water data for McHenry County, North Dakota" was prepared by P. G. Randich. The report is a compilation of groundwater data and it makes available the geologic and hydrologic data that were collected during the county groundwater 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 McHenry County. 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. The report is 446 pages long and includes one plate which shows the locations of wells and test holes in McHenry County. It is available free of charge from the North Dakota Geological Survey.

Bulletin 75, Part III -- "Ground-water resources of Sheridan County, North Dakota" was prepared by M. R. Burkart. The report is one of three parts dealing with the geology and groundwater flow systems in Sheridan County. It is a result of an investigation to determine the quantity and quality of groundwater available in the county. Groundwater is available from glacial-drift and bedrock aquifers. The major glacial-drift aquifers, which range in depth from 0 to 725 feet, may yield as much as 500 gallons per minute. Groundwater is available from bedrock aquifers in amounts generally less than 50 gallons per minute. Aquifers in the glacial drift consist of sand and gravel deposits that occupy buried valleys, meltwater channels, and outwash plains. Bedrock aquifers are in the Fox Hills and Hell Creek Formations. The report is 32 pages long and includes maps showing groundwater availability and bedrock topography in Sheridan County as well as hydrogeologic sections. The report is available free of charge from the North Dakota Geological Survey.

Bulletin 76, Part III -- "Ground-water resources of Billings, Golden Valley, and Slope Counties, North Dakota" was prepared by Lawrence O. Anna. It is one of three parts dealing with the geology and groundwater flow systems in the three-county area. Major aquifers are those in the Fox Hills-lower Hell Creek; upper Hell Creek-lower Ludlow; upper Ludlow-Tongue River and the Sentinel Butte aquifer. Yields from the various aquifer systems may range from about 50 gallons per minute in the Sentinel Butte to as much as

250 gallons in the upper Ludlow-Tongue River aquifer. Aquifers in alluvial deposits consist of thin beds of sand and gravel and generally yield less than 50 gallons per minute. The most dependable supplies of relatively good quality water in the three counties are obtained from the Fox Hills-lower Hell Creek aquifer system. The report is 56 pages long and includes hydrogeologic sections of the three-county area. It is available free of charge from the North Dakota Geological Survey.

A report entitled "An Evaluation of Hydrothermal Resources of North Dakota" by Kenneth L. Harris, Laramie M. Winczewski, Howard R. Umphrey, and Sidney B. Anderson, originally published in 1980, has been reissued and is now available. The report summarizes the first phase of a study of North Dakota's hydrothermal resources. It includes stratigraphic data, bottom-hole-temperature data, and chemical data, all presented by means of a series of maps to show geothermal gradient, temperature, and depth of potential hydrothermal aquifers and the chemical characteristics of potential hydrothermal aquifers.

The report also includes a coding guide to the GEOSTOR Computer well file and an introduction to the GEOSTOR Map-Oriented data management system. The report, which was prepared in cooperation with the U.S. Department of Energy, Division of Geothermal Energy, is available from the North Dakota Geological Survey in limited quantity, or from the National Technical Service, U.S. Department of Commerce, Springfield, Virginia 22161.

FLY ASH DISPOSAL PROJECT IS EXTENDED

--Gerald Groenewold

The Department of Energy, Grand Forks Energy Technology Center, has awarded a one-year continuation for a research project entitled "Disposal of Fly Ash Alkali FGD Sludge in a Western Decoaled Strip Mine." The period of funding is February 1, 1981, through January 31, 1982. Funding for this period totals $63,490. This project, originally funded by EPA and presently in its fourth year, has received a total of $520,000 in federal funds. Co-principal investigators are Gerald Groenewold (NDGS) and Oscar Manz (Department of Civil Engineering at the University of North Dakota). The major objectives of this project are an evaluation of the effects of these waste products on groundwater quality and a determination of optimum design criteria for disposal sites. This project involves monitoring and analysis of groundwater in and near areas of fly ash and FGD sludge disposal at the Center Mine near Center, North Dakota, laboratory leaching experimentation utilizing these waste products, and computational geochemical studies. This project is the most detailed study of its kind in North America.

NEW GRANT

--Gerald Groenewold

The Department of Energy, Grand Forks Energy Technology Center, has awarded a grant for $41,000, effective June 1, 1981, for the preparation of a manual entitled "Hydrogeological and Geotechnical Procedures Manual for Western Strip Mine FGD Disposal." This project will provide a document for use as a guide in designing surface-mine disposal sites for thermo-electric utility wastes in the western U.S. The specific objectives are to:

1. Identify and provide procedures for collecting the hydrogeologic and geotechnical information necessary to design a strip mine disposal site;

2. Identify and provide site-selection evaluation criteria, using pertinent federal regulations, to assess proposed strip mine disposal sites;

3. Identify and provide groundwater quality evaluation criteria, using pertinent federal regulations, affecting disposal in a strip mine;

4. Identify existing western mining and reclamation practices affecting disposal in a strip mine;

5. Identify groundwater monitoring procedures and requirements at a strip mine disposal site.

The co-principal investigators for this project are Gerald Groenewold (NDGS) and Oscar Manz (Department of Civil Engineering at the University of North Dakota). The termination date for this project is May 31, 1982.

COMPUTER SYSTEM-ASSISTED STRATIGRAPHIC INTERPRETATION OF THE INYAN KARA FORMATION

--Brad Wartman

The NDGS is currently in the process of assessing the potential geothermal resources of North Dakota under a cooperative agreement with the U.S. Department of Energy, Division of Geothermal Energy (FC07-79ID12030).

One aspect of our study, which is currently in its third year, is a study of relatively shallow aquifers. Such aquifers are of greatest potential interest to users in developing the low-temperature hydrothermal resources (<90°C) of the state.

One of the shallow aquifers is the Inyan Kara Formation. The basal Cretaceous unit in North Dakota, the Inyan Kara, is composed of alternating layers of sand and shale. It is laterally extensive, found in all parts of the state except in parts of the Red River Valley (Figs. 1 and 2).

As a part of our study, structure, isopach, and sand/shale ratio maps have been constructed using computer graphics. Data for these maps were obtained from the more than 8,000 geophysical well logs on file at the NDGS. Data from these logs were then encoded and entered into our computer library system, WELLFILE. For each map, township-average values were calculated by computer and then plotted using the SURFACE II graphics system.

The isopach map (Fig. 3) shows the thickness of the Inyan Kara sediments. The isopach map was constructed by recording formation thicknesses from all logs penetrating the Inyan Kara Formation. The computer then contoured the township-average thickness values (Fig. 4). The sand/shale ratio map (Fig. 5) shows the ratio of sand to shale throughout the area. It was constructed by recording thicknesses of sand and shale penetrated in each well; the summation of the sand thicknesses (in metres) was divided by the summation of the shale thicknesses for each well and the township average of these ratios was mapped by computer (Fig. 6). When the ratios are used in conjunction with the isopach maps, the total thickness value for sand and shale at each location can be calculated. Thus, if the sand/shale ratio at a given point is two and the isopach map shows 90 metres of sediment for that location, we can expect 60 metres of sand and 30 metres of shale.

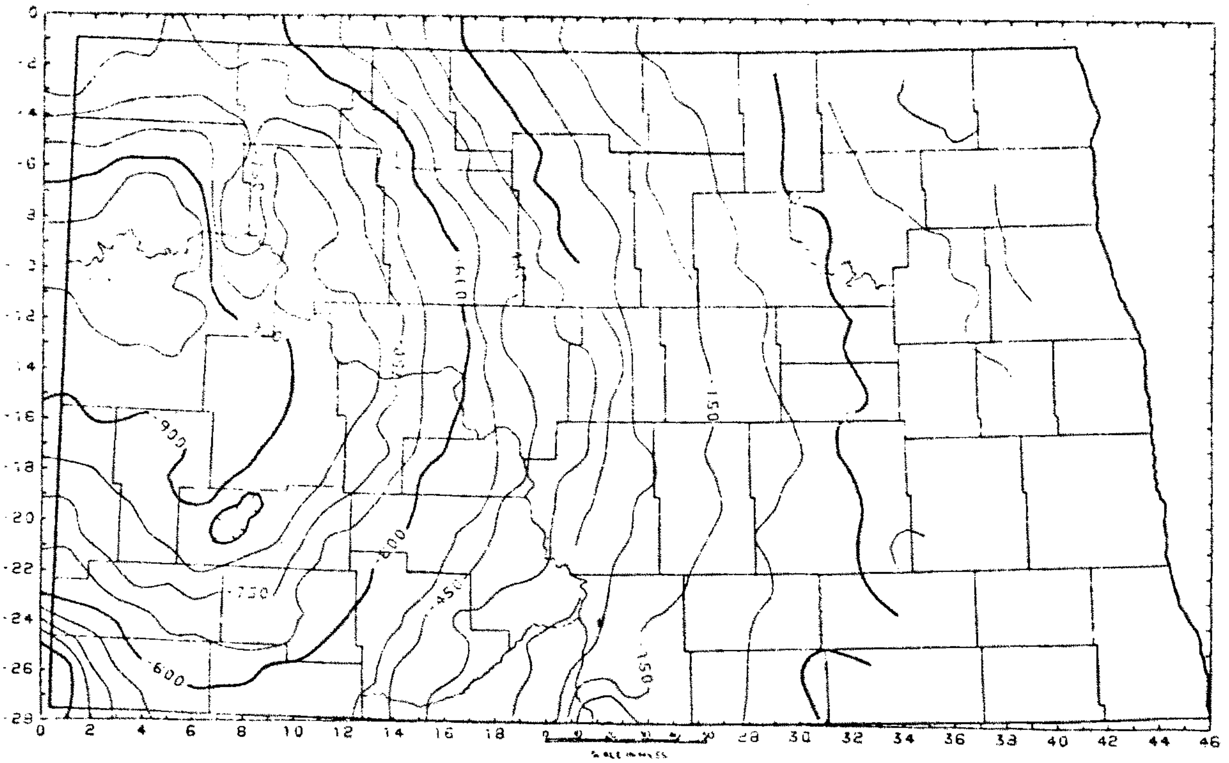


Figure 1. Structure map on top of the Cretaceous Inyan Kara Formation. Contour interval is 75 metres.

