NEWSLETTER

NDGS

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NORTH DAKOTA GEOLOGICAL SURVEY
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COVER PHOTO

Doug Nichols of the U.S. Geological Survey (left) and John Hoganson of the North Dakota Geological Survey (right) collecting samples of a coal bed in an outcrop overlooking the Little Missouri River in Slope County (Pretty Butte is in the background). The scientists are obtaining samples to analyze for pollen as a means of paleontologically determining the placement of the Cretaceous and Tertiary Boundary. This summer the trio (including Ed Murphy, NDGS) spent one week measuring sections, collecting samples, and conducting paleontological reconnaissances of western and south-central North Dakota as part of the U.S. Geological Survey and N.D. Geological Survey cooperative mapping project (COGEOMAP). Photo by Ed Murphy.

CURRENT SURVEY ACTIVITIES

--John Bluemle

Sid Anderson, who was Acting State Geologist, and a geologist with the North Dakota Geological Survey for 39 years, retired at the end of August (see the article immediately following this one). I am currently serving as Acting State Geologist while a search is underway for a permanent State Geologist. We expect a person to be named early in 1991. Sid reports he is enjoying his retirement and has managed to get in quite a bit of hunting. He says the goose and duck hunting was excellent and his annual deer hunt resulted in a lot of good exercise. Sid is still working on some North Dakota geologic projects; right now he is helping with a cross section of the Mississippian rocks in Manitoba and North Dakota.

My own (**John Bluemle**) activities for the past several months have centered on directing NDGS operations. I've attended several meetings during that time; they include a Central Region Cluster Meeting of the State Geologists and the United States Geological Survey, held in Baton Rouge in September, and the Rocky Mountain Section Meeting of the American Association of Petroleum Geologists, held in Denver in September. I helped with a field trip of the North Dakota Natural Science Society in the Turtle Mountains in August. I've been working on two reports, one with Mark Lord on the geology of the Hogback Ridge (a long drumlin in McHenry County) and the other on the results of some radiocarbon dates we obtained on buried soils along the shore of Devils Lake. **Randy Burke** is continuing his work on the Devonian system in North Dakota. He presented a paper at the American Association of Petroleum Geologists meeting in Denver in September titled "*Porosity Development in Evaporite Dissolution Breccia*." The talk elicited considerable interest and numerous questions. Randy is working on the Duperow Formation in southwestern North Dakota, and he and Tom Heck have a report on Devonian System electric-log cross sections in progress. Randy participated in two short courses at the AAPG meeting, one titled "*New exploration tools for the 90's*" and the other "*Exploration of the Morrow Sandstone*." He made a trip to Regina to examine cores (including Tableland reef core) at the Saskatchewan core facility. He returned from Regina by way of Montana, where he examined Paleozoic outcrops, primarily the Devonian type section near Logan.

Randy is also continuing to work on mapping the Ratcliffe Formation in Mountrail County. He spent some of his time over the past several months examining Mississippian and Devonian core at the core library in Grand Forks.

Randy was appointed Co-Chairman of the technical program for the upcoming Williston Basin Symposium (see separate article in this newsletter on the Symposium). His job is to solicit papers for the meeting. He asks that abstracts be submitted before the end of January.

Tom Heck completed a report on oil and gas activity in North Dakota during 1988 and 1989. It is Miscellaneous Series 74, titled "*Oil Exploration and Development in the North Dakota Williston Basin: 1988-1989 Update*." Tom is also working with the occurrence of radon gas in North Dakota. He and Randy Burke have a report nearly ready to publish on Devonian stratigraphy of North Dakota. This report went out for bids two months ago, but the prices we were quoted for printing it were much more than we could afford. Tom and Randy have altered the publication somewhat, placing the cross sections on more, but smaller size sheets of paper. We hope that this will make it easier for local printers to give us realistic (affordable) bids so that we can publish the report early next year.

Among his other activities, Tom (along with Julie LeFever, Sid Anderson, and David Fischer) is nearly finished condensing the report we submitted to the U.S. Forest Service last summer into a format that the North Dakota Geological Survey can publish. He is also nearly done compiling his reserves estimates for the Potential Gas Committee. Tom recently attended the meeting of the Potential Gas Committee in Denver. His work on the occurrence of radon gas in North Dakota continues and he is currently reviewing a draft of a chapter of a U.S. Environmental Protection Agency report; the chapter is titled "Radon Potential of North Dakota."

Tom is compiling new "blob" maps which show individual producing oil pools by formation. This series of maps is now ready for drafting. Tom's research on salt collapse areas and on Red River Formation gas potential are continuing, but this work has been delayed somewhat by the activities I've just mentioned.

John Hoganson has been involved in a number of activities relating to the state's fossil resources. He routinely evaluates oil and gas lease tracts for possible impact on paleontological resources. This past summer he wrote rules governing fossil collecting on state lands in North Dakota. These rules are now in effect (see separate article in this newsletter). John is also concerned with managing the fossil resources on state and federal lands. He is now working toward establishing a memorandum of understanding (MOA) with the Corps of Engineers and Bureau of Reclamation for cooperation in managing fossil resources found on land administered by these federal agencies. John is continuing to develop the State Fossil Collection here in our Bismarck offices; we are rapidly filling the available space and will soon have a problem storing fossils in the Collection.

John has recently been, and continues to be, involved in a number of special projects. Last summer he oversaw the placement of an 80-foot-long Paleocene petrified wood log on the state Capitol grounds (article in the June, 1990 *NDGS Newsletter*. He is currently finishing the preparation of an exhibit of North Dakota fossils at the Heritage Center here in Bismarck. This display should be ready early in 1991.

In other research, John is continuing his work with Ed Murphy and Nels Forsman (University of North Dakota) on our COGEOMAP project, which involves study of Middle Tertiary units in North Dakota. The three are also hoping to study the Cretaceous/Tertiary boundary in the state; they are currently awaiting approval by the USGS for funding of their proposal. John is working with Alan Cvancara (University of North Dakota) on three projects; one of vertebrate fossils in the Paleocene Cannonball Formation, another of fossil mollusks of the Alkali Creek Paleoindian site, and the third of Cretaceous marine fish in North Dakota. He is working with Allan Ashworth on fossil beetles as indicators of Ice Age climates.

John has given several lectures recently. They include talks on "Vertebrates of the Cannonball Formation" to the Central Dakota Gem and Mineral Society; one on "Beetles as indicators of climatic conditions at the Monte Verde Paleoindian site" to the North Dakota Archaeological Association; and one on the use of fossil beetles in archaeology to a group at Bismarck State College. John presented two papers at the Geological Society of America meeting in Dallas in October. The first, with Ed Murphy and Nels Forsman, was titled "*Stratigraphy, age and biochronology of the White River Group and Arikaree Formation in southwestern North Dakota*" and the second, with Allan Ashworth, was "*Timing and magnitude of the last glacial/interglacial transition at latitude 40 S. in South America.*"

Julie LeFever is currently working on two projects with the geologists at the Petroleum Branch of the Manitoba Energy and Mines. The first project, with Carol Martiniuk of the Manitoba Mines Branch and Sid Anderson, involves constructing a geologic cross section across the United States-Canada International Boundary. This project is nearing completion. The second project, also with Carol Martiniuk, examines a sandstone unit in the middle member of the Bakken Formation. This sandstone unit extends from Manitoba and Saskatchewan into North Dakota. Julie intends to define its distribution, its petroleum potential, and its possible relationship to oil migration within the Bakken Formation.

Julie is also involved in a more detailed study of the Bakken Formation. This is a joint project with Leigh Price of the United States Geological Survey. Their study involves examining the Bakken as a source rock. In addition, Julie and Leigh are examining the methods used in drilling and completing Bakken wells with an eye to determining how these methods affect production.

Mark Luther worked in the field with Ken Harris of the Minnesota Geological Survey for several weeks this past summer, drilling and collecting till samples in the Red River Valley. The resulting data will be included with previously collected till data to produce a document outlining till stratigraphy in the Red River Valley. This will be a regional look, dealing with tills deposited throughout the valley, both in North Dakota and Minnesota. The data will also be used later in producing Atlas maps by the respective Surveys (NDGS and MGS). Sediment analyses for the study are being done by a student at the University of North Dakota under the direction of Dr. John Reid. During Mark's and Ken's fieldwork last summer, they learned the hard way that vertical outcrop faces do collapse (no one was injured)!

Mark says that the draft copy of the Atlas Area 14 (Goose River) sheet surface geology map has been completed and has been sent to the Minnesota Geological Survey where Ken Harris and the MGS' drafting department are working at producing a final draft for us to publish. We are hoping to acquire computer drafting capability as soon as money becomes available. This possibility has led us to rethink and modify some of the long-range goals of the Survey. A computer drafting system sophisticated enough to produce geologic maps will also handle Geographic Information System (GIS) software that will be used extensively in the future to manage the state's resources. The NDGS hopes to play a central role in the use of GIS systems in the state, perhaps becoming a centralized "clearinghouse" for digital data collected by other agencies/sources. It is in providing geologic maps in digital format that the Survey has had to reconsider some of its goals. This is due to the anticipated need for digital geologic maps at a 1:24,000 scale. Much of the geologic mapping that has so far been done in the state (including the Atlas Series) has been done at 1:125,000 or 1:250,000. At that scale, there may not be sufficiently accurate information available for use in GIS type applications. The NDGS will need to place an increased emphasis on more detailed mapping in the future.

Mark worked with archaeologists several times during the past summer and fall, looking at the stratigraphy of sites along the Red River, Devils Lake, and near Sentinel Butte. He says he enjoys this work very much (in addition to his degree in geology, Mark has a minor in archeology). The work has been mutually beneficial, with archaeologists receiving assistance in unraveling ofttimes complex stratigraphy, and the NDGS having access to many fresh cuts into interesting geologic sections. Mark has begun collecting samples and references in preparation for producing (with Robert Christensen, of Cultural Research and Management) an NDGS publication detailing the lithic resources of the state that were exploited by American Indian groups. An interesting aspect of this has been the experimental use of ultraviolet light in the identification of different lithic types/sources.

Our study of trace elements in Cretaceous shales is nearing completion. Mark Luther and Dave Brekke (of the UND Energy Research Center) hope to coauthor an open file report on the topic early next year. Results to date indicate that the entire Colorado Group has above average levels for many trace elements, including arsenic and selenium.

Mark continues as a member of the North Dakota Water Quality Task Force for Nonpoint Source Pollution. His principle activity on the task force so far has been to provide input into the development of the Barnes County abandoned well pilot project. Mark assisted personnel from the North Dakota State Health Department and the Barnes County Soil Conservation District in three public demonstrations of well-plugging techniques. To date, 57 abandoned wells have been plugged by their owners during this first year of the project.

Ed Murphy is in the process of writing survey reports on two recently completed projects. The first report is on his three-year study of six North Dakota landfills and the second report is on his three-year study of pesticide movement in the subsurface in McHenry County. He presented his results of the landfill study at several meetings this past year, to the Interim Legislative Political Subdivisions Committee, which drafted legislative bills dealing with solid waste issues, at the North Dakota Water Quality Symposium in Fargo, and at the North Dakota Solid Waste Symposium held in Bismarck.

Ed and John Hoganson presented a poster session at the Annual Meeting of the Geological Society of America in Dallas, Texas. The paper was entitled *Stratigraphy, Age and Biochronology of the White River Group and Arikaree Formation in southwestern North Dakota*. This paper resulted from the work that they had done with the U.S. Geological Survey under the COGEOMAP Program. Holes were again drilled and cored this summer on a number of buttes in western North Dakota under this program. This work will be presented in a Survey report which should be completed by the end of 1991. Ed and John spent a week this summer measuring sections and collecting samples along the Cretaceous/Tertiary boundary in western and central North Dakota. They were accompanied by Doug Nichols, a palynologist with the U.S. Geological Survey in Denver. The group is hoping to obtain additional COGEOMAP funding to study the Cretaceous/Tertiary boundary in south-central North Dakota.

Ed recently rewrote the regulations concerning the state's geothermal program (geothermal production is regulated by the Geological Survey). The revised rules governing geothermal production now more effectively address shallow closed-loop heat pump systems, which are the most numerous geothermal systems in the state. Ed will be touring the state this winter to inspect these sites and to issue permits to all non-residential geothermal systems in the state.

Ed has also been busy overseeing the closure and cleanup of the AKZO Salt plant in Williston. The Geological Survey has jurisdiction at this site because we regulate both the subsurface mineral program and also the Class III underground injection control program in the state.

This fall, Ed and **Russ Prange** (our driller) augered and cored several holes for Phil Gerla (Geology Department at the University of North Dakota). A portion of the drilling took place in the city of Larimore and was part of the municipal Wellhead Protection Program, which is administered by the Health Department. The rest of the drilling took place near Manvel and was part of the Geological Survey's contribution to Dr. Gerla's N.D. Water Resources Research Institute funded-study of the movement of groundwater through lake clay.

SID ANDERSON RETIRES FROM THE SURVEY

-- John Bluemle

Sid Anderson retired on August 31, after almost 39 years with the North Dakota Geological Survey. We had a reception for Sid at the Kelly Inn here in Bismarck on the evening of August 21; several people, including Governor Sinner and Attorney General Nicholas Spaeth, spoke at the reception and a considerable number of Sid's friends showed up to recognize his long service to the State. I made some remarks at the reception too, and I'll excerpt from them for this article.