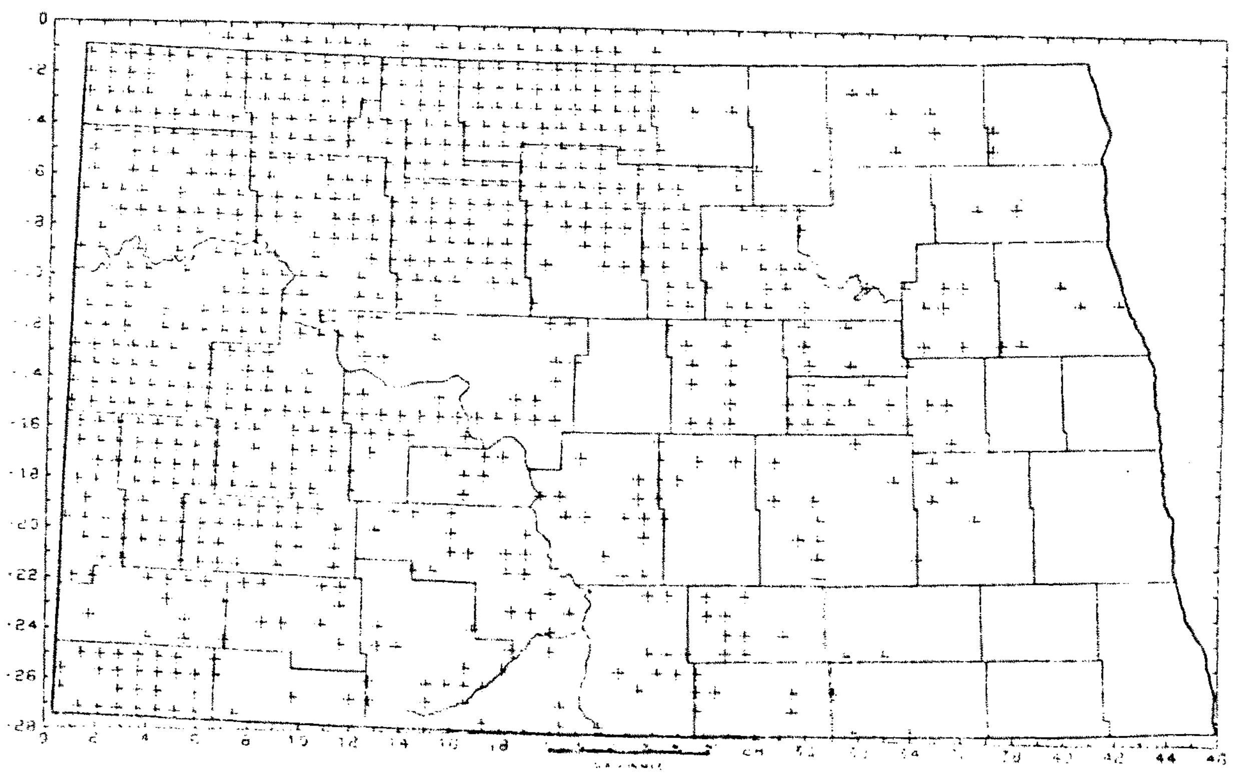


Figure 2. Posting of townships contributing well control for the Cretaceous Inyan Kara Formation structure map.

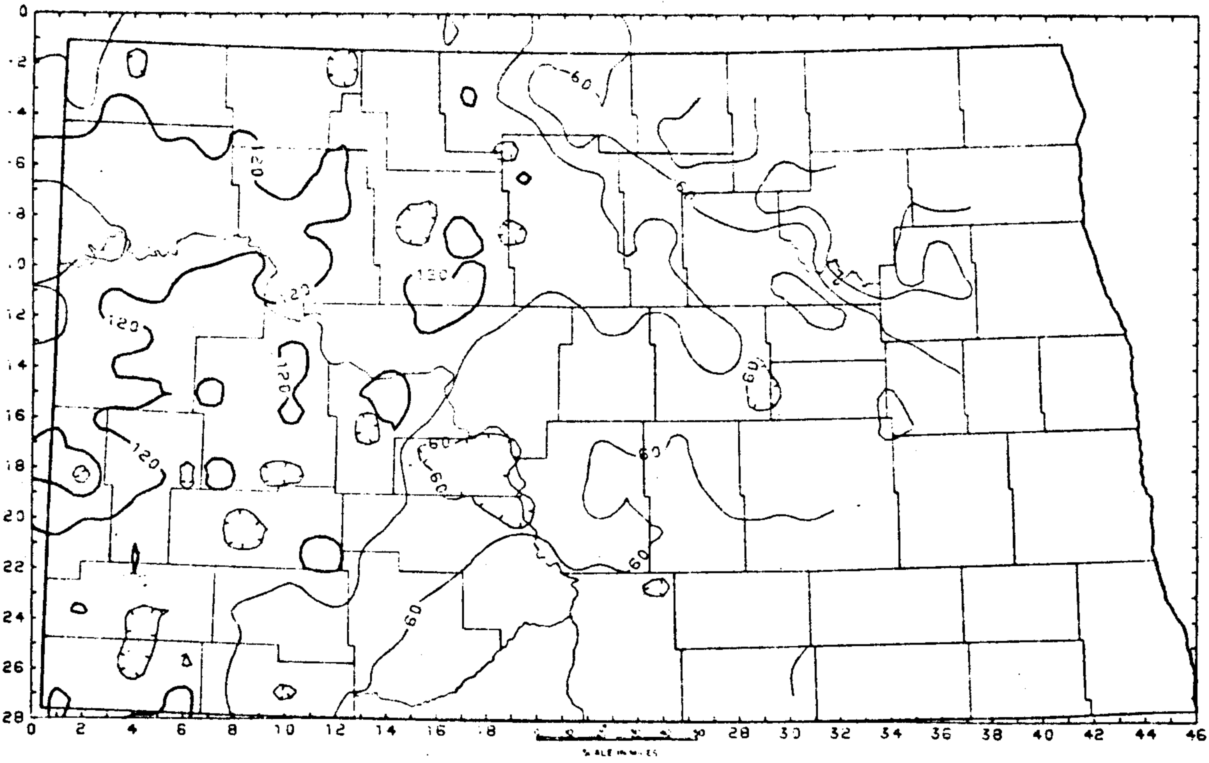


Figure 3. Isopach map showing thickness of the Cretaceous Inyan Kara Formation. Contour interval is 30 metres.

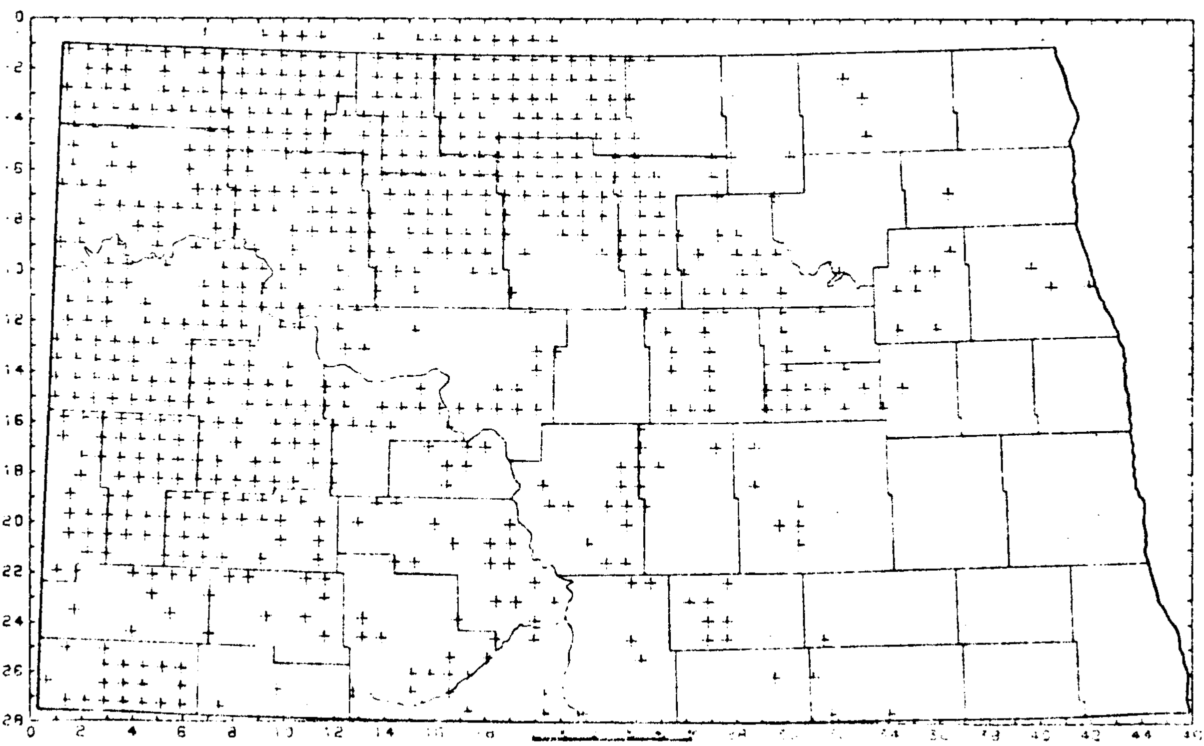


Figure 4. Posting of townships contributing well control for the Cretaceous Inyan Kara Formation isopach map.

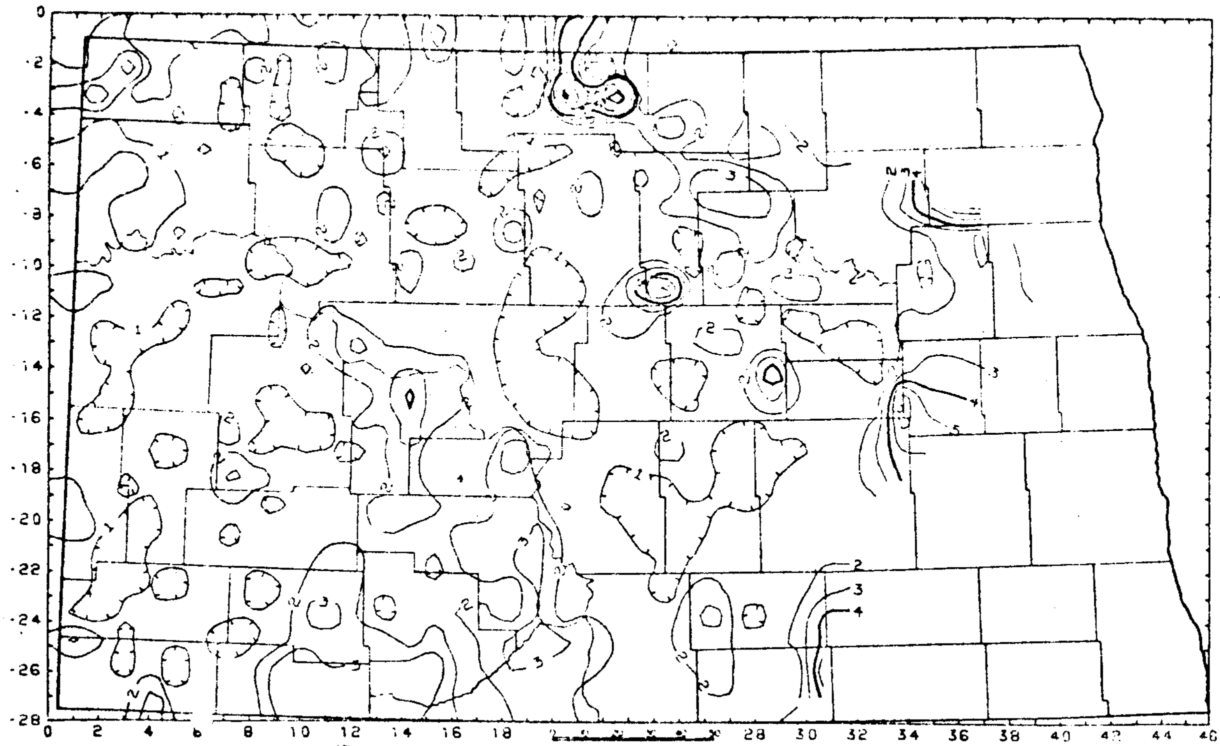


Figure 5. Sand/shale ratio map for the Cretaceous Inyan Kara Formation. Contour interval is 1.

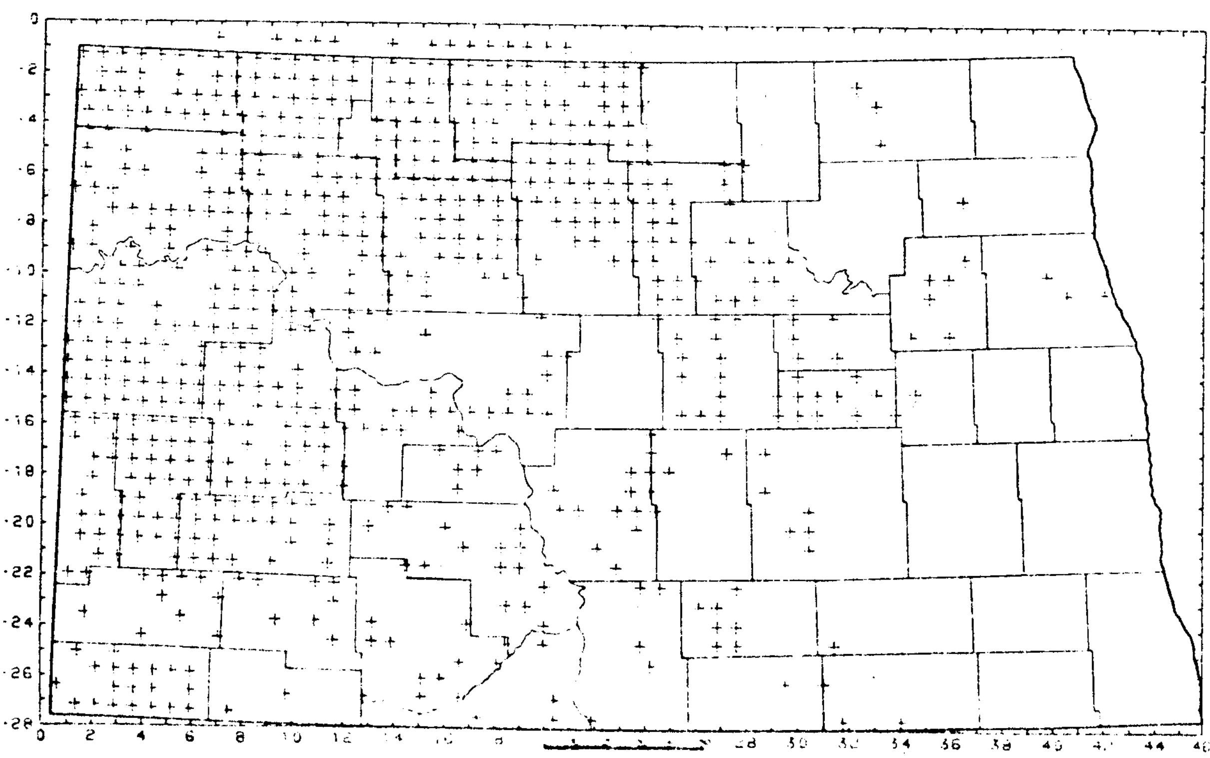


Figure 6. Posting of townships contributing well control for the Cretaceous Inyan Kara Formation sand/shale ratio map.

Previous work has established that the sediments of the Inyan Kara Formation were deposited in a marine-marginal marine environment, with the Lower Cretaceous seas transgressing from the west and southwest toward the east.

The isopach and sand/shale maps show that the Inyan Kara sediments were derived from source areas to the east, south, and possibly the north. In addition, the variable, log-derived sand/shale ratios, especially in eastern North Dakota, suggest that isolated sand bodies, such as channel sands, may be present.

The structural contour map (Fig. 1) and the isopach map (Fig. 3) show that, during the Lower Cretaceous, both the Williston Basin and the Nesson Anticline were active structural features.

ENERGY-RELATED PROJECTS UNDERWAY BY THE NDGS

Several months ago, before the 1981 Legislative Assembly adjourned, I compiled a listing of energy-related projects in which the North Dakota Geological Survey is involved. Although the legislation enacted during the 1981 session does substantially alter the Survey's role in North Dakota's energy development--it relieves us of our oil and gas regulatory responsibility--the Survey is still deeply involved in researching the geology of North Dakota's energy-related resources.

Geologic Studies of the Oil & Gas Bearing Rocks

State law still requires oil companies operating in North Dakota to supply us with all samples, cores, logs, and other data requested by the State Geologist. As a result, we maintain what is probably the most complete collection of well core available in any oil-producing state. We also maintain geophysical logs for over 8,000 exploratory and producing wells in our offices. In short, the recent legislation does not change anything insofar as our access to technical materials is concerned. We will still receive the same information.