I think it is safe to say that no one comes even close to matching Sid's understanding of the geology of the Williston Basin. I suspect that, if Sid had been paid for even a fraction of the oil he has directed people toward and helped them find, through the ideas he has generously shared with industry people, consultants, and students who went on to work in the Basin, he would have become a very wealthy person. During his 39 years with the NDGS, Sid worked tirelessly with large numbers of graduate students, helping them with their projects. I don't know how many students there were, but I know it's safe to say there are many of those students who owe a good portion of their degrees and education to Sid's help and advice. Many of those former students went out and found a lot of oil, a lot of it in the Williston Basin in North Dakota.

As a member of the Survey for 39 years, Sid was always a steadying and reliable influence. He was unflappable in most situations. He served as a "mentor" for many Survey employees who have come and gone. All of us regularly and routinely sought out Sid's advice about this or that geologic problem. Sid served and chaired numerous committees with the AAPG and other professional organizations and he devoted large amounts of his own time to this service.

Sid has been dedicated to North Dakota and the outdoors all his life--that may be why he chose geology as his career. I know Sid had any number of chances to leave the state and perhaps double or triple his salary; he stayed in North Dakota and didn't take the chance to make a great personal profit from his knowledge.

I'll close by stressing a final point: Sid has an absolutely enormous stature among his colleagues and he has their deepest respect--people throughout the oil industry and in academia as well. They include a broad range: college students and faculty, consulting geologists, oil company geologists, oil company presidents and others. The reason for his stature is obvious: if Sid hasn't done more to further knowledge of North Dakota geology than any other person, he has certainly come close. Certainly, if we are talking about the geology of the Williston Basin, then no one even comes close to matching Sid's contribution!

Although he is retired, Sid is planning to spend some time continuing to work on the geology of North Dakota. He has an office in Leonard Hall on the University of North Dakota campus in Grand Forks. His phone number there is 701-777-5055.

THE SIXTH INTERNATIONAL WILLISTON BASIN SYMPOSIUM AND FOURTH SASKATCHEWAN PETROLEUM CONFERENCE

--Randy Burke

The Sixth International Williston Basin Symposium will be held in Regina, Saskatchewan during the 7th through the 9th of October, 1991 at the Ramada Renaissance Hotel. The meeting is sponsored by the Saskatchewan, North Dakota, and Montana Geological Societies in association with the South Saskatchewan Section of the Petroleum Society.

Registration at the Symposium allows access to all technical sessions of both the Williston Basin Symposium and the Petroleum Society Conference. This is the first time that the Symposium will be held in conjunction with the Petroleum Society, and a large registration is expected for the concurrent technical talks, poster session, and core workshop. A half-day session is planned for presentation of papers describing geology related to horizontal drilling. A summary of the specifics about the Symposium follows.

Williston Basin Symposium (held jointly with South Saskatchewan Petroleum Society Branch Meeting - CIM)

October 7th through 9th; Technical Sessions the 8th & 9th

Regina, Saskatchewan, Canada, Ramada Renaissance Hotel

Registration Fee - $200 (Canadian) before August 1st, $225 after the 1st [includes icebreaker, published proceedings, a banquet, and access to Petroleum Society technical sessions]

Student Registration Fee - $20 (Canadian) [only includes admission to technical sessions]

Field Trip to Winnipegosis Formation (Devonian) outcrops in Manitoba
Presymposium: Saturday Oct. 5^{th} to Monday Oct. 7^{th}
Trip leader: Dr. Don Kent
Cost: $200 (Canadian) before June 30^{th}, 1991

Core Workshop on October 7^{th}
Cost: $20 (Canadian) [includes transportation to core facility, light (Molson's?) refreshments, and copies of and written material describing the displays]

CALL FOR PAPERS - Abstracts due January 11, 1991: Please send abstract to:

Dr. Laurence W. Vigrass
Program Chairman
Sixth International Williston Basin Symposium
c/o Saskatchewan Geological Society
P.O. Box 234
Regina, Saskatchewan
Canada S4P 2Z6
[phone: (306) 585-4571]

Completed manuscripts due: May 1, 1991
General Inquiries or Commercial Displays: call Malcolm Wilson at (306) 787-2618 or Chris Gilboy at (306) 787-2573

For more information, please contact me (Randy Burke) at our offices in Bismarck.

SERVICES AVAILABLE FROM THE STATE GEOLOGICAL SURVEYS

[Editor's Note: many people are unaware of the great variety of services available from the North Dakota Geological Survey and other state geological surveys. I recently came upon an article describing the services available from the state surveys by Wallace W. Hagen in the September, 1990 issue of The Professional Geologist, a publication of the American Institute of Professional Geologists. Much of what Mr. Hagen wrote seems applicable to North Dakota and I extracted much of the following information from his article.]

The original enabling legislation, or later legislation, along with the administrative structure within the state system, help to determine the services each of the geological surveys perform. The services provided by the various state geological surveys differ from state to state depending upon differences in natural resources, and the specific geologic situation of each state. North Dakota, for example, has important oil and gas resources that have, over the years, made it necessary for the NDGS to provide certain services required by the petroleum industry.

The requests of the public also help determine the kind of services that are provided. Even so, all of the state surveys share many functions that make them key sources of information and services to the geologic community.

Thirty-eight of the state geological surveys are either directly answerable to the governor and legislature, or they are divisions of various departments of state government. The North Dakota Geological Survey, for example, is a division of the North Dakota Industrial Commission, which is chaired by Governor Sinner. Attorney General Nicholas Spaeth and Agriculture Commissioner Sarah Vogel are the other two members of the Industrial Commission.

Thirteen of the state geological surveys are affiliated with universities. Some are involved in teaching, and others are research entities within geology departments. Prior to 1989, the North Dakota Geological Survey was under the Department of Higher Education and affiliated with the geology department at the University of North Dakota. The 1989 Legislature placed the Geological Survey under the Industrial Commission.

Many of the state geological surveys, including the NDGS, have regulatory responsibilities. Our regulatory duties include varying degrees of control over geothermal resources, coal exploration, paleontological resources, underground fluid injections, and oil well core and drilling samples.

The kind of services provided by the various geological surveys depends mainly on the public's needs. According to Dr. Larry D. Fellows, State Geologist of Arizona, "Most state geological surveys communicate regularly with those who use our products and services. Constituents tell us that, first of all, they need to know what geologic reports, maps, and data are available. Up-to-date bibliographies and computerized data bases are usually mentioned. Secondly, they need accurate, detailed maps of bedrock and surficial geology. Finally, they request a variety of scientific, objective, topical, and interpretive reports and maps, many of which are based on, or derived from, detailed geologic maps."

The level of service provided by each state survey is also dependent to an extent on the size of the staff. The state surveys range in size from as small as one person on staff in Massachusetts to as many as 238 in Illinois. The average size is about 43. North Dakota has a staff of 8.

All of the state geological surveys provide some, but not all, of the following information services to users, services that are specialized by the circumstances described and therefore likely to be pertinent to the solution of specific geologic problems in their state.

* Published geologic reports and open-file reports.

* Publication lists and bibliographies.

* Various types of maps: topographic maps, hydrologic maps, surface and bedrock geologic maps, subsurface structural and isopach maps, mineral resource maps, geophysical maps, and others.

* Computerized data on mineral, water, oil and gas records, stratigraphy, geophysics, and energy resources.

* Geologic hazards: landslides, earthquakes, mine subsidence, sinkholes, radon gas, radioactive wastes, pollutants from oil and gas

wells, air and mine wastes.

* Sanitary landfills and waste disposal.

* Aerial photographs.

* Educational materials for schools, talks, exhibits, rock and mineral sets, fossil collections, etc.

* Field trips and field guidebooks.

* Libraries as depositories for geologic publications and maps.

* Services to other local, state, and federal agencies, and cooperative programs with them.

* Paleontological information.

* Various public information services, such as identification of rocks, minerals, and fossils.

* Advisory councils.

* Economic geology studies and reports.

* Repositories of logs, cores, and rock cuttings for study; our Core and Sample Library is located in Grand Forks.

SURVEY MAP SALES

--Mark Luther

Since we published our last newsletter in June, our Earth Science Information Center (ESIC) maps sales operation has settled into a pattern consisting of furious activity at the beginning of each month, revising the map inventory, collecting sales figures, and ordering new and replacement maps. This is followed, during the remainder of each month, by a more leisurely routine of answering the day-to-day process of receiving and sending orders and responding to inquiries we receive about map availability and other cartographic information. Eula Mailloux, our publications clerk, handles the day-to-day operations. Eula does an excellent job, especially in view of the continually increasing work load she is facing.

So far, we have received overwhelmingly positive feedback from other state and federal agencies, businesses, and the public for our map-sales operation. We are gradually building up our supply of maps as money becomes available and we are now in a position of being able to fill nearly all orders for North Dakota topographic maps the day they are received. This has been of great benefit to businesses in the state, and a great convenience to the general public. One significant advance made over the past six months was the modification of our inventory spreadsheet program to determine which maps need reordering. This has cut the time required to submit a map order to the ESIC by about 75%.

COCORP COMPLETES DATA ACQUISITION IN NORTH DAKOTA

--Tom Heck

COCORP, the Consortium for Continental Reflection Profiling, based at Cornell University in Ithaca, New York, has completed its deep reflection seismic survey across eastern Montana and the western two-thirds of North Dakota (Fig. 1). Data acquisition began in North Dakota on July 17, 1990 and ended on September 25. Approximately 170 miles of seismic data were recorded in North Dakota.

The purpose of the project is to investigate the nature of the rocks beneath the Williston Basin--the deeply buried Precambrian rocks that underlie the sedimentary formations. COCORP has recorded deep reflection seismology data from many areas within the United States and has greatly added to our understanding of the earth's crust and mantle. Sid Anderson provided a more detailed description in the June, 1990 NDGS Newsletter of what COCORP is looking for.

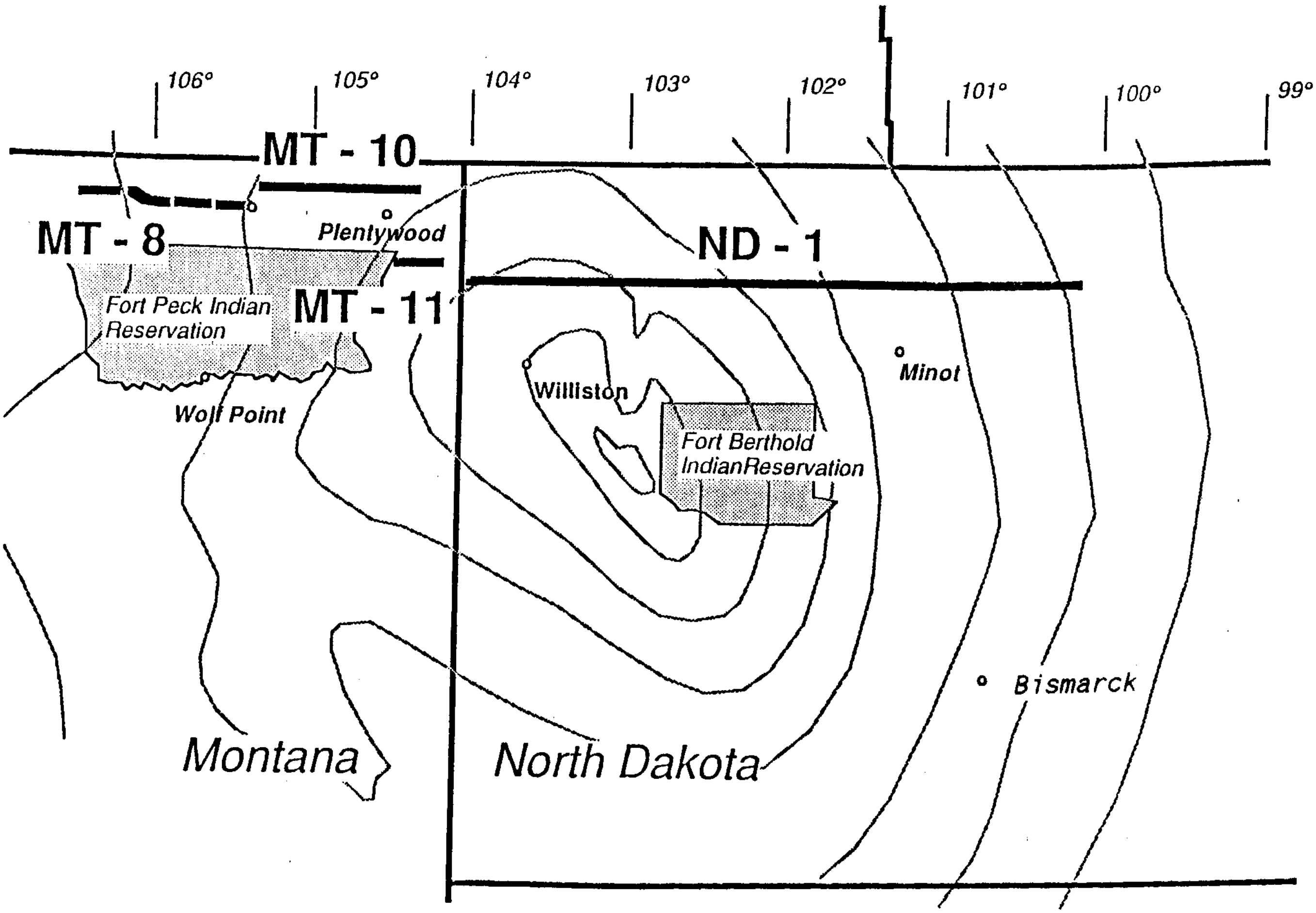

Figure 1. Location of the 1990 COCORP Williston Basin Survey. The seismic line was originally planned to cross the Fort Peck Indian Reservation in Montana, but it was not possible to obtain the necessary permits.

How the Seismic Data Were Collected

The seismic data were recorded with equipment owned by Amoco Oil Company and operated by Grant-Norpac, a geophysical contractor. Eight vibrator trucks (Fig. 2) were used as the primary energy source. Energy is supplied by the controlled application and release of pressure through a metal plate that is pressed into the ground (Fig. 3). The frequency content of the energy, input signal, is controlled by the number of times energy is applied to the ground each second. For example, if the plate is pressed and released twice each second, then the vibrator truck has an input signal with a frequency of two hertz (cycles per second) into the ground. All eight trucks are linked by a telemetry system so that the same frequency is applied by each truck simultaneously (Fig. 4). The signal is input in "sweeps," the period of time when the trucks are vibrating over a specific range of frequencies.

A different type of technology was used to record the data. Geophone groups are normally linked by cables (Fig. 5) and the data recorded by each group are transmitted to a recording truck via another cable. The technology employed by the Amoco crew differs in how the data are recorded. A battery-powered recording "box" containing memory chips is connected to every two geophone groups. A radio signal tells each box when to begin recording. At the same time, another signal is sent to the trucks and tells them to begin their sweep. The input signal generated by the trucks penetrates into the ground and is reflected back to the surface by changes in rock properties such as lithology, density, and compaction. The returning signal is then recorded in the boxes. Each box will record a different returning signal because each box has a slightly different location with respect to the buried reflection point. The signal remains stored in the boxes memory until the box is collected and transferred to computer tape at the crew's base station at the end of each day.

The data is "field processed" and a display of the day's recording printed for quality control. Tapes of both the raw data and the "field processed" data are then shipped to Cornell University where final data processing and interpretation are done. The final processing of the data is done with a "supercomputer," but other, smaller computers are used to both display the data and to make seismic models of the earth.

The COCORP data was recorded with a sweep length of 30 seconds, with five sweeps made at each slot point, and a sweep frequency content of 10 to 56 hertz. "Upsweeps," where each sweep started at 10 hertz and ended at 56 hertz were used.

The seismic line was recorded with a 50-meter (164 foot) geophone group spacing with 10 geophones per group and a shot point spacing of 183 meters (600 feet). Approximately every six miles a short cross line was also recorded. Fifty seconds of data were recorded, but only 20 seconds of fully correlated data will remain after processing because the 30-second input sweep is compressed during processing. Some additional, but not fully correlated data will be displayed.

A seismic line is the record of times when energy reflected from a particular place in the subsurface was recorded at the surface location of a particular geophone group. Most of these reflections are due to geologic changes in the subsurface and the data recorded on a seismic line helps in the interpretation of these changes.

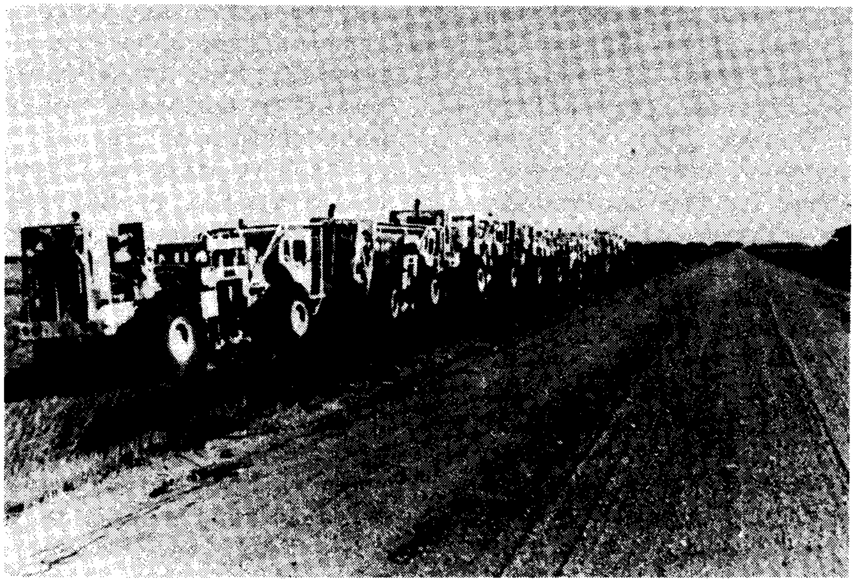

Figure 2. Eight vibrator trucks at work in northeast McHenry County.

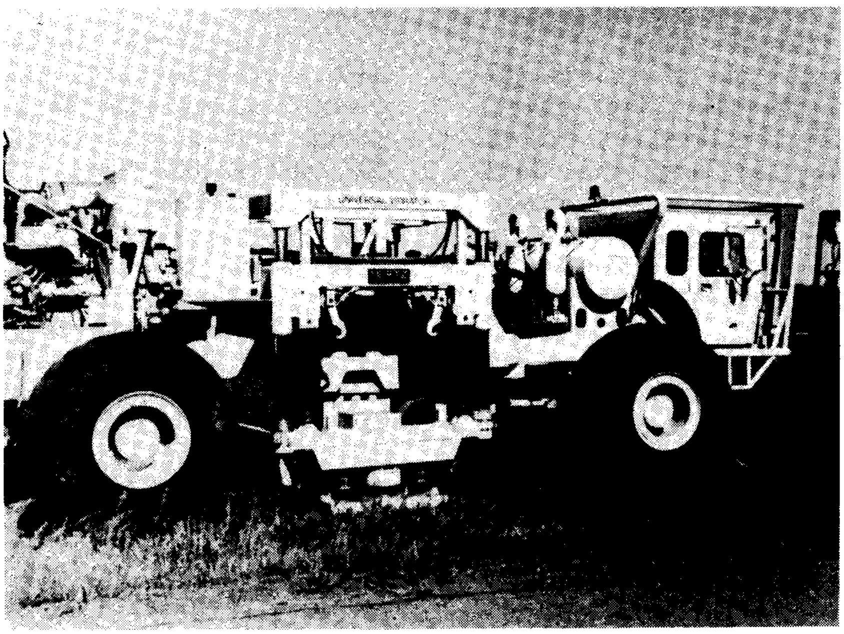

Figure 3. Close-up of vibrator truck. Base plate (center of truck) is pressed against the ground. Hydraulic system applies and releases pressure through baseplate.

Figure 4. Control station for telemetry system. Equipment in truck sends signal to vibrator trucks through telescoping radio mast. Mast is bent in strong winds.

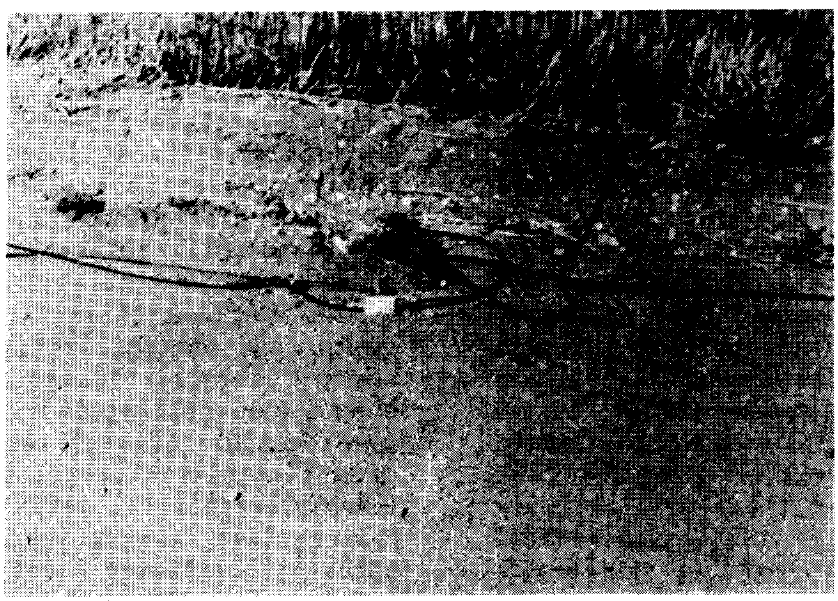

Figure 5. Close-up of a single geophone and connecting cables.

Preliminary Geologic Results

A change can be seen between the western and eastern ends of the seismic line. Coherent reflectors, with a low frequency content and high amplitudes become less coherent, have a higher frequency content, and lower amplitudes. The preliminary interpretation is that this change reflects a fundamental change in the basement rocks in North Dakota. Two possible interpretations are that the line has either crossed from the Superior Precambrian Province into the Trans-Hudson Orogen, or the line has crossed a boundary within the Trans-Hudson Orogen. Geologists at the North Dakota Geological Survey are looking forward to the final interpretation of the data. We may be in a better position to understand what forces formed the Williston Basin and we should also learn much more about the composition and nature of crustal and mantle rocks under the Williston Basin.

GEOTHERMAL PRODUCTION IN NORTH DAKOTA

--Ed Murphy

Geothermal energy is defined as the internal energy of the earth, available to man as heat from rocks or liquids. The North Dakota Geological Survey is given the duty, under the State Industrial Commission, of regulating geothermal energy production in North Dakota. Under the N.D. Century Code (38-19-01), we are mandated to "...encourage, and promote the proper use of geothermal resources...".

Most people, when they think of geothermal energy, have visions of Old Faithful Geyser in Yellowstone National Park. When you mention harnessing geothermal energy, many people visualize steam rising out of deep production wells such as can be found in northern California. Although the extremely high temperatures found in those settings are also present in North Dakota, they are found only at extreme depths below the surface. Several North Dakota companies have explored the feasibility of extracting geothermal energy from within the Dakota Group to heat greenhouses for growing vegetables and also for heating buildings and ponds on fish farms. The Dakota Group occurs at depths ranging between 4000 and 6000 feet below the surface in western North Dakota. Temperatures in the Dakota Group (Inyan Kara Formation) typically range between 125 and 175 degrees Fahrenheit (52 to 79 degrees Celsius) in western North Dakota.

The geothermal energy production going on in North Dakota today is of a much less dramatic, but no less significant, nature than that found in California. Geothermal systems in North Dakota typically operate at subsurface temperatures ranging between 45 and 55 degrees Fahrenheit (7 to 13 degrees Celsius). Currently, there are approximately two dozen commercial and hundreds of residential buildings in North Dakota that are being heated in the winter and cooled in the summer by geothermal energy. This geothermal energy is being tapped by shallow, closed-loop heat pump systems. (We printed an article on open-loop groundwater heat pumps in the *NDGS Newsletter* in June, 1982. The open-loop systems operate by pumping the actual groundwater through a source well, up into the heat pump and then reinjecting the water into the ground through a discharge well).

Closed-Loop Systems Closed-loop systems get their name from the fact that the fluid within the system never comes in contact with the environment (unless there is a leak in the pipe). Generally, the fluid that is used in the system is propylene glycol, which is nontoxic (food-grade propylene glycol is used as antifreeze in trailers and recreation vehicles). These systems include a series of wells, which are referred to as loops. They are called loops because a loop of pipe (commonly one-inch polypropylene) is placed in the well bore and then the well is filled with bentonite and neat cement (figure 1). In North Dakota, the wells are generally less than 400 feet deep. As the fluid is circulated down the pipe in the borehole, its temperature changes to that of the surrounding sediment/rock and groundwater. In the summer, the temperature in the fluid decreases as it is circulated down hole; in the winter the temperature in the fluid increases. These closed-loop systems are used in combination with a heat pump, which is actually responsible for transferring the heat to or from the building. In the winter, the heat from the circulating fluid is absorbed by a low-pressure liquid refrigerant, which then vaporizes. The vapor is then compressed to about 160 degrees and transferred to the air heat exchanger. At the air heat exchanger, the heat from the refrigerant is released and the building is heated (figure 2). In the summer, the refrigerant flow is reversed, enabling it to cool the house.

Central Valley School In 1985, a large, shallow closed-loop system was constructed at Central Valley School near Buxton, in Trail County (figure 3). The closed-loop system

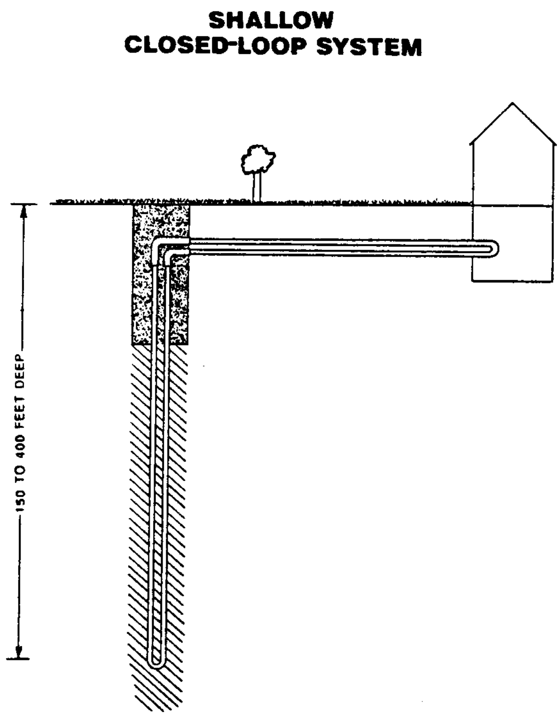

Figure 1. Profile of a typical closed-loop heat pump system in North Dakota. The diagram shows one loop, but the number of loops in a system may range from 2 to 3 up to 600.