Studies by NDGS geologists are ongoing on all of these resource materials. It is hard to pinpoint which of our general or specific studies have been most significant or fruitful. Research by Survey staff geologists resulted in recognition of the "Billings Nose," which is now the object of intense exploratory drilling and development. Several University of North Dakota graduate students have recently completed theses on a variety of pertinent topics and several more studies are underway on Williston Basin carbonates. Recently completed studies include those on the Tilston interval rocks; Tyler Formation paleozoology; Bottineau interval rocks; Upper Red River Formation; and Carrington Shale facies.

All of the North Dakota Geological Survey's resource materials are always available for research by private consultants, industry geologists, and virtually anyone who is interested in using them. Clearly, the most significant energy-related research function accomplished by the NDGS is to continually study and reevaluate the rapidly accumulating new data--core, samples, logs, and engineering data--to better understand Williston Basin geology.

We have several specific energy-related studies underway. One of these is an appraisal of the environmental effects of oil well drilling muds, and the manner in which these muds are being disposed of. The common method of drilling mud disposal is to retain the mud in a reserve pit constructed adjacent to the drilling rig. This pit is usually lined with a sheet of plastic. After drilling is completed, the pits are reclaimed by covering the mud residue with soil. The water is usually injected back into the ground. We want to determine whether any of the drilling mud components are migrating through the soil, thereby causing possible pollution of groundwater supplies. The study involves installing observation wells and monitoring the movement of leachate from the mudpit site. So far, the indication is that some movement of the fluids is taking place, and certainly some potential danger exists.

Our Carbonate Core and Sample Laboratory was established in 1976. It utilizes the extensive collection of oil-well core maintained in the Wilson M. Laird Core and Sample Library. In view of the fact that about 85% of North Dakota's oil production is from carbonate rocks (limestone and dolomite), these studies are particularly pertinent here. Of the total 555 million barrels of oil that had been produced in North Dakota through January 1, 1980, only about 80 million barrels came from non-carbonate reservoirs. In contrast, nationally, more oil is produced from sandstone reservoirs than from carbonates.

Several projects currently underway by NDGS staff, UND faculty, and graduate students deal with many aspects of carbonate geology. They include studies of carbonate units in about a dozen North Dakota oil fields; analysis of carbonate sedimentary structures (oolitic, etc.); and studies of modern carbonate units to help us better understand our own ancient deposits. Examples of the third type of study include work by Survey geologists on the barrier reefs of Florida and the Virgin Islands, and the Belize Barrier Reef. We recently conducted a drilling project to examine the carbonates in the Carlsbad area of New Mexico. As the carbonate studies progress, we are gaining a better understanding of the nature of these oil and gas reservoirs. More hydrocarbons are being found as a result of these studies, and more will ultimately be recovered.

Geologic Studies of the Coal-Bearing Rocks

For approximately the past five years, the NDGS has had a study underway to assess the lignite resources of the state. The evaluation, which is now essentially completed, has been aimed at obtaining information over as wide an area as possible. The reconnaissance study has consisted primarily of drilling a limited number of test holes in the area of coal resources. Generally, we have drilled two or three test holes per township; these holes averaged about 200 to 500 feet deep. We logged all of the test holes and many of the cores were chemically analyzed by the U.S. Bureau of Mines. Our geophysical logs include gamma ray, density, self-potential, and resistivity. We now have a much better understanding of North Dakota's lignite resource; where it is located, how much is surface-mineable, and its overall quality.

Recently, we began a study of the entire Cenozoic section--the coal-bearing sediments--in the Williston Basin of North Dakota and Montana and the Powder River Basin of Wyoming and Montana. The near-surface sediments of these two associated basins contain vast amounts of coal and uraniferous minerals, enough of each to play an important role in the growing national energy emergency.

In North Dakota, the most important resource is lignite, which, apart from its use in generating electricity, has potential for liquefaction and gasification. In the Wyoming and Montana portions of the two basins, the most important near-surface resources are subbituminous coal and uraniferous minerals. Throughout the entire area, a major concern is the effect large-scale mining is having and will have on groundwater resources, reclamation procedures, etc. Our goal is to study and understand the amount, location, and stratigraphic framework of the resources; the geohydrologic setting; and the geochemical setting and characteristics of the various resources, so that problems that might otherwise arise during development of the resources can be avoided. Our study deals with such things as coal mineralogy, uranium and the feasibility of in-situ mining, geochemistry, geohydrology, inter-coal lithology, and sedimentary environments of deposition. We shall also deal with other resources and topics such as potable and subpotable water, clays, vertebrate fossils, climatic changes throughout Paleocene time, and the placement of the Cretaceous-Tertiary boundary.

As a major early step in our studies of the Cenozoic rocks of the Powder River and Williston Basins, we are conducting a week-long field trip in early August through the two basins. Approximately 25 geologists from state and federal government agencies, industry, and universities will be attending this conference. We expect to look at the Cenozoic rocks in the field in both basins, concentrating on definition of the stratigraphic units present. We will exchange ideas about the theory of the nature and development of the Fort Union depositional systems, localization of resource concentrations, groundwater systems, and other geologic problems.

Even though the North Dakota Geological Survey is not directly involved in regulating either the mining of lignite or the reclamation of the mined lands, we are doing a considerable amount of work on the geologic problems relating to the mining and reclamation procedures. For the past several years, the NDGS, with the help of UND geology graduate students, has been researching many of the problems and potential problems relating to the mining of North Dakota lignite and the reclamation of surface-mined land. A partial listing of research projects completed and/or underway by the Survey includes the following:

* How groundwater recharge takes place in reclaimed land
* Groundwater problems associated with potential stripmine areas
* The effects of groundwater on fly ash and flue-gas desulfurization (FGD) waste-disposal in strip mines
* The hydraulic properties of coal
* Subsidence and surface collapse problems in reclaimed areas
* Potential hydrogeochemical impacts of surface mining

Geologic Studies of the Uranium-Bearing Rocks

Over the years, the NDGS and the UND Geology Department have studied the state's uranium potential. Some uranium was mined in North Dakota near Belfield between 1956 and 1967. The uranium occurs as weakly radioactive lignite. The mining process involved burning the lignite, thereby concentrating the uranium minerals in the ash, which was shipped away for further milling. This type of uranium mining--by burning coal--has not been attempted elsewhere, as far as I know, and unless the economics change, it is unlikely that the method will be a profitable way to mine uranium. Uranium, does, however, occur in much greater concentrations and quantities in sandstone bodies, especially in Wyoming and Colorado. We will be evaluating the uranium potential as part of our study of the Cenozoic rocks of the Powder River and Williston Basins.

Geothermal Resource Evaluations

The North Dakota Geological Survey, the UND Physics Department, and the UND Experiment Station are cooperating with the Department of Energy/Division of Geothermal Energy in a study of the state's geothermal energy. As a part of this study, we have assembled a computer library system containing all relevent oil and gas well data. We have developed a computer graphics system to display the data. We have characterized "deep" aquifer systems according to:

* geographical distribution
* aquifer depth
* aquifer thickness
* water temperature
* water quality

As a result of these studies, we have generated a geothermal gradient map of North Dakota; this map should be available in the near future. The article on page 9 of this Newsletter describes in more detail some of the results of a study of the hydrothermal potential of the Cretaceous Inyan Kara Formation in North Dakota.

Our current activities under this program include assembling a computer library system that will contain all relevant water well data; refining our computer graphics capabilities; characterizing "shallow-water" and "shallow-local" aquifer systems according to the same parameters as we have done for the "deep" aquifers; conducting field studies to gather more precise data on heat-flow determinations and near-surface temperature gradients. We expect to be able to summarize the state's geothermal resource potential as a result of our studies. Future activities under the current program will include characterizing all potential hydrothermal aquifers and maintaining and expanding the geothermal data base.

NORTH DAKOTA OIL AND GAS DEVELOPMENT HISTORY AND RESOURCES

It is appropriate on this, the 30th anniversary of the discovery of oil in the North Dakota Williston Basin, to review the state's discovery and production history and offer our best prognosis of future possibilities. In addition to the overview presented in this article, this Newsletter also includes a look at one of the earliest exploration efforts (see page 22).

Historical Review: Pre-1951 Events

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

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

In September, 1916, a wildcat well was started by the Des Lacs Western Oil Company on the farm of A. F. Blum, about 1½ miles southeast of Lone Tree in Ward County. The well was abandonded at 244½ feet in October, 1916 (for more details about this episode in the State's Oil and Gas History, see page 22, this Newsletter).

In September of 1917, the Des Lacs Western Oil Company asked the Survey to investigate the possibilities of finding oil and gas in the Minot area. Dr. Leonard and Assistant State Geologist, Howard Simpson, found enough evidence to recommend further exploration. On the basis of their report, a well was drilled aobut two miles west of Des Lacs in 1923. The well penetrated to a depth of 3,980 feet, into the Cretaceous Inyan Kara Formation, but it proved to be nonproductive. It was located only about two miles east of present production in the Lone Tree Field.