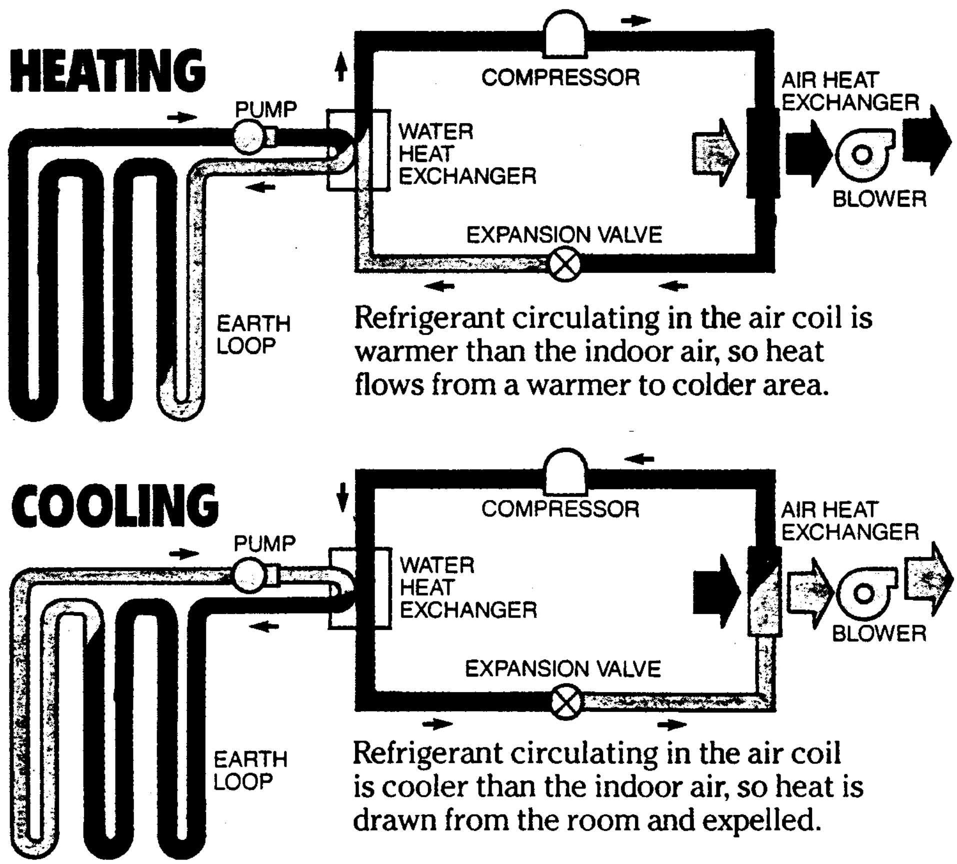

Figure 2. A schematic diagram demonstrating how the closed-loop heat pump systems operate.

consists of 120 wells (or loops), each of which are 210 feet deep. The pumps operate at 360 gallons per minute and completely recirculate the propylene glycol in the system every 15 minutes. The school building, which contains 58,000 square feet, is heated in the winter and cooled in the summer by this system. In addition, the closed-loop system is used to heat the hot water system.

The geothermal system at Central Valley School was one of the largest closed-loop systems in the country when it was installed five years ago. The total cost of the system was $250,000. The projected annual electric cost at the school was $60,000 before the geothermal system was installed. The current annual electric cost is $13,000, an 80% reduction over the projected costs. As a result of this savings, the geothermal system will completely pay for itself this year.

Future of Geothermal Systems in North Dakota The future of closed-loop heat pump systems in North Dakota appears bright. The heat-pump industry claims they can save the individual homeowner or company anywhere from 40% to 70% on their annual heating costs and from 25% to 35% on their cooling costs. At this years annual meeting of the North Dakota Water Well Contractors, a number of drillers expressed interest in learning how to install the loop systems. Our office has been getting an increasing number of calls from people inquiring into the rules and regulations for installing these systems. As the cost of electricity, gas, and heating fuel increases, and as concerns grow for the environmental problems associated with the burning of fossil fuels, these geothermal systems will become more and more attractive.

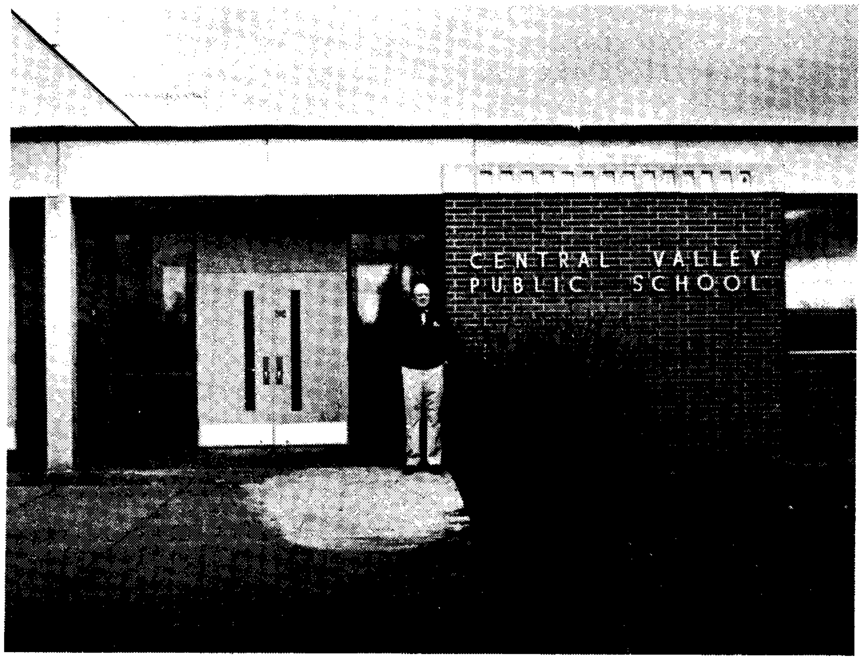

Figure 3. Superintendent Dale Duggan stands in the doorway of Central Valley School in Traill County.

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FLUORESCENT MINERALS IN NORTH DAKOTA

--Mark Luther

Fluorescence is a property that is often used both in the prospecting for, and the identification of minerals with a characteristic fluorescence. Although North Dakota is not naturally endowed with a large variety of fluorescent minerals, there are several occurrences worth noting; but first, a description of fluorescence.

To fully comprehend fluorescence requires an understanding of the basic principles of light itself. White (or visible) light, as we all know, is composed of light of several different wavelengths or colors. The colors (wavelengths) contained in visible light range from red (longest wavelength) through orange, yellow, green, blue, and indigo to violet (shortest wavelength). There are also wavelengths of light that are not visible to the human eye. The shorter wavelengths just beyond violet are called ultraviolet ("black-light") and the longer wavelengths just beyond red are called infrared.

The production of light is called luminescence and is caused by exciting electrons to a high enough state to emit pulses of light. When produced by heat (as in an incandescent light bulb) light is called thermoluminescence, and when produced by the bombardment of a material with particles of light, or photons (as in a fluorescent light tube), light is called photoluminescence. The terms photoluminescence and fluorescence mean the same thing, the older term fluorescence being derived from the light given off by the mineral fluorite when exposed to ultraviolet light sources.

In 1852, Sir George G. Stokes, a British physicist, discovered that the mineral fluorite, when exposed to short wavelength light, would absorb it, convert it to a longer wavelength, and give it off again as visible light. He called this behavior fluorescence. According to Stoke's Law, all fluorescent (photoluminescent) light must be of longer wave wavelengths than that of the light used to excite it. It follows then, that if visible light is used to excite electrons, fluorescence (photoluminescence) will be in the infrared and therefore not visible. For that reason, a short wave, invisible light source (ultraviolet) is used to excite fluorescent minerals, causing them to produce visible light.

Although fluorescent minerals appear to glow immediately when exposed to ultraviolet light, the visible light given off does not occur instantaneously. First, photons from the ultraviolet source must dislodge electrons in the fluorescent mineral from their normal positions, or orbits; imparting additional energy to the displaced electron. And second, as soon as possible, the electron will try to move back to its original position, or orbit, and on doing so will release the excess energy as a small pulse of light. When this is done simultaneously by millions of electrons, all of the ejected light pulses added together form the fluorescent glow. Sometimes the displaced electrons in some minerals do not immediately fall back into their original positions, but instead are held in their higher energy position for a short period of time. However, eventually they do fall into their original position and release light as they do. This after glow is called phosphorescence.

Whether or not a mineral is fluorescent depends on the presence of impurities, or activators. These are traces of particular elements which may be part of a mineral's crystal structure, or may be present as impurities. These activators introduce extra electrons into a mineral as well as defects in the crystal structure, that make it easier for electrons in the mineral to be dislodged from their positions. Many minerals that do not fluoresce normally, will fluoresce if the proper activator is present, and in the right amount. Common activators include manganese, copper, silver, lead, uranium, and chromium. Often different minerals containing the same activator will fluoresce in widely differing colors. An excellent example is the bright pink fluorescence of the mineral calcite and the bright green of the mineral willemite from Franklin, New Jersey; both due to traces of manganese.

Now that some of the fundamental concepts of fluorescence have been covered, let's go back to the beginning and talk about fluorescent minerals that occur naturally in

North Dakota. I recently met with William Buresh and Robert Randall, two Bismarck-Mandan area mineral collectors, who have extensive collections of fluorescent minerals from around the world, and who were gracious enough to give me a tour of their collections. They were able to show me several specimens, although limited in variety, of minerals occurring in North Dakota that fluoresce. The specimens could be broken down into four main varieties: selenite (a form of gypsum); nodular calcite/aragonite; petrified (silicified) wood; and cherts and chalcedonies.

The selenite crystals were very interesting, fluorescing a very light yellow. In addition, the selenite crystals were phosphorescent, continuing to glow for a few seconds after the ultraviolet light was turned off. The calcite/aragonite nodules fluoresced a light pink to dark red color. Most of the petrified woods fluoresced in a pumpkin orange color, as did some of the cherts such as Knife River Flint. Some of the other cherts/flints such as the Sentinel Butte, or Miocene? flint fluoresce a different color when exposed to longwave ultraviolet (fluoresced light orange) than when exposed to shortwave ultraviolet (fluoresced light green) light.

Fluorescence is a common way to identify some minerals, and it is the potential that fluorescence can be used to identify different types and sources of cherts/flints that has led to a renewed interest in fluorescence by NDGS geologists and archeologists across the country. At the 48th Plains Anthropological Conference, Michael Collins (Texas Archeological Research Laboratory) presented a paper on "Ultraviolet Fluorescence In Chert Identification". Michael's findings have spurred several researchers across the country to begin looking as some of the lithics (stone tools) used by prehistoric peoples, with ultraviolet lights in order to more accurately determine the lithics place of origin. A more accurate determination of a stone's point of origin is very important in determining prehistoric trade routes, migrations, etc. Since many cherts/flints look nearly identical in hand-sample and under the microscope, it is hoped that fluorescence will provide a means by which to differentiate between lithics from different source areas.

The NDGS plans to produce a document detailing the characteristics, locations, etc. of lithic materials (ie. cherts, flints, chalcedonies, etc.) used by American Indians, that occur in the state (publication planned for late-fall 1991). Fluorescence will be one of the characteristic used in describing the lithics types. This publication should be useful to archeologists working in the region, as well as mineral collectors. We would encourage mineral collectors or archeologists with knowledge of sources of knappable materials to contact the NDGS. We hope to have a fluoroscope (ultraviolet light source) available by early this spring (1991) and would encourage you to bring in your minerals, flints, etc., to see if they fluoresce; one of the most beautiful sights in the mineral world.

MISSISSIPPIAN NOMENCLATURE IN NORTH DAKOTA

--Julie LeFever

The sequence of rocks referred to as the Mississippian Madison Group is the most important oil producer in North Dakota. It is not only prolific in oil, it is prolific in names. Anyone who has studied or had to deal with all or any part of the Madison Group can confirm this. The terminology can be quite confusing.

The term "Madison Limestone" was first introduced by Peale in 1893 for a section of rocks exposed in the Madison Range of western Montana. Then, in 1922, the Madison was split into two separate formations, the Mission Canyon and Lodgepole (both from the Little Rocky Mountains in north-central Montana) and grouped under the name Madison by Collier and Cathcart. However, when the terms were extended into the subsurface, an additional formation, the Charles, was recognized and added to what is now the Madison Group. Problems arise when the names applied to rocks exposed at the surface are extended to rocks in the subsurface.

At this point, the terminology seems fairly clear: one group, Madison, comprising three formations, the Charles, Mission Canyon, and Lodgepole. However, the formation names are based on the lithology of the rocks, and this changes frequently in the Madison. One soon realizes that the Charles, Mission Canyon, and Lodgepole Formations have an interfingering relationship (i.e., what is considered to be in the Mission Canyon Formation in one location belongs to the Charles Formation in another location) (Fig. 1). Therefore, in an attempt to avoid this problem, workers have assigned a variety of names to various parts of the Madison Group. In this article I will try to explain what the current usage is and how it is applied. I will also show several of the names that have been used in the past or are currently used to describe the same section of rocks.

As I said, the formations of the Madison Group have an interfingering relationship and become difficult to work with in the subsurface of the North Dakota Williston Basin. The Mississippian Committee of the North Dakota Geological Society proposed a solution to the problem in 1960 (Smith, 1960). They divided the Madison Group into five informal intervals based on marker beds defined by wireline logs. In ascending order, they are the Bottineau, Tilston, Frobisher-Alida, Ratcliffe, and Poplar. These marker beds cross facies boundaries laterally across the Williston Basin. The North Dakota Geological Survey currently uses these informal interval (Bluemle and others, 1966).

The Frobisher-Alida interval was further subdivided into beds, based on wireline markers. Harris and others (1960) subdivided the Frobisher-Alida into six cyclic units or beds. In ascending order, these are the Landa, Wayne, Glenburn, Mohall, Sherwood, and Bluell. In 1987, Voldseth added two additional units to the top, the Coteau and Dale. These names were used to describe rocks in the north-central part of North Dakota. However, more recently, this terminology has been extended across the margin of the Williston Basin in North Dakota.

The accompanying diagram (Fig. 2) shows some of the names that have been used to describe the producing rocks of the Madison Group. It is evident that a variety of names exist for the same sequence of rocks. Many of the names refer to producing beds in Canada; the names were extended into North Dakota. Other names refer to the field where that particular sequence of rocks produces oil. The list on figure 2 is not complete; it is restricted to names in use in the north-central part of North Dakota. More names would have to be included in a state-wide compilation.

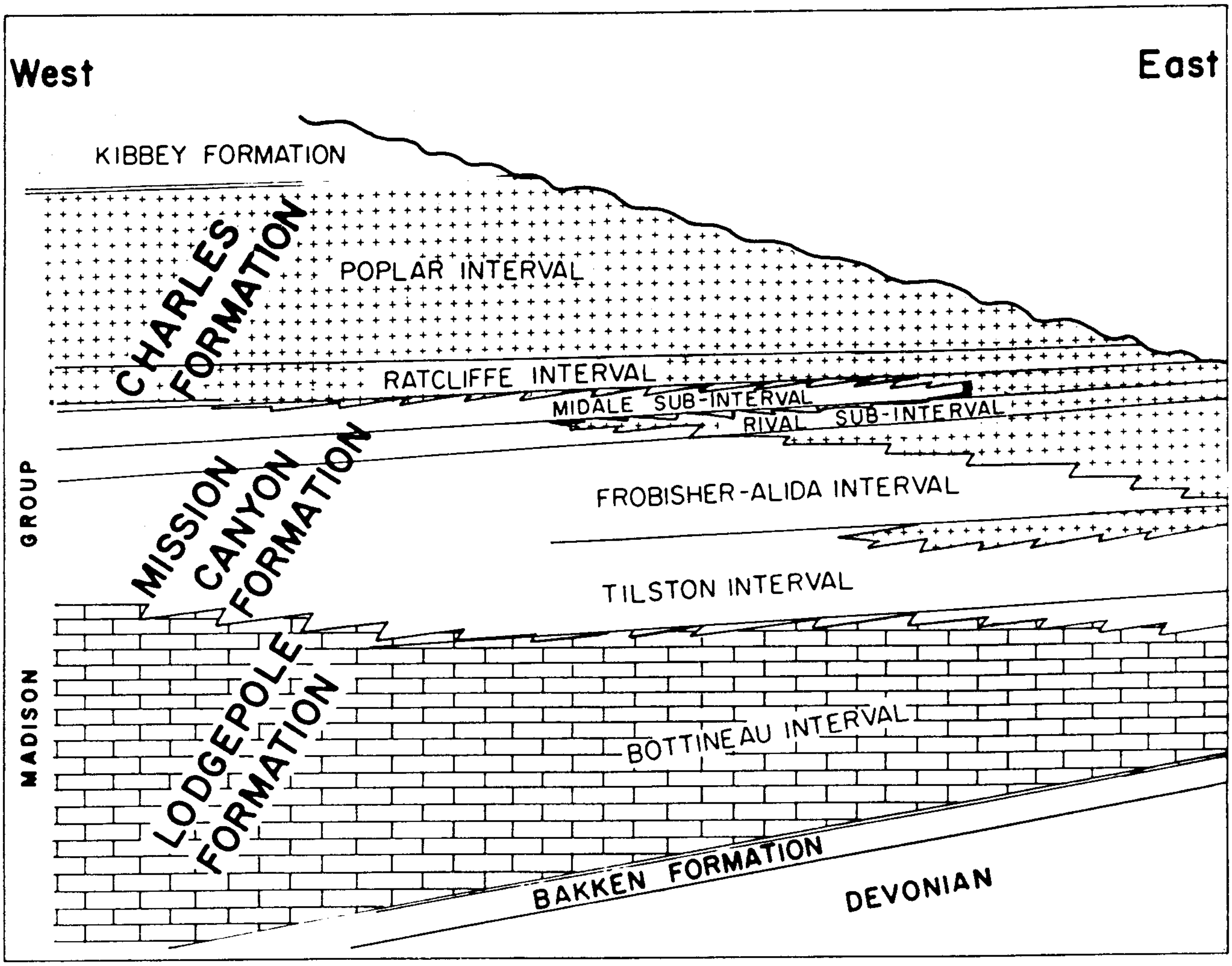

Figure 1. Generalized cross-section of Mississippian rocks in the Williston basin showing the relationship of facies and stratigraphic nomenclature (Gerhard et al., 1982).

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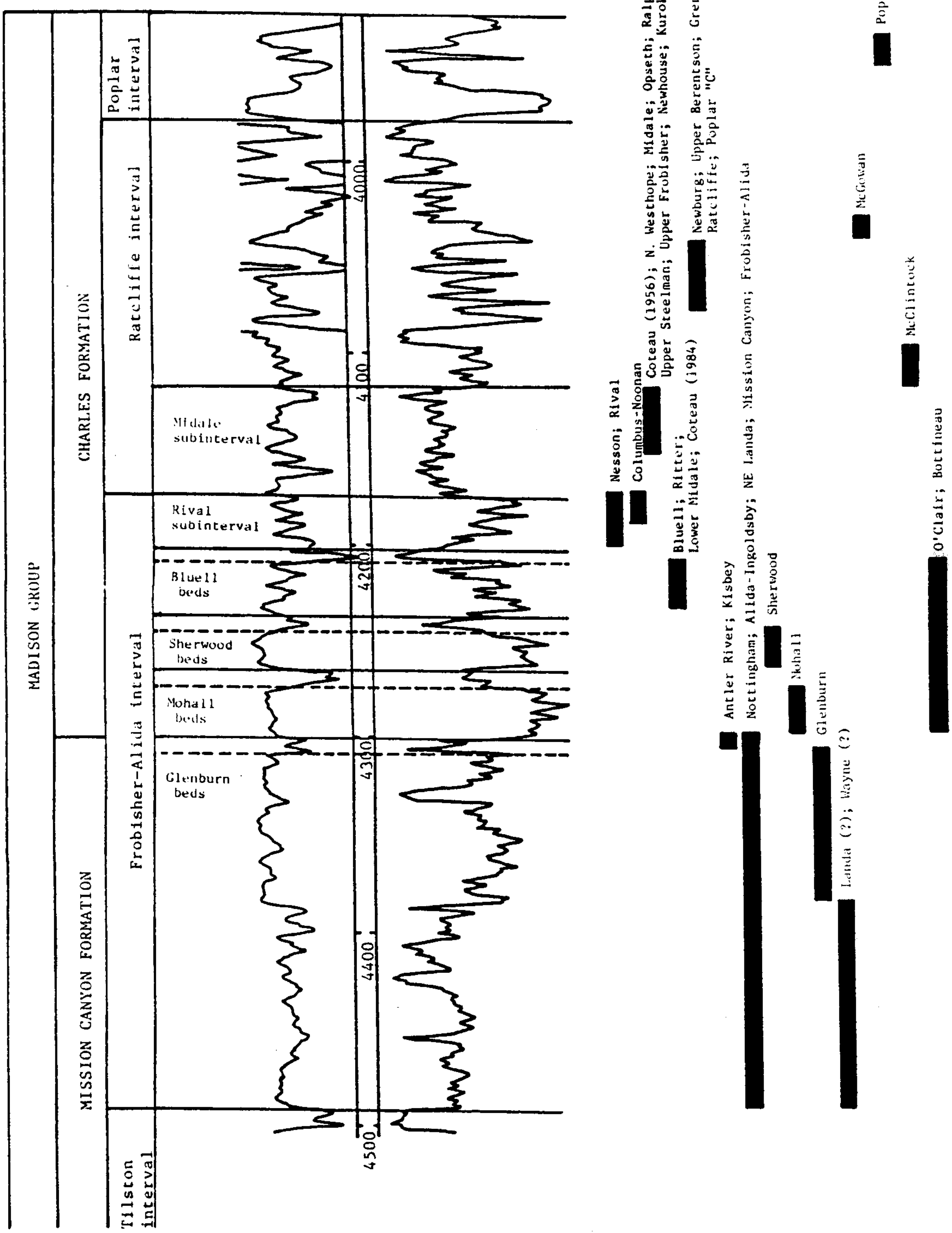

Figure 2. Subsurface wireline log characteristics for the Mississippian Madison Group. Informal names for the various pays are indicated adjacent to the corresponding interval.

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NORTH DAKOTA REMAINS UNDERTESTED FOR OIL

--Tom Heck

Twice in the past, in the December, 1975 and June, 1980 *NDGS Newsletter*, John Bluemle published articles on exploratory drilling in North Dakota. He pointed out in these articles that much of the North Dakota Williston Basin was, at best, only sparsely tested. This remains true to the present time, despite ten years of additional drilling since the 1980 article was written.

HISTORY

The oil boom that began with the Arab oil embargo in 1974-1975 caused an increase in exploratory drilling levels as oil companies searched within the U. S. for a more secure supply of oil. The years 1979 through 1982 was a period of intense activity (figure 1) with record levels of exploratory activity in North Dakota. In 1981, oil prices fell due to an oversupply of oil and, at that time, activity dropped off dramatically. In 1986, oil prices collapsed and drilling all but ceased in North Dakota. Since the collapse, drilling levels have fluctuated at levels close to the lowest seen in the North Dakota before rebounding slightly in recent months as a result of uncertainty in the Persian Gulf.

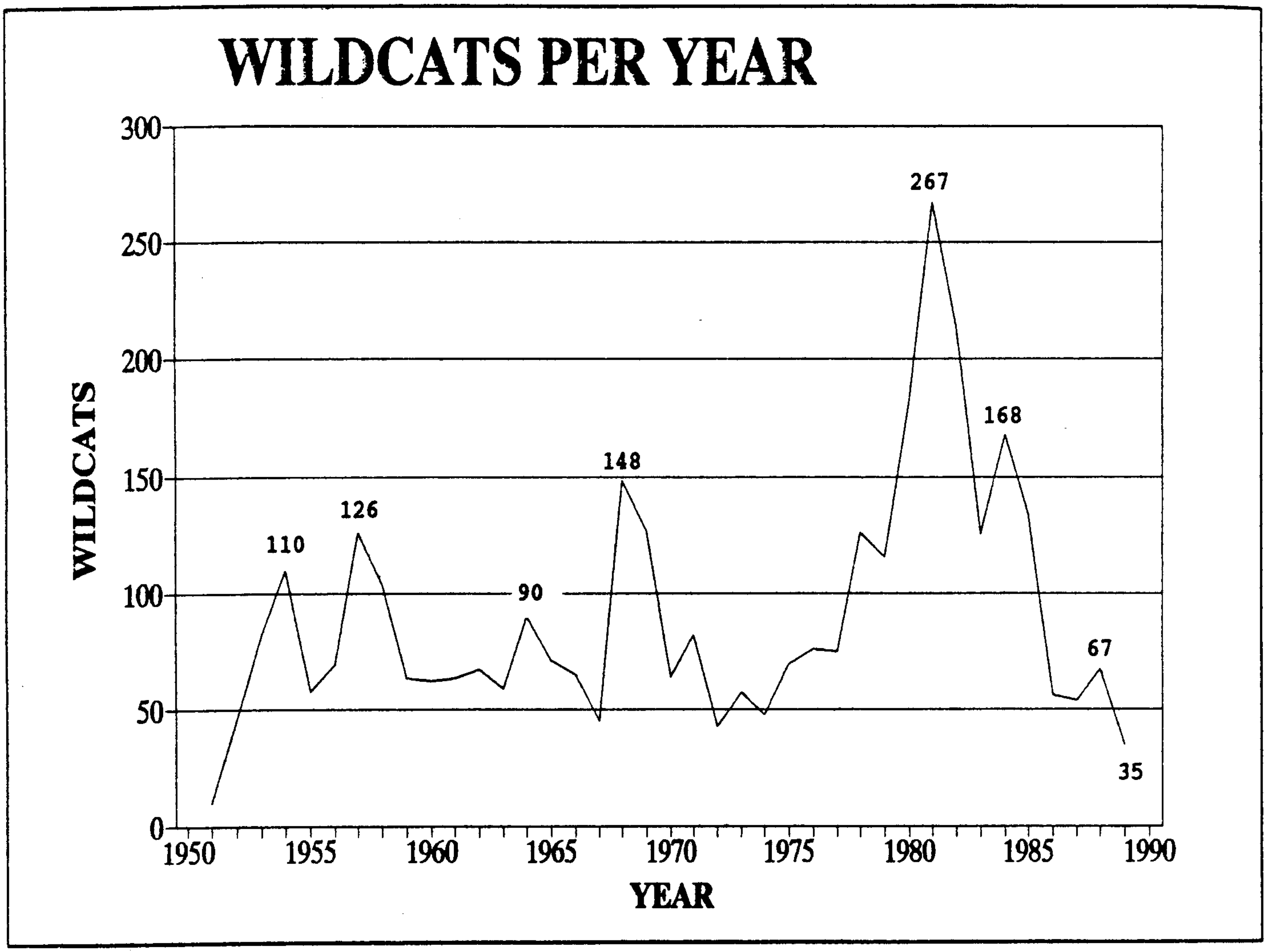

Figure 1. Graph of total number of exploratory wells drilled annually in North Dakota since 1951.