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

On August 15, 1938, the California Company abandoned its Nels Kamp #1 in Williams County. This well was drilled only 1,866 feet from a well drilled in 1956 that became a producer. At 10,281 feet, total depth, the Kamp well had penetrated the Madison Formation, which is a productive zone in the area. Apparently, the Kamp well was circulating mud at the time and any shows were overlooked. This well was the first in North Dakota on which an electric log was run.

Due to the absence of Dr. Wilson Laird, Mr. Nicholas Kohanowski signed the drilling permit for Amerada Petroleum Corporation's #1 Clarence Iverson well to be drilled in the SW¼SW¼Sec. 6, T. 155 N., R. 95 W., Williams County. The permit was issued on August 4, 1950. Drilling began at 6:00 a.m. on September 3. On January 4, 1951, a drill stem test, from 10,452 to 10,803 feet, recovered one pint of free oil in the bottom of the test tool. The recovery was from the Devonian Formation. The well was completed in the Silurian on April 4, 1951.

Historical Review of Development: Post 1951

North Dakota's 1951 Nesson Anticline discovery was not the first oil production from the Williston Basin. Oil was discovered in the Williston Basin in Montana on the Cedar Creek Anticline in 1936 and in Manitoba in

1950. Since 1951, several significant cycles of exploration have been completed in North Dakota and another is now in progress. Annual production increased in North Dakota until 1966 (26 million barrels), then declined until 1974 (19.6 million barrels), and is now on an uptrend again. Production in 1979 (31 million barrels) surpassed the previous (1966) high and new highs are now being recorded each year (40 million barrels in 1980).

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

The year 1954 saw widespread wildcatting around the state, but with a notable lack of success, except for small discoveries in Bottineau County. The lack of success slowed exploration until 1957 and 1958, when the Burke-Bottineau stratigraphic trap play occurred. The increasing production between 1958 and 1961 largely reflects development of these pools. Production from this area was marketed first by rail and then, in 1963, via the Portal Pipeline to refineries in Minnesota and Wisconsin. A slight increase in wildcats in 1964 reflects the expanded market provided by the pipeline.

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

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

The decline in production from 1966 to 1974 represents the failure of new discoveries to replace the natural decline of the major producing areas. The normal pattern is discovery, followed by development, leading to peak production for 1 to 3 years, followed by a gradual decline. Secondary recovery methods are used in an attempt to alter this pattern. Water injection for pressure maintenance was installed in many of the Madison reservoirs along the Nesson trend, but this was relatively unsuccessful. Similar programs begun in 1967 in the Newburg-Spearfish and Madison reservoirs, in 1970 in the Medora Field, and in 1973 in the Tyler sand reservoirs in Dickinson Field increased production levels above the initial development in those fields. However, these successful programs could not offset the natural decline of the major producing areas.

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

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

OPEC created the first substantial worldwide increase in the price of oil. As a result, exploration was once again a profitable venture. Prior to this, many companies found that exploration risk money had a better return in a regular bank savings account than in actual wildcat drilling. The price increases created risk capital, and thus exploratory drilling was enhanced.

The Red Wing Creek discovery at about the same time excited basin oil operators because of the relatively high productivity of the wells and because of the anomalously thick pay section. Since no one really understood the nature of the Red Wing Creek structure at the time, industry's only possible response was to gain lease foothold in the area. The lease play set off by the Red Wing Creek discovery set the stage for much further development. The five-year-term leases of western North Dakota tend to increase exploratory activity as compared to ten-year leases. The lease play, coupled with the sudden availability of venture capital, caused exploratory drilling to begin to increase in 1975 and 1976, in part in response to the lease expiration dates.

It is also of interest that exploration and production have followed technology. Initial production was from Nesson Anticline seismic-origin prospects; Amerada Petroleum Corporation drilled a string of successes 75 miles long without a dry hole. As interpretation of basin geometry progressed, stratigraphic/structural traps were defined along the northeast basin flank. Later, in Bowman County, North Dakota, seismic technology successfully defined small Red River structural "bumps." Stratigraphic plays and long-shot deeper drilling sporadically generated interest until the well-known unusual seismic configuration at Red Wing Creek became productive.

Assessment of the future involves an evaluation of source rocks as well as reservoir capabilities. Geochemical studies have classified Williston Basin oils into three types and, based on carbon isotope studies, it has been postulated that the source rocks for most of the oil are type I - Winnipeg shale; type II - Bakken Formation; and type III - Tyler shale. In a 1974 paper, Dow further estimated volumes as type I - 600 million barrels; type II - 10 billion barrels; and type III - 300 million barrels. He estimated that 50% of type I, 30% of type II and lesser quantities of type III had been discovered at that time.

Various researchers who have studied the rock sections in the Williston Basin would agree that the Winnipeg, Bakken, and Tyler represent the most concentrated source of organic materials; however, we believe that many producing horizons contain sufficient organic material to be self sourcing. Specifically, the Red River, Birdbear, Duperow, Winnipegosis, and Madison Formations have sufficient indigenous organics to provide large quantities of liquid hydrocarbons. If this is so, much more oil remains to be found in the Williston Basin.

If new pool discoveries during the past four years are compared to preceding years, the significance of the present development boom becomes obvious. Except for the 1954 east side and 1968 "Muddy" Sandstone wildcat programs, high levels of wildcat activity have a corresponding peak of new pool discoveries. However, the number of new pool discoveries per wildcat well drilled has risen dramatically in the last four years. This increase in success is attributed first to use of CDP seismic, second, to a better understanding of reservoir geology, and third, to completely revised testing and completion techniques.

Dramatic expansion of producing areas has occurred during the present cycle. This includes new producing counties, new pay horizons, and new producing depths. In 1970, about 20 active locations existed in the entire basin; in 1980, there were about 150 active locations, on the average.

Activity is now centered in western North Dakota and the bordering Montana counties. Significant new discoveries have been Little Knife Madison (109 wells, 125 million barrel reserve, 1977); Mondak Madison (112 wells, 100+ million barrels reserve, 1977), and the Billings Nose area, which consists of a group of Madison reservoirs and Duperow wells which have recorded initial potentials over 2000 barrels a day and a few with potentials over 3000 barrels (158 wells, 100 million barrels reserve).

Another significant recent development is the deeper horizon exploration along the Nesson trend. Here it should be emphasized that the Beaver Lodge Duperow pool is outperforming the Madison Pool.

Shallow gas plays are in their infancy in the basin, but they are in process. Air drilling is necessary for adequate testing of Pierre (Judith River and Eagle Sands), "Muddy," Inyan Kara, and Niobrara rocks, but these rigs are uncommon in the basin and surface holes can be a problem with air drilling. Little testing has been done on the southeast extension of the Antelope Anticline, an area we have only recently begun to delineate as a major potential hydrocarbon area. Stratigraphic traps around the Cedar Creek, Nesson, and Poplar Anticlines are untested for the most part, as is much of the eastern and western basin flanks.

The northwest shelf, west of the Nesson Anticline holds promise, and has been tested mostly on the Montana side of the basin. Many prospects remain to be drilled. The independents who kept the basin oil industry going in the sixties are largely frozen out of the main activity now by high lease prices. One example of this is in state land sale values. In 1970, the total bonuses paid for the year for state leases was $294,000. In 1978, the annual total neared $20,000,000. In 1980, for the last quarter sale only, over $30,000,000 was paid.

The future for oil and gas production in the Williston Basin looks bright at least for the next few years. New rigs moving in, major exploratory programs underway, and high lease prices all support a continuation of the present exploratory boom, with several years of developmental drilling still needed after decreased exploratory drilling occurs.

The financial impacts on the state of North Dakota from the oil business are very significant. For the 1980's, oil and gas-generated revenues will be the most significant single source of income to the state government.

A BRIEF REVIEW OF THE HISTORY OF NORTH DAKOTA'S CONSERVATION LAW--Erling Brostuen

In light of the recent passage of House Bill No. 1536 by the North Dakota Legislative Assembly amending certain parts of the state's oil and gas conservation law (see article elsewhere in this Newsletter), it is interesting to take a look at the evolution of the law.

North Dakota's conservation statute has undergone several transformations as the circumstances have changed over the years. The North Dakota Oil and Gas Conservation Law was amended several times by succeeding legislative assemblies and it was revised in 1953 into its present form. The 1953 act was preceded by earlier acts in 1911, 1929, 1937, and 1941.

The act of 1911 was designed to project adjacent landowners and the public from the escape of natural gas from open or improperly abandoned gas wells. A penalty for violation of the statute was provided, but no regulatory authority was specifically charged with enforcement duties.

The 1929 act was the first statute which required the permitting of wells and the filing of basic data. The State Geologist was named as the regulatory authority and a penalty was provided for violation of the statute.

The 1937 act provided for the conservation of oil and gas, and it provided that the State Geologist was to prescribe rules and regulations. Such rules and regulations were to be the same as those adopted by the Bureau of Mines or the Secretary of the Interior, pursuant to an act of Congress approved on February 24, 1920.

In 1941, the legislature passed the first comprehensive oil and gas conservation law. The act placed the supervision and control over crude petroleum oil and natural gas with the Industrial Commission. The State Geologist was named as a supervisor and charged with the duty of enforcing the regulations and orders of the Industrial Commission. The 1941 act also provided that the Industrial Commission was to obtain the assistance of the State Geologist in carrying out its responsibilities.