NORTH DAKOTA ACTIVITY

Western North Dakota has seen several significant changes in the focus of exploratory drilling over the years. Prior to 1975, drilling was concentrated primarily along the Nesson Anticline in eastern McKenzie, Williams, and Divide Counties. Scattered fields were found in a few other parts of these three counties as well as in Golden Valley, Billings, and Dunn Counties. Between 1975 and 1989, 525 new pools were discovered in North Dakota, most of them still in the above six counties. Despite the additional drilling since 1975 in these counties, entire townships remain untested and many more townships have still had only one or two wells drilled in them. For example, in 1980, Williams County had 19 untested townships--no wells at all had been drilled. Today, three townships remain untested and 16 more have had 3 or less wells drilled in them. More than 210,000,000 barrels of oil have been produced in Williams County since 1951. The potential reserves of these untested lands could be significant. Elsewhere in North Dakota, the potential reserves are also high.

During the last five years, a series of remote Madison wildcats found five new fields. In Mountrail County, Wabek (Sherwood Zone) and Plaza (Bluell Zone) Fields were discovered during 1985 and 1989 respectively. These two fields are located approximately 15 miles basinward of the nearest stratigraphically equivalent production. Each of these fields will produce 4 to 6 million barrels of oil. Two additional fields were discovered along the Sherwood trend in previously unexplored areas of McLean County this year. Centennial and Lucky Mound Fields have extended the Wabek trend another 15 miles basinward into a county that has been only sparsely drilled. When Torning Field (Mohall Zone) was discovered in 1988, it became the southern- and easternmost Madison Formation production in North Dakota. All of the fields I just mentioned were found in relatively under-explored parts of North Dakota. It's almost a certainly that other, equally significant fields remain in other under-explored parts of the Williston Basin.

In areas that many people consider to be the prospective portion of North Dakota where oil is likely to be found there are many virtually entire untested counties. For example, Adams, Hettinger, Morton, Mercer, McLean, McHenry, and Rolette Counties contain a total of only four oil fields, but they border on six counties that have produced a total of 250,000,000 barrels of oil. Three of these four fields are in McLean County and two of them were discovered just this past year. The counties just mentioned cover approximately 10,000 square miles, but only 342 wells have been drilled in them to date. That's about one well for every 29 square miles. The two discoveries in McLean County will help to encourage drilling there, but the other unexplored areas also have high potentials for production.

Recent successful wildcat wells have demonstrated that North Dakota is not yet a mature petroleum province. However, even these successful wells were targeted only for the Madison Formation; most of the potentially productive stratigraphic section beneath the Madison remains untested, even directly beneath the newly discovered fields I just mentioned. The deeper section, in virtually all of the counties east of the Nesson Anticline, an area of more than 50,000 square miles, is essentially untested and its petroleum potential, at best, is very poorly known.

In short, North Dakota still needs more exploration drilling!

OIL AND GAS DRILLING AND PRODUCTION PROCEDURES IN NORTH DAKOTA

--John Bluemle

[Editor's Note: We regularly get questions from people who wonder what actually goes into drilling an oil well--just what has to be done, how the wells are taken care of after they no longer produce oil or gas, and a variety of other questions. People who live in western North Dakota see rigs drilling or pumping every day, and they know

many or most of these things, but people from the non-producing areas sometimes view the whole process as somewhat mysterious or, at least, they don't understand it well. What I've tried to do here is describe, briefly and in very general terms, the whole process of permitting, drilling, production, clean-up, etc. For readers interested in a somewhat more thorough discussion, the NDGS has a nontechnical publication available: PETROLEUM--a Primer for North Dakota (our Educational Series 13, by Erling Brostuen, published in 1981)].

Permitting

Before it's possible to begin drilling an oil or gas well, the operator has to obtain a drilling permit from the Oil and Gas Division of the State Industrial Commission. Before issuing the permit, the Division checks to see whether a bond is on file, to ensure that the operator will properly plug and abandon the well when it stops producing. The drilling permit is issued if the notice from the applicant contains certain required information and meets established rules on bonding, spacing, setting of surface casing, and public notice. The permit application asks for information about the type of well, name of the operator and surface owner, location, depth, and a variety of other things. In addition to the Oil and Gas Division's requirements, the Geological Survey requires that the operator supply all requested cores and samples. Although the North Dakota Oil and Gas Division's authority covers all land in North Dakota, other agencies have various degrees of control over land they manage (the Forest Service, Bureau of Land Management, Indian Reservations, the State Land Board, etc.).

Siting and Construction

Different depths of drilling require different types of equipment. Figure 1 shows the components of a typical drilling rig. In north-central North Dakota, where wells normally reach only 4,000 or 5,000 feet deep, a small rig may be used for the drilling. Such a rig may require only a half dozen truckloads of equipment and a single derrick about 70 feet high. In the western and southwestern parts of the state, however, the deeper drilling rigs require 20 to 50 loads of equipment and a derrick 100 to 120 feet high.

Access roads and drilling sites vary according to the size of the rig used. Shallow wells may require less than an acre for the drill site, whereas deep test holes may require as much as 5 or 6 acres.

An earthen "reserve" pit is excavated near the location where the rig is set up (Figs. 2 and 3). The size and location of this pit are determined in part by the depth to be drilled. The pit serves as storage (reserve) for drilling fluids and a receptacle for drill cuttings and other solids removed from the circulating system. Whether the reserve pit needs to be lined, and the requirements for doing so may depend on the type of drilling fluid used, its chemical contents, the permeability of the near-surface materials in the area (that is, how easily fluids will pass through them), and the depth to groundwater at the location. The pit may also be used as a flare pit, should natural gas be encountered. During the drilling process, mud is pumped down the well, and it then circulates through the system back to the reserve pit.

Other excavations near the rig may include a small trash pit for collection of mud sacks and other trash generated on site. Privy pits

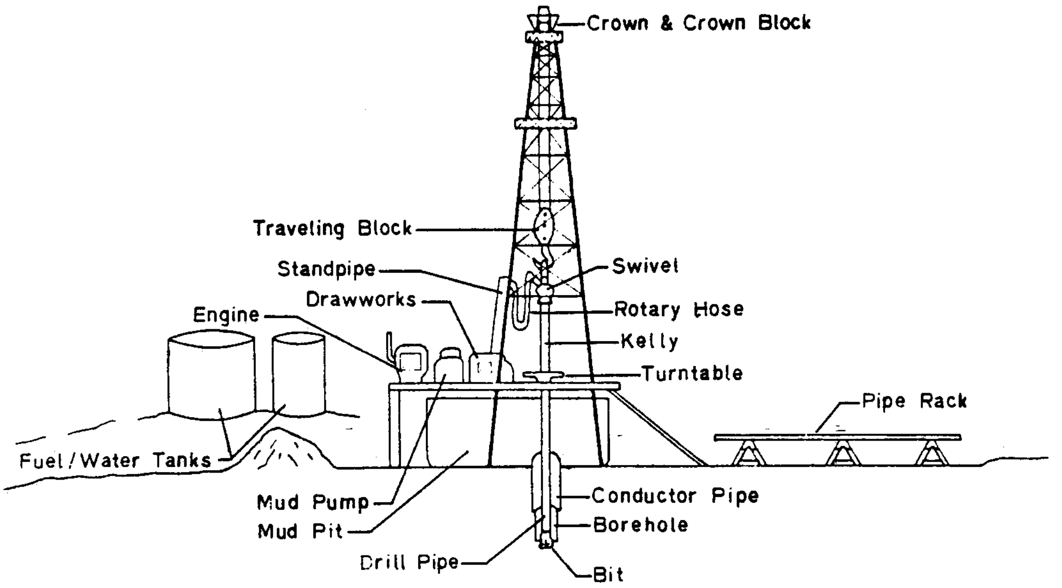

Figure 1. Diagram of a a typical drilling rig, showing the major components and related equipment.

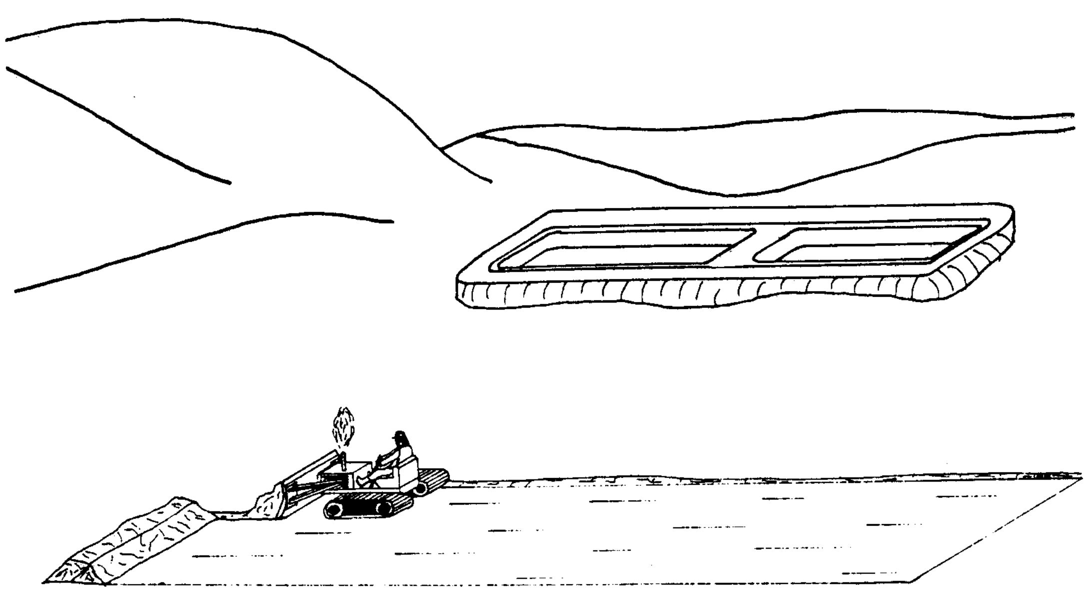

Figure 2. Drawing showing the preparation of a drill site. A reserve pit is constructed and the gound is leveled for the erection of the drilling rig.

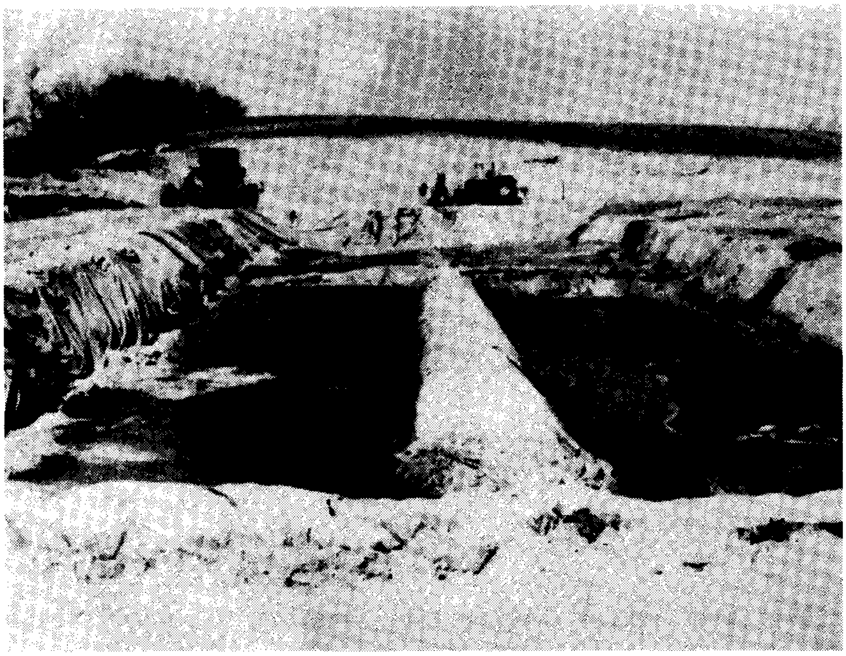

Figure 3. Photo of a reserve pit. This particular pit is already being filled after completion of the well. Note the plastic liner on the walls of the pit. This is to keep the pit from leaking.

or holes and sometimes sewage containment tanks are installed, depending on how long the operator expects it will take to drill the well.