At the time the 1941 act was enacted, the only commercial production in the state consisted of a minor gas field in the Eagle Pool on the Cedar Creek Anticline in Bowman County. The 1941 law was based on the then Model Act that had been drawn up by the Legal Committee of the Interstate Oil Compact Commission. It made the Industrial Commission the regulatory authority and designated the State Geologist as advisor and enforcer of the regulations promulgated by the Commission.

The act of 1941 was revised in 1953. Both acts were essentially the Model Oil and Gas Conservation Acts, which had been developed by the Interstate Oil Compact Commission. The current statute is patterned after the Interstate Oil Compact Commission's Model Act of 1950.

Since 1911, North Dakota has had in place the statutory regulatory control necessary for the level of oil and gas exploration and development being conducted at any given time. The role of the State Geologist in the regulation of oil and gas exploration and development has been significant since 1929. This represents over half a century of involvement in oil and gas regulatory activity. The Industrial Commission has been responsible for the conservation of oil and gas since 1941, a period of forty years.

The State Geologist and the Geological Survey have a long history of involvement in oil and gas conservation and regulation. Over the years, the Geological Survey has developed the systems and the geological expertise necessary for the acquisition, interpretation, and utilization of oil and gas exploration, development, and production data. This is the result of fulfilling the provisions of the original act and subsequent acts.

EXCERPTS FROM EARLY EXPLORATION EFFORTS

On this, the 30th anniversary of the discovery of oil in North Dakota, it seems appropriate to recall some of the first attempts at oil exploration in the state. Letters and reports included in the NDGS files dating to between 1915 and 1925 contain an assortment of interesting, often humorous observations and anecdotes about early wells that were drilled for oil in North Dakota, and about other topics of interest at the time. The files are lengthy, and include hundreds of pieces of correspondence. I will not attempt to provide any kind of accurate chronology of the history of the Survey (that is available in North Dakota Geological Survey Miscellaneous Series 58 by C. B. Folson), but simply excerpt, by paraphrase and quote, some of the things that interested me.

Even though shallow gas was utilized in parts of northwestern and southeastern North Dakota before 1910, the low-heating value gas was obtained from glacial deposits at depths of 150 to 200 feet, and no serious attempt was made to drill a real "oil well" until 1916. About that time, a North Dakota corporation calling itself the Des Lacs and Western Oil Company was organized at Minot. Officials of this company attempted to drill several wells in northwestern North Dakota. It is difficult to be certain just what was going on much of the time, as the various press releases and reports were sometimes a blend of hearsay, promotional statements, and facts. The quote that follows is from a prospectus of the Des Lacs and Western Oil Company. It dates to about three years after the first attempt by the company to drill a well.

July 14, 1919

The Des Lacs Western Oil Company is a North Dakota Corporation, incorporated for 275,000 shales all common stock and non-assessable.

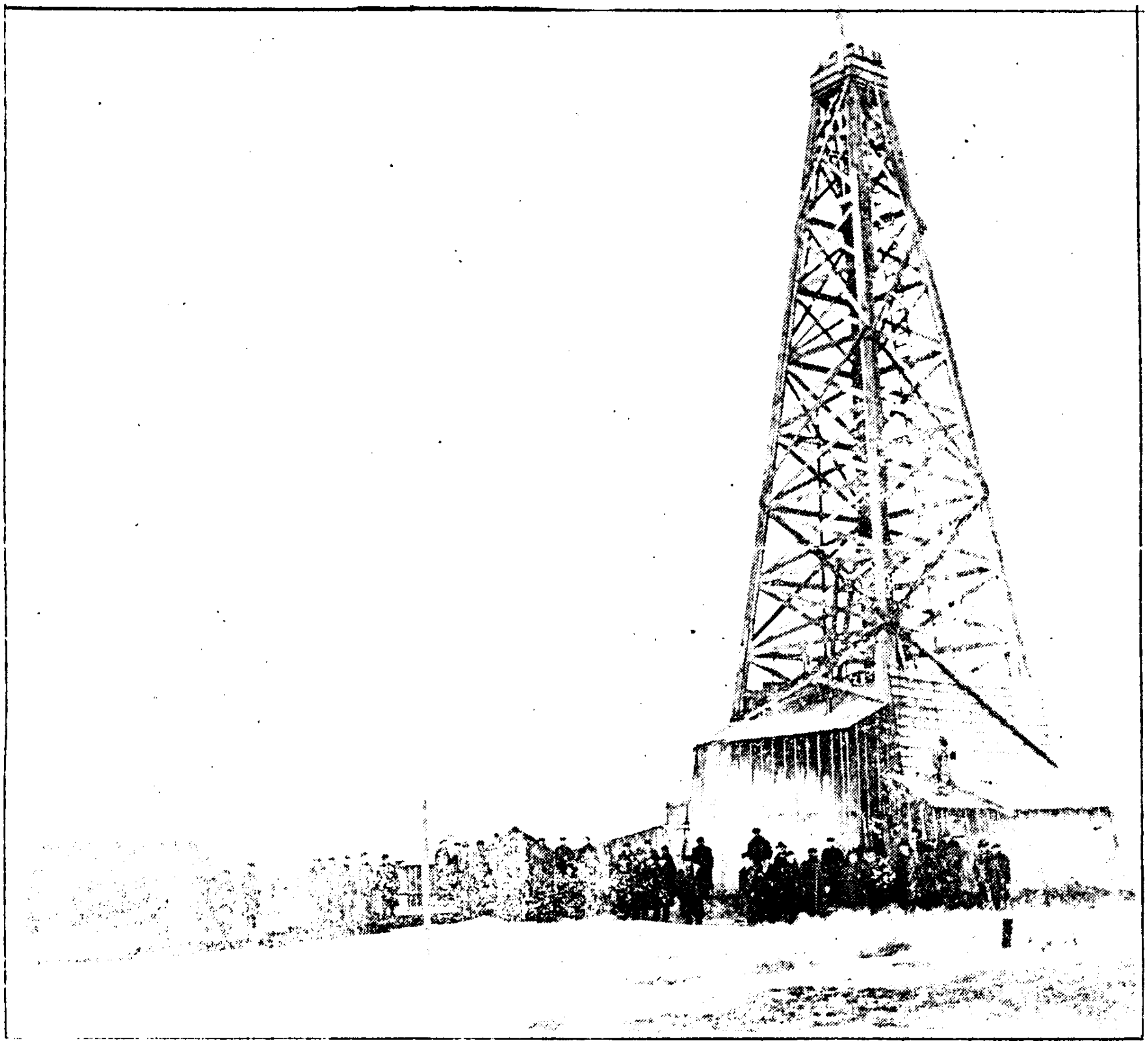
We now have a Lease acreage of more than 60,000, located favorable for both Oil and Gas by prominent Geologists and Oil Men.

We encountered showings of Oil in seven test wells and also established our "Blum Anticline." We are encountering some very nice seepages of Oil and Natural Gas in "BLUM WELL" which has now reached a total depth of 2125 feet. We are still carrying 8 1/4 Casings and have sufficient casings now on ground for a 3000-foot well. Yes, Blum Well will be carried down 3000 to 3500 feet or even deeper in order to bring in Commercial production, which we sincerely believe will be encountered when the big Drill taps the proper formation.

This is a North Dakota proposition. Commercial Oil has been encountered in our sister state, South Dakota, and we believe that it will be only a matter of reaching the proper formation to put North Dakota in the Oil producing column.

A small block of stock is being offered at $5.00 a share. All stock participates in Lease holdings and other property of the company.

We are now below Sea Level and nearing formations which have been known to be productive of commercial Oil and Gas. You can help develop the natural resources of your home state by becoming a stockholder with us now.



Scene on the Blum Farm where Drilling Operations are in Progress

The earliest attempt by the Des Lacs and Western Oil Company was apparently in September, 1916, when, over a one-month period, they drilled a 224-foot hole in Section 9, T. 155 N., R. 85 W. in Ward County. Interestingly enough, the hole was located approximately two miles from current production in the Lone Tree Field. Wells in the Lone Tree Field produce from the Sherwood (Mississippian Madison) at a depth of approximately 6,500 feet, so the choice of location was not really too bad, and if the well had been drilled another 6,000 feet or so, it is possible it might have been a producer.

At the time the well was being drilled and for a period of about 5 years from 1916 to 1921, the Assistant State Geologist, Howard E. Simpson, provided technical services to the Des Lacs and Western Oil Company by traveling to their well sites and observing and advising on the test being conducted by the company. In one handwritten letter, he submitted an itemized statement for his services (dated February 9, 1917) (it was hard to read in places).

Feb. 7.	Taxi, baggage, Grand Forks	.50
	Checking baggage	.20
	Breakfast	.50
	Chair, GF to Minot (train fare)	1.00
	(entry I can't read)	.80
	Lodging, Minot	1.00
Feb. 8.	Taxi to depot	.25
	Breakfast	.55
Feb. 9.	Lunch	.50
	Checking baggage	.20
	Supper on train	.85
	Seat, Minot to GF (train fare)	1.00
	Taxi, baggage	.50
	Express	.50
	Expenses	9.20
	Three days services @ 10.00	30.00
		39.20

The addition is off slightly. A letter written a few months later to Dr. Simpson, from the oil company secretary, notes that they apologize for a delay in paying the bill, but they will be paying it as soon as they raise more money. Following a similar billing by Dr. Simpson a few years later, Simpson subsequently agreed to deduct $7.00 from his bill as a sort of contribution to the cause.

Another series of letters written in 1921 is interesting in its dogged persistence at a single topic--attempts to measure the temperature of samples obtained during the drilling of a 4,000-foot hole by the Des Lacs and Western Oil Company in the same general area. The letters span all of the year 1921. The first letter is dated January 31, 1921, and addressed to H. S. Johnson, Secretary of the Des Lacs and Western Oil Company (I have not included the entire content of most of these letters).

January 31, 1921 -- Letter to Johnson from Dr. Simpson:

"I have thought often of the temperature test we made on the muds. I am anxious to secure from you or Mr. Blum, if he owns it, the little thermometer with the blue colored wooden back which we used in taking the temperature of 110° at that time, in order that I might test out the instrument at the same temperature to see what the reading would be for this on a standard thermometer. I should greatly appreciate therefore, your sending me that thermometer the next time you are at the well and have the opportunity, in order that I may make the proper correction. I will return it to the owner." (The letter is signed by Howard Simpson, Assistant State Geologist.)

February 14, 1921 -- Letter from V. Smith to Howard Simpson:

"Mr. Johnson has instructed Mr. Blum to send you the thermometer used in your test of December 6th out at the well and will be pleased to receive your thermometer."

April 30, 1921 -- Letter from Simpson to Johnson:

"Accept my thanks for the thermometer which was sent from Mr. Blum's residence...I should like very much to get some additional data on the temperature of the sludge as it come up, and will try and provide you with a special thermometer which could be used for getting the temperature, in case you are still drilling. Regarding the bill of December 7, amounting to $29.76, permit me to make a contribution to the work of the company as I did in the earlier work, and deduct $7.00 from that portion of the bill rendered for service."

May 5, 1921 -- Letter from Simpson to the Director of the U.S. Bureau of Mines, Washington, DC:

"I visited the well in December when a depth of approximately 3,800 feet had been reached, and the temperature of the sludge, indicated on the crude thermometer available, was over 100 degrees in Fahrenheit. I have just secured the thermometer used and hope to compare it with standard instruments in order to determine the true temperature as nearly as we may from thick sludge removed by a sludge bucket.... I am very desirous of securing more satisfactory temperature data in case the well is drilled further...I would request your advice with regard to what type of thermometer should be used in getting the temperature and what method you found most suitable for this purpose...Is the high temperature due to friction in the drill? Have you a thermometer suitable for deep well work which could be loaned to the North Dakota Geological Survey for a time for use in this well?"

May 5, 1921 -- Letter from Simpson to the Director of the U.S. Geological Survey:

(Dr. Simpson wrote essentially the same letter to the USGS as he did to the Bureau of Mines.)

June 6, 1921 -- Letter from Simpson to Johnson:

"...the Director of the U.S. Geological Survey, George Otis Smith, has assigned Mr. C. E. Van Orstrand, Physical Geologist of the U. S. Geological Survey, to work with me in securing a series of temperature observations upon the deep well." (The letter goes into more detail about how to obtain temperature readings in deep wells.)

June 17, 1921 -- Letter from the Acting Director of the USGS, Philip Smith, to Simpson:

"I am pleased to learn from your letter of June 6 that you are making final arrangements for a temperature test of the deep well being drilled near Lone Tree, North Dakota..."

July 29, 1921 -- Letter from Johnson to Simpson:

"I am starting out on the road again and will send you your expenses on last years trip just as soon as I can raise the money."

October 25, 1921 -- Letter from Johnson to Simpson:

"...we enclose your expenses for $30.00. I am sorry that I have been unable to send this to you before...Before sending the samples to you, it will be necessary for us to have some more of the little bags as I notice that several of the little bags have dry rotted and can not be handled."

December 19, 1921 -- Letter from Director of USGS to Simpson:

"...we enclose the results of the temperature test taken on the well..."

A PERSPECTIVE ON CLIMATE CHANGE: THE CHILEAN CONNECTION --John W. Hoganson

One of the most intriguing, challenging and controversial areas of research of immediate importance in the science of geology is that of climatic change. A resurgence of interest in climates on all scales, both ancient and modern, and recognition of climatic change as a pressing problem, has developed from concern with man's impact on the environment and ultimately on the world's food supply. This interest became acute after the unstable climatic conditions of the 1970's impressed on governmental leaders that climate is indeed dynamic. During that decade, numerous anomalous weather conditions were experienced, such as the coldest winter in Europe since 1740, the first snow in Miami (1977), the first snow in memory in the Sahara (1979), and extreme drought conditions accompanied by widespread famine in India (1972).

The climate has been cooling at the rate of about 0.2°C per decade, at least in the Northern Hemisphere, since about 1940, following a warm interval of about 50 years, which was manifested by extreme arid conditions such as the "dirty thirties." It is uncertain whether this cooling is a natural phenomenon or of anthropogenic (man-caused) origin caused by a rise in atmospheric turbidity due to particulate air pollution. Some researchers advocate that this cooling trend will be overshadowed by warming of the atmosphere through a "greenhouse" effect resulting from introduction of carbon dioxide into the atmosphere (about 20 billion tons a year) by burning of fossil fuels. It has been predicted that, at the present rate of fuel consumption, average temperatures could rise by 10 degrees in the Midwest within 50-70 years. A temperature increase of that magnitude would have devastating effects such as altering precipitation patterns and causing desertification of areas such as North Dakota.

As we become more populous (the world's population is expected to double by 2030 and world-wide food needs will triple) and approach the limits of our resources, we become more dependent on climatic factors and vulnerable to fluctuations in the climate. Any climate change can cause unimaginable social and economic chaos. This has been realized as evidenced by the establishment of a Climate Dynamics Division of the National Science Foundation; federal funding of major research programs such as CLIMAP; and increased federal funding for individual research projects such as the one Allan Ashworth, Geology Department, North Dakota State University, and I are currently involved in.

Major climatic shifts, accompanied by expansion or retreat of mountain and continental glaciers, are caused by changes in the earth's orbital geometry, altering the amount of solar radiation received by the atmosphere. These celestial oscillations were studied in the 1930's by the brilliant Yugoslavian astronomer Milutin Milankovich. The oscillations were found to occur on a cyclical basis with periodicities of about 23,000, 40,000, and 100,000 years. At the midpoint of each of these cycles, the earth receives less solar radiation, thereby cooling the climate. Recent investigations, mainly from analysis of fossils from deep-sea sediments, have substantiated the Milankovich Theory by finding that in the last 700,000 years eight major ice ages have occurred along with some 30 smaller ones. Earth's climate, is therefore, a product of these astronomic forcing factors and complex interactions and feedbacks between the hydrosphere, atmosphere, lithosphere, biosphere, and cryosphere (glaciers).

It is believed that we are now entering one of these ice ages, one governed by the 23,000 year cycle, but this is not of immediate concern to mankind. Random, short-term and often regional climatic events may be superimposed on these long-term cycles, it seems, at any time. These abrupt, random climatic fluctuations are the ones that may affect us all profoundly; they have been the focus of my research for the last few years.

Before a unifying theory of climatic change can be developed, the timing and duration of past climatic events has to be established. It is of specific importance to establish whether the climatic changes have been in phase between the Northern and Southern Hemispheres. An overall in-phase relationship seems to apply with respect to the major changes caused by cyclical perturbations in the earth's orbital geometry. But what of the shorter climatic oscillations that are superimposed on these major climatic events? Climatic fluctuations on this smaller scale; that is, fluctuations that last a few centuries or millennia, can not be explained by changes in the earth's orbital geometry. These are of much more immediate concern to the world. It is important to determine whether these events are regional or worldwide in extent.

Although a great deal is known about when, how, and possibly why climate has changed in Europe and North America, studies in the Southern Hemisphere are critically lacking. For this reason, we have undertaken a paleoclimatic study in southern Chile ranging from the present back to 18,000 years ago.

During this 18,000-year period, the earth underwent dramatic climatic change from full glacial conditions about 18,000 years ago to full interglacial conditions about 10,000 years ago. During this same period, an abrupt, short-lived deterioration (cooling) in climate (11,000 to 10,000 years ago) occurred in Europe. Geologists disagree whether that cooling event was worldwide. It has been a source of controversy for many years and it is the main focus of our research. Some researchers have proposed, from studies of fossil pollen, that this cold interval also occurred in southern Chile. However, studies of glacially formed land features imply a continued warming through this interval. The problem presented by the incompatible conclusions presented by the botanical and geological studies is addressed in this study by investigations of fossil beetle assemblages.