After the road and drill pad are built and the reserve pit excavated and lined, the rig is trucked in and rigged up. A 30-foot-long string of large- diameter (24- to 36-inch) conductor pipe is installed first (Fig. 4). Once the conductor pipe is in place, the rig drills the "surface hole." The surface hole is normally lined with surface casing set through the glacial deposits or, in areas where there are no glacial deposits, to a depth of 50 feet into the Pierre Formation shale. The setting depth is selected to protect freshwater aquifers and to provide a competent seat for additional casing strings, which are mechanically attached to the top of the surface casing. To further protect groundwater, the surface hole is normally drilled with fresh water, although sometimes the mud may be lightly treated with bentonite to enhance its usefulness for drilling.

Drilling Muds

Drilling fluids serve several purposes and their compositions may be quite complex. Drilling fluid lifts the cuttings from the hole as it is being drilled, it lubricates and cools the bit, provides pressure to control the influx of fluids from formations that are penetrated, and builds a hole-stabilizing filter cake to control caving and loss of drilling fluid to porous zones.

Most of the drilling muds used in North Dakota are saltwater-based to avoid washing out or dissolving the salt-bearing formations encountered in drilling. In some instances,

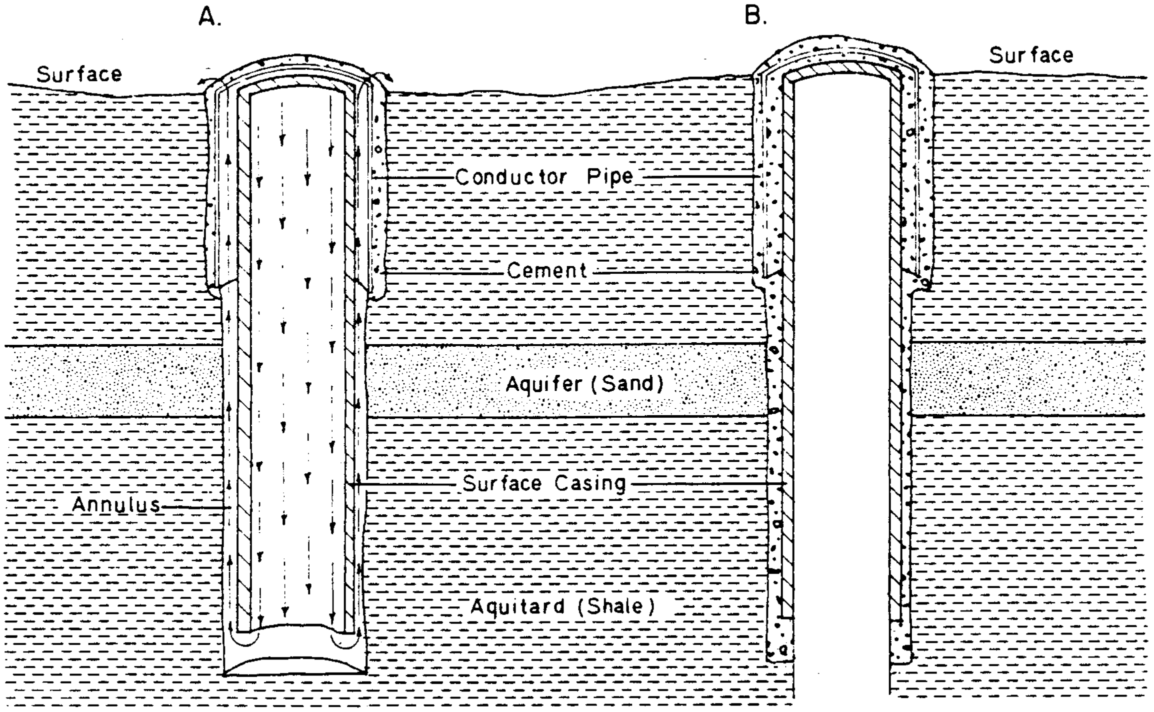

Figure 4. Diagram showing the casing of a surface hole to prevent contamination of any fresh water supplies (in this case the zone labeled "aquifer."). The surface casing also supports the production casing.

A. Conductor pipe has been cemented into place. A predetermined amount of casing has been inserted into the well bore below the deepest fresh water zone. Cement is pumped down the inside of the casing until cement flows to the surface through the annulus.

B. The cement has hardened and both casing and cement have been tested under pressure. The cement in the bottom of the casing has been drilled out so that drilling can be resumed.

such as in the Bakken Formation, oil-based muds may be used to avoid "wetting," and thereby sealing off, the oil-bearing rocks.

Additives of various kinds are used with drilling mud to produce various qualities. They may include such things as corn starch to reduce fluid loss to rock formations, barite to increase fluid weight (and control high pressures in the formations), or caustic soda to control acidity. Other additives may be used to thin or thicken the mud, lubricate the bit, inhibit pipe corrosion, and prevent bacterial action in the mud system.

Blowout Prevention Procedures and Equipment

Blowout prevention equipment is used to prevent the loss of control of a well while it is being drilled. This loss of control can occur when the well encounters formations with high-pressure fluids, which can be oil, gas, water, or a combination of these. These fluids normally can be kept out of the well bore by the weight of the drilling fluid, but if the drilling fluid is not dense enough, they may enter the well. Natural gas is the most common fluid encountered, and the most difficult to control. Highly pressured nitrogen gas may also be encountered. The reason the gas is under high pressure is because it is compressed by the pressure at the depth at which it is buried (generally, the deeper it is buried, the higher the pressures that may be encountered), and when it travels up the well toward the surface, it expands as the pressure decreases. This expansion displaces mud and further reduces the pressure in the well, allowing more gas to enter the well. If not controlled, this gas can cause the well to blow out, pushing all the mud out of the hole.

In areas already producing oil or gas, the Oil and Gas Division requires use of blowout prevention equipment sufficient to meet the known conditions. For exploratory wells in regions where conditions are not known, an array of blowout preventors sufficient to meet any foreseeable situations is required.

Well Logging and Completion

Drilling operations continue until the predetermined total depth of the well is reached. A logging company is then called to the well site and the drill string (the drill pipe and bit) is removed from the well bore to allow the insertion of logging tools, which are lowered on a cable all the way to the bottom of the hole. The cable contains a number of electrical circuits. The tools are reeled slowly back to the surface and, as this is done, specific properties of the rock units are measured. Signals detected by the tools are recorded in a recording truck at the surface by means of the electrical circuits contained in the cable.

The logging tools measure a variety of properties of the rock formations, including natural electrical potential, the effect of induced electricity on the formations, radioactivity, the velocity of sound waves in the rocks, and other characteristics. By analyzing these logs, geologists and engineers are able to determine the depth from the surface to various formations and intervals, formation characteristics such as rock type and porosity, and indications of the presence of oil or gas and how much there may be.

If a completed well appears capable of commercial production, the drilling rig runs production casing into the hole. A well's production is usually tested for 10 to 30 days before permanent surface equipment such as tank batteries are installed.

Production

A well can produce either gas or oil, or both. Oil wells generally require more surface equipment than gas wells. Individual wells may have their own tank batteries consisting of two or three storage tanks for oil, a water tank, and a heater-treater. The heater-treater is used to separate the water that often is produced along with the oil. The tanks provide storage for several days' production. In fields where all the owners share in the total production (unitized fields), one or more consolidated tank batteries may serve the entire field.

The size of oil and gas fields in North Dakota can range from one-well fields producing from one horizon, to fields with over a hundred wells and production within the field from a number of different horizons. The type of geologic structure or feature contributes greatly to the size of any particular oil or gas field. In fields with more than one well, the spacing of wells is based on the amount of hydrocarbon-bearing rock that one well can efficiently and economically drain. Gas wells typically require spacing based on one well per 640 acres (one well per section of land). Oil wells usually require more wells to drain a subsurface area than do gas wells. In North Dakota, oil wells usually are spaced at 320 or 160 acres (2 to 4 wells per section), although in areas of shallower production in the north-central part of the state, 80-acre or 40-acre spacing are common.

Some oil wells flow without pumping, and these usually do not require any surface equipment other than a wellhead and valves to control the flow. Once a well stops flowing, some method of artificial lift must be employed. Natural gas may be injected to lighten the fluid and renew the flow, or any of several types of pumps may be installed. Such pumps may be electric or hydraulic submersible, or a mechanical rod pump. The rod pump is the familiar "rocking horse" type, which may be powered by an electric motor or internal combustion engine. In some instances, gas produced from the well may be used to power the engine. The deeper the well, the bigger the pumping unit.

Disposal of Produced Water

The water produced from oil and gas wells in North Dakota tends to be quite salty; it may be several times saltier than sea water. Most salt water is disposed of in injection or disposal wells; the Dakota-Lakota Formation has been used for disposal in many places.

Well Abandonment and Site Restoration

Dry holes are normally plugged immediately upon completion of the well. Cement is placed through the drill string to plug off the wellbore where it penetrates porous formations, or as necessary. A plug is set at the bottom of the surface casing and another at the top.

Surface restoration begins after the drilling rig and equipment are removed from the site. Liquids may be skimmed from the pit, loaded into trucks, and hauled to a disposal well or to another drilling operation for use as drilling fluid. In the case of dry holes, fluids may be pumped back down the hole as part of the plugging operation. After the fluids have been removed, the pit is filled in; some operators have experimented with blowing material into the pit and solidifying the resulting mass (Fig. 5). Dirt is mounded on top of the pit to allow for settling. Muds normally are left in the pit. It is common to tear or break the pit liner after the top water has been removed, then dig trenches to drain any remaining fluids, and conclude by backfilling the pit.

Release of Bond

Before bond can be released, the site has to be restored to the satisfaction of the Oil and Gas Division Field Inspector. Typically a year's wait (or one "wet season") is necessary to be certain grass is established and the site is not going to settle any more. All information (logs, forms, drill-stem tests, samples and cores must be turned in before release of bond.

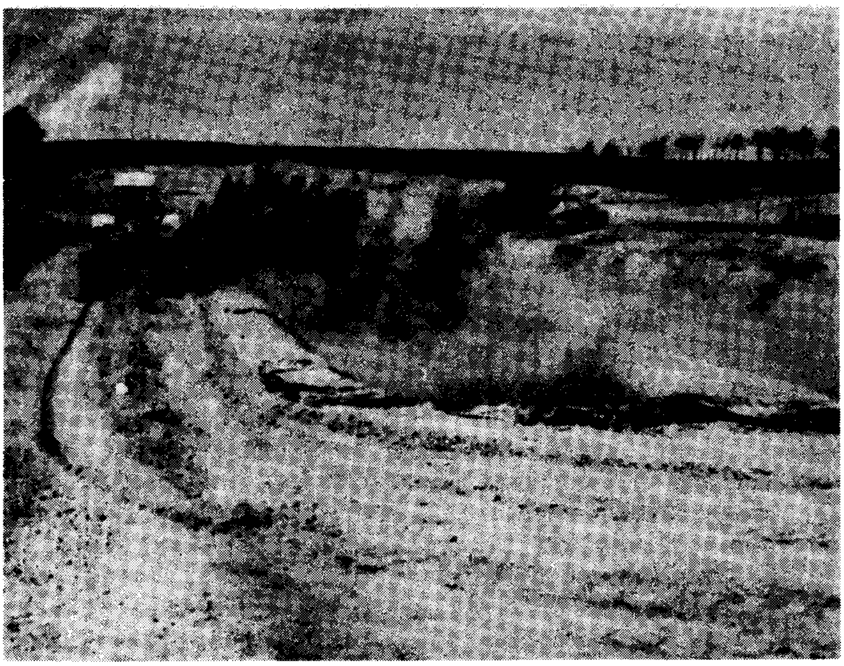

Figure 5. Reserve pit nearly completely filled in. Soil is being blown into the pit.

THE CONCEPT OF GEOLOGIC TIME

John Bluemle

Much like historians who study ancient civilizations, geologists relate important events of the past to one another. Unlike historians, though, geologists typically speak of "a million years" as a unit when dealing with the history of the earth, and they talk casually of 50 or 500 million years, periods of time quite outside most people's comprehension. In fact, even though geologic time is fundamental to all geological research, very few people are really able to visualize its immensity and scale.

I've found that one way to help visualize the vast scale of geologic time is to compare it to distance. If one hundred years is considered to be equivalent to 100 feet, then the five thousand years of recorded history would extend 5,000 feet, about a mile or fifteen minutes' walk. Archaeologists work mainly within a ten-thousand-year time scale that extends a "distance" of about two miles. The last glaciers melted from North Dakota about two "miles" ago (about 10,000 years ago). The three million years back to the start of the Ice Age in North Dakota, still a relatively "recent" geological event, takes us about 550 miles, maybe from Fargo to Billings (a considerable walk). The last dinosaurs died 65 million years ago. To reach that time would require a "walk" halfway around the world, about 12,000 miles; to reach the time when dinosaurs first appeared on earth would necessitate a trip of about 35,000 miles--around the world one and a half times. Covering the whole span of geologic time, since the earth formed about 5 billion years ago, would require a trip of about a million miles, 40 times around the world. Remember, at the scale we are "walking," an average human lifespan is only 75 feet, just a walk across the street.