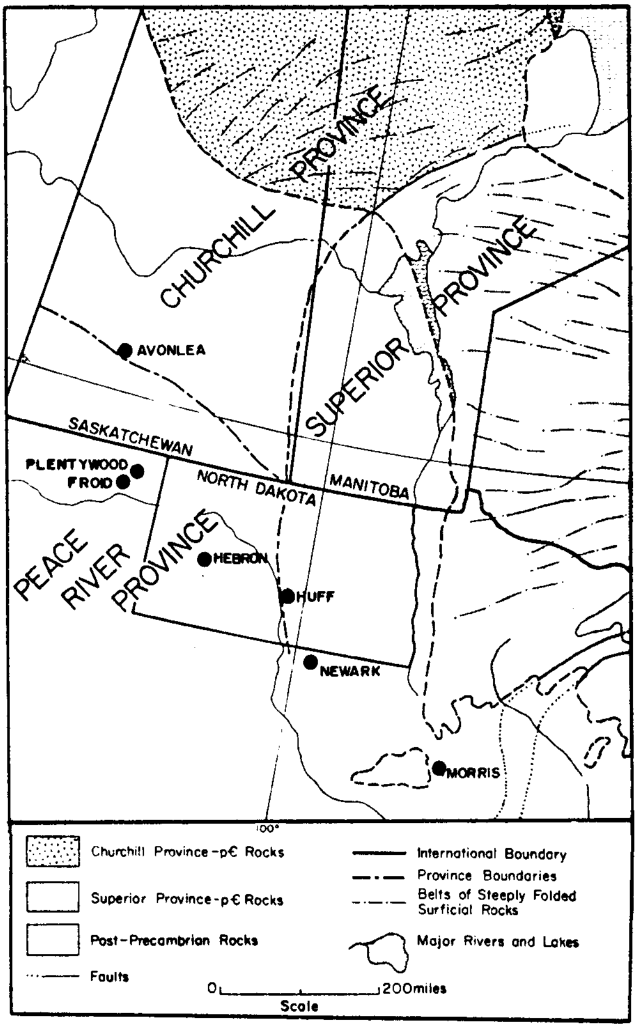
Beetle remains occur as detached skeletal parts in silt and peat layers deposited in lake, pond, and bog environments. They are usually well preserved and can often be identified to species. Beetles have evolved little over at least the last million years; therefore, most fossils can be assigned to modern species whose environmental requirements are known from ecological and taxonomic studies. Once this was realized and because beetle populations are known to respond rapidly to changes in their thermal environment (they will migrate when climate changes), they have proven to be excellent proxy indicators of short-term climatic changes. Beetles have been used successfully as paleoclimatic indicators in Europe and North America, including North Dakota, and other areas in the Midwest. Although this was the first study of its kind in the Southern Hemisphere, it was assumed that fossil beetles could also be used to study past climates in South America. That assumption has proved to be valid.

Several thousand well preserved fossil beetles were extracted at 4-inch intervals from a 15-foot-thick sequence of lake-deposited silts, clays, and organic debris collected in the glacial Lake Region of southern Chile. A complete record of earth history spanning the time from 14,600 to 4,500 years ago is recorded in those deposits. All the fossil beetle species recovered from the sediments live today in the temperate, low elevation, Valdivian Rain Forest; the dominant forest type in southern Chile today. In other words, the beetle fauna remained essentially unchanged from 14,600 to 4,500 years ago in that area, implying that the climate also remained unaltered throughout that time. No evidence was found that cold conditions existed between 11,000 and 10,000 years ago as previously inferred from pollen studies. This study then has resolved a long-standing question as to whether the deterioration of climate experienced by Europe during that millenium was a worldwide event. Apparently it was not worldwide but rather was restricted to that part of the Northern Hemisphere and, therefore, caused by a localized climatic anomaly.

In this article I have tried to point out the importance of climatological research, very briefly discuss what is known about climatic change, and present a case study of a relatively new line of research being used to define past climatic trends. The ultimate goal of climate-related geological research is to eventually be able to forecast future climatic trends. Recognizing those trends may be the ultimate challenge faced by mankind because of the consequences alluded to above from even slight shifts in climate. Joint projects between North Dakota State University and the North Dakota Geological Survey are continuing in North Dakota, other areas of the Midwest, and possibly South America pending additional federal funding.

EARTHQUAKES IN NORTH DAKOTA

North Dakota's location in the middle of the continent has spared it from much seismic activity. However, the boundaries between three Precambrian rock provinces cross the area in various directions (see accompanying illustration). One of these boundaries passes from north to south through the approximate center of the state. The western province may be further subdivided into two parts, according to some geologists, by an east-west boundary in southern Saskatchewan (I've shown it in that way on the illustration, although opinions differ as to whether the east-west boundary actually exists). East of the north-south boundary in eastern North Dakota, the Precambrian rocks of the Superior Province are about 2.5 billion years old. West of the boundary, rocks of the Churchill-Peace River Province are generally less than two billion years old. The Precambrian rock provinces are deeply buried beneath younger deposits in North Dakota, so it is difficult to be certain just where the boundaries that separate them are really located.



Earthquakes may result from movement between various blocks of the earth's crust, such as along the San Andreas fault in California. In North Dakota, they might occur if movement between the provinces I just mentioned ever took place. An earthquake might also occur due to the collapse of materials overlying areas of salt solution. Northwestern North Dakota is underlain by a thick and extensive salt deposit, which is between about 3,000 and 10,000 feet deep. Throughout geologic time, much of this salt has dissolved, due to groundwater action. As the solution of this salt has occurred, and is presumably still occurring, the overlying materials have tended to settle. Continued settling of the sediments above the areas of salt solution could result in earthquakes.

Generally, faults (fractures in the earth's crust) can be identified in the vicinity of the earthquake epicenters. In North Dakota, however, it is difficult to definitely identify faults, since any that might be responsible for movement are probably deep and not obvious at the surface due to a thick covering of younger material.

On July 8, 1968, an earthquake registering between IV and V on the Mercalli scale (4.4 on the Richter scale) occurred near Huff, about 15 miles southeast of Bismarck. The location at which an earthquake occurs is called the epicenter and the shaking that results from the earthquake is felt in all directions from the epicenter, less intensively with distance from the epicenter. The epicenter of this minor earthquake was located over the boundary between the two Precambrian provinces mentioned earlier.

The Huff earthquake, which was felt over a 9000-square-mile area, is the only one with an epicenter that was instrumentally verified in North Dakota. Several other earthquakes that have been felt in North Dakota had epicenters in adjoining states and provinces. Another earthquake that may have had an epicenter in North Dakota, although it was not verified by seismographs, occurred near Hebron on April 30, 1927. This earthquake was felt by one person who reported fairly rapid trembling and rocking, mostly east-west, hanging pictures and lights moving, and plaster creaking. The earliest reported earthquake felt in North Dakota was centered at Avonlea, Saskatchewan on August 15, 1909. This shock was felt over an area of 500,000 square miles, throughout North Dakota.

Several "scales of intensity" have been devised to measure earthquakes; most of those now in use are modified from a scale proposed in 1914 by an Italian priest/geologist named Guiseppi Mercalli. The Mercalli scale extends from I to XII. The Richter scale, which is probably better known to most people, ranges from 1 to 10, with each higher number representing a tenfold increase in energy measured in ground motion; thus, an earthquake with an intensity of 6 releases ten times more energy than one with an intensity of 5 and a hundred times more than one with an intensity of 4.

A low-intensity (no measured Mercalli or Richter number) earthquake, centered near Newark, South Dakota on January 29, 1934, rattled dishes in North Dakota. A somewhat more intense earthquake (VI on the Mercalli scale) was centered in northeastern Montana on June 24, 1943 in the area around Froid, Homestead, Medicine Lake, and Reserve. This earthquake, which was felt over much of western North Dakota, is described as follows:

> Froid: Felt by many; buildings swayed slightly and creaked; a well-constructed granary cracked so severely that wheat spilled out. The report from this town stated: "One man north of Brockton was outside when it occurred. He said it felt as though the earth was heaving up and down."
>
> Homestead: Felt by many; faint subterranean sounds heard; houses creaked and chandeliers swayed; basement walls reported cracked.
>
> Redstone: Chandeliers swung; chimneys cracked.
>
> Reserve: Two shocks; thunderous, roaring subterranean sounds; many cracks in plaster; chimneys damaged.

Another earthquake that occurred between Williston, North Dakota and Plentywood, Montana on October 26, 1946, registered IV on the Mercalli scale. It is described as "a light shock of about 5 seconds duration, felt by many in the vicinity." There was no damage, but beds swayed and dished rattled in Williston.

Finally, an earthquake that occurred in 1975 near Morris, Minnesota was apparently felt by some people in southeast North Dakota.

Although it is unlikely that North Dakota will ever have a serious earthquake, it is interesting to realize that strong earthquakes are not limited to Alaska, California, or the Rocky Mountain Region. What was probably the most severe earthquake on the North American continent during the past two centuries was centered in Missouri. In 1811-1812, several earthquakes occurred in the New Madrid area in southeastern Missouri. The most severe of these earthquakes were felt over a 1,000,000-square-mile area, which would have included North Dakota. Over 1,800 earthquakes were felt over a two-year period, and more would have been recorded if seismographs had been available at the time. These earthquakes caused a remarkable amount of damage in a part of the country that was still only sparsely populated at the time.