So much for the distance analogy. Unlike the historian, who may refer to units of equal duration and to events that happened at specific times (the U.S. Revolution was in 1776; the Civil War in 1860; North Dakota became a state in 1889), geologists don't usually define time in terms of definite, measured intervals--minutes, days, and years. Just as our own personal view of time is probably most closely tied to major events that have been important parts of our lives--our birth date, high school graduation, marriage--unequally spaced events to which we relate other, less easily remembered happenings, geologic time is most conveniently measured in terms of important events--successions of volcanic eruptions, inundations by ancient seas, times of mountain building, evolution and extinction of various animal or plant species, the expansion and melting of continental glaciers--events which form sets of reference points that enable geologists to tell their story.

Finally, to help the average non-geologist better comprehend the concept of geologic time and its immense duration, I will use a series of seven time-flow charts of North Dakota's geologic history (figures 1 through 7). Each successive chart represents the last tenth of the geologic time shown on the preceding chart. Thus, the first chart (fig. 1) gives a very general accounting of the events that occurred over the entire 15-billion-year history of the universe. The second chart (fig. 2) amplifies and gives details about the last 1.5 billion years on earth, the third deals with the last 150 million years, etc. I owe the idea of showing geologic history in this way to Dr. Lee Clayton, who was a professor of geology at the University of North Dakota for many years. Dr. Clayton also did much of the actual compilation of the information included on the charts.

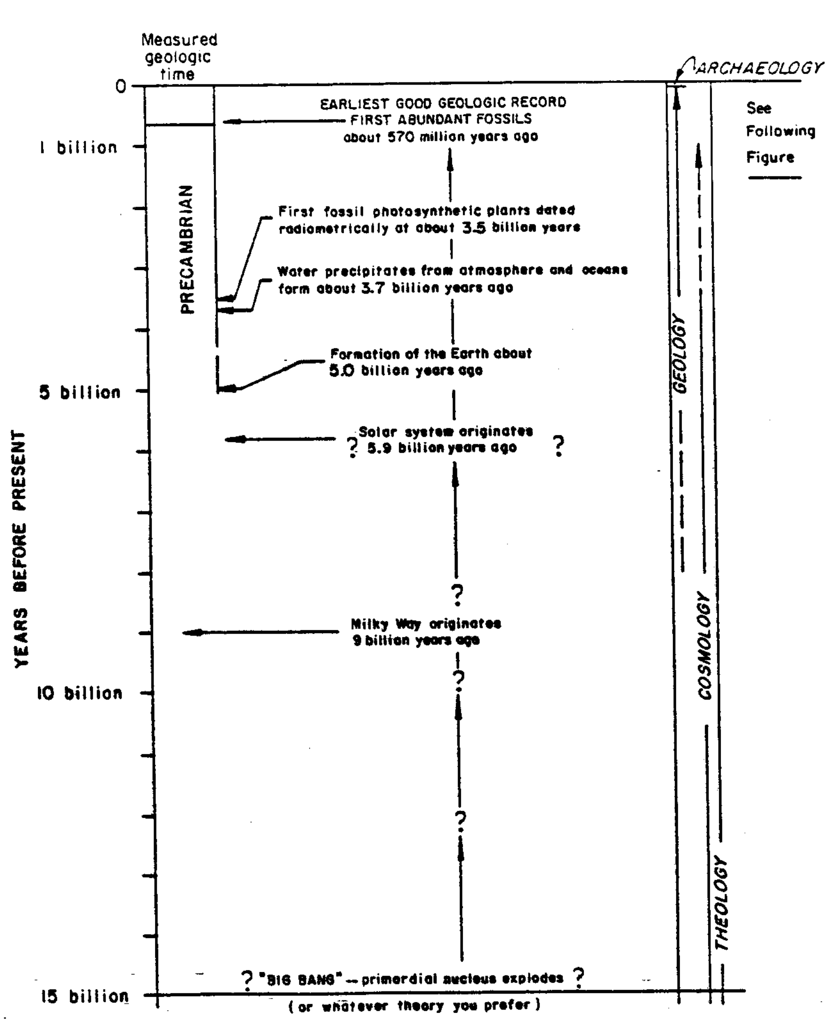

Figure 1. Entire 15 billion years of the Earth's history, from the "Big Bang" until the present. The last tenth--1.5 billion years--of the Earth's history is shown on figure 2.

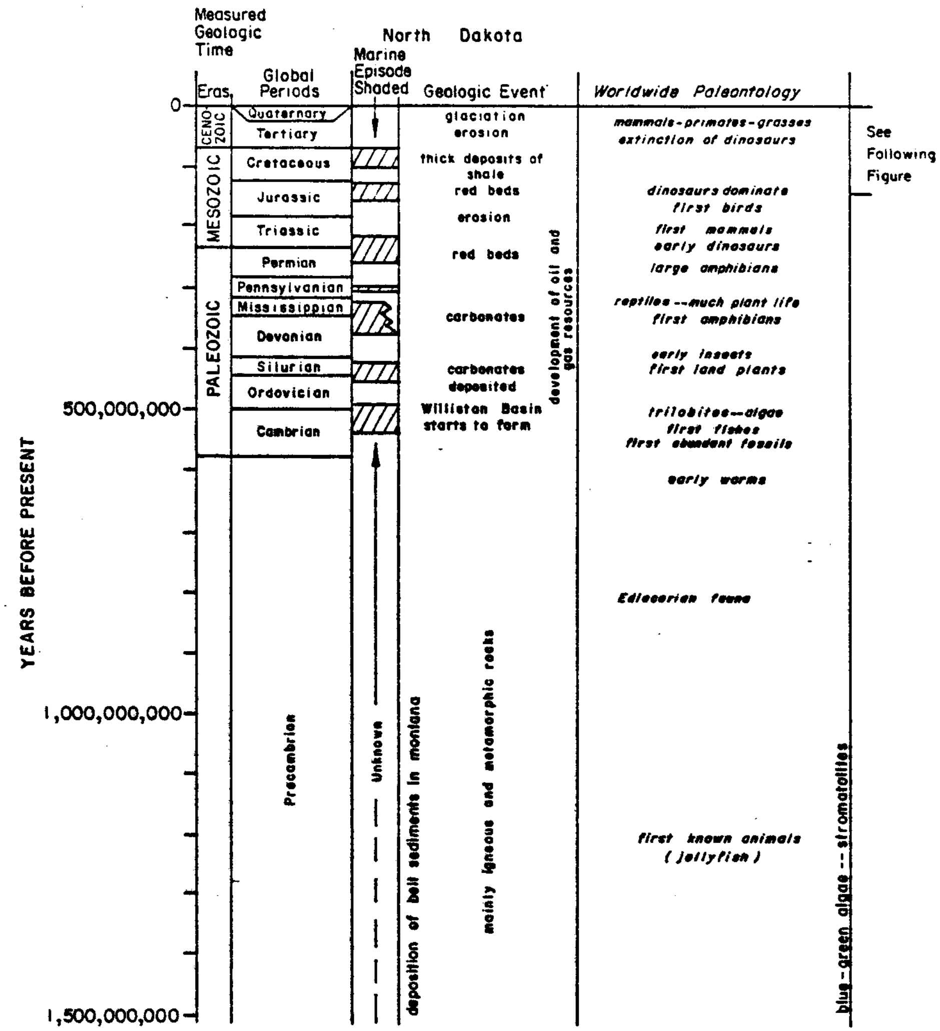

Figure. 2. The last 1.5 billion years of the Earth's history. Most of the work geologists do in North Dakota concentrates on the last 600,000 years, since the beginning of Cambrian time, which is also the time that hard shelled animals capable of forming abundant fossils developed. The oil-bearing rocks found in the Williston Basin began to be deposited in Cambrian time.

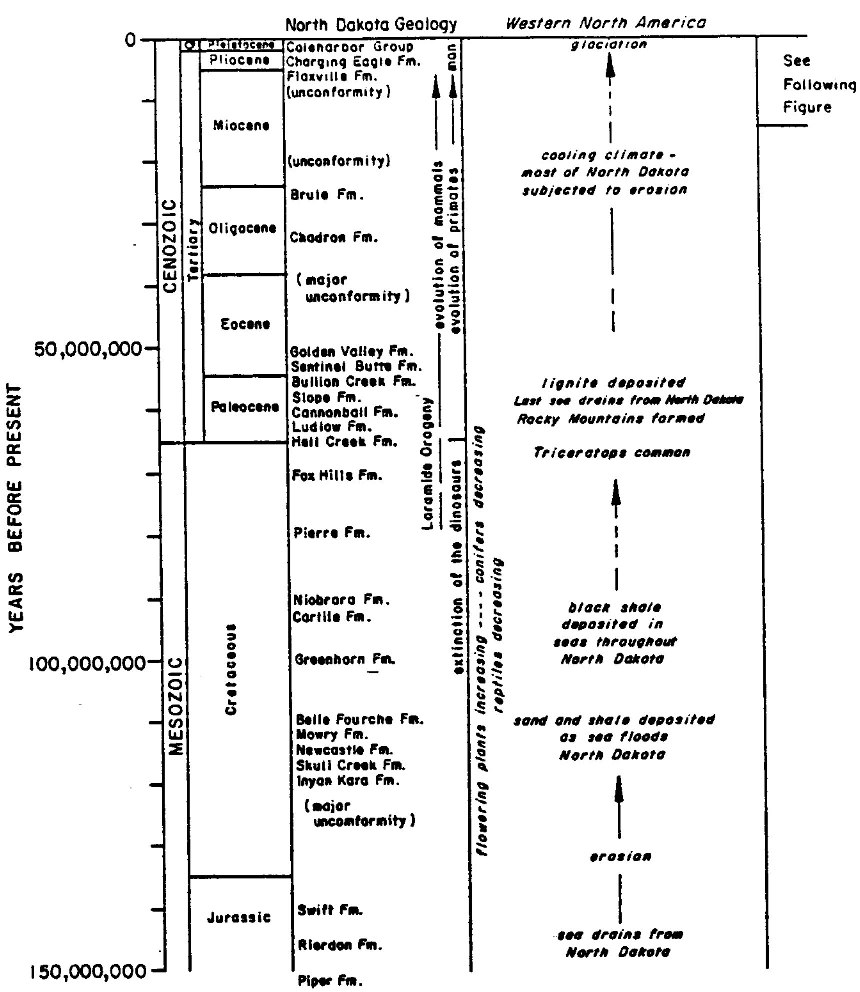

Figure 3. The last 150 million years of the Earth's history. This diagram goes back to a point midway in the age of dinosaurs.

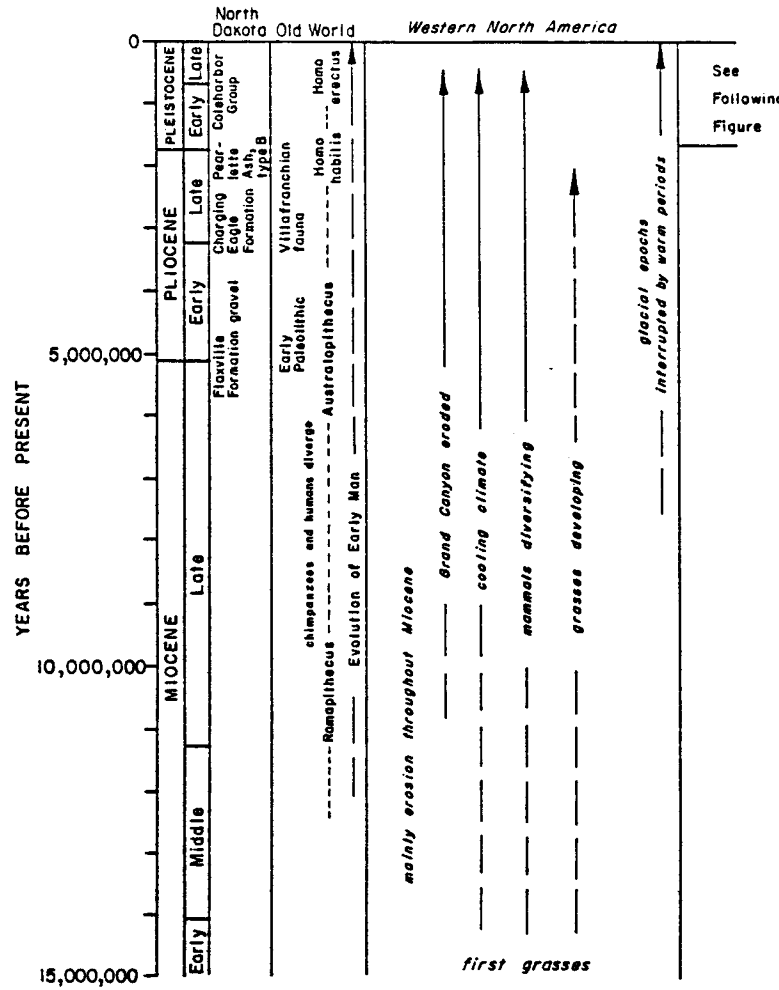

Figure 4. The last 15 million years of the Earth's history. On this scale, the evolution of man can be visualized. Humans and chimpanzees diverged between 5 and 10 million years ago and modern man dates back only to the last one and a half million years.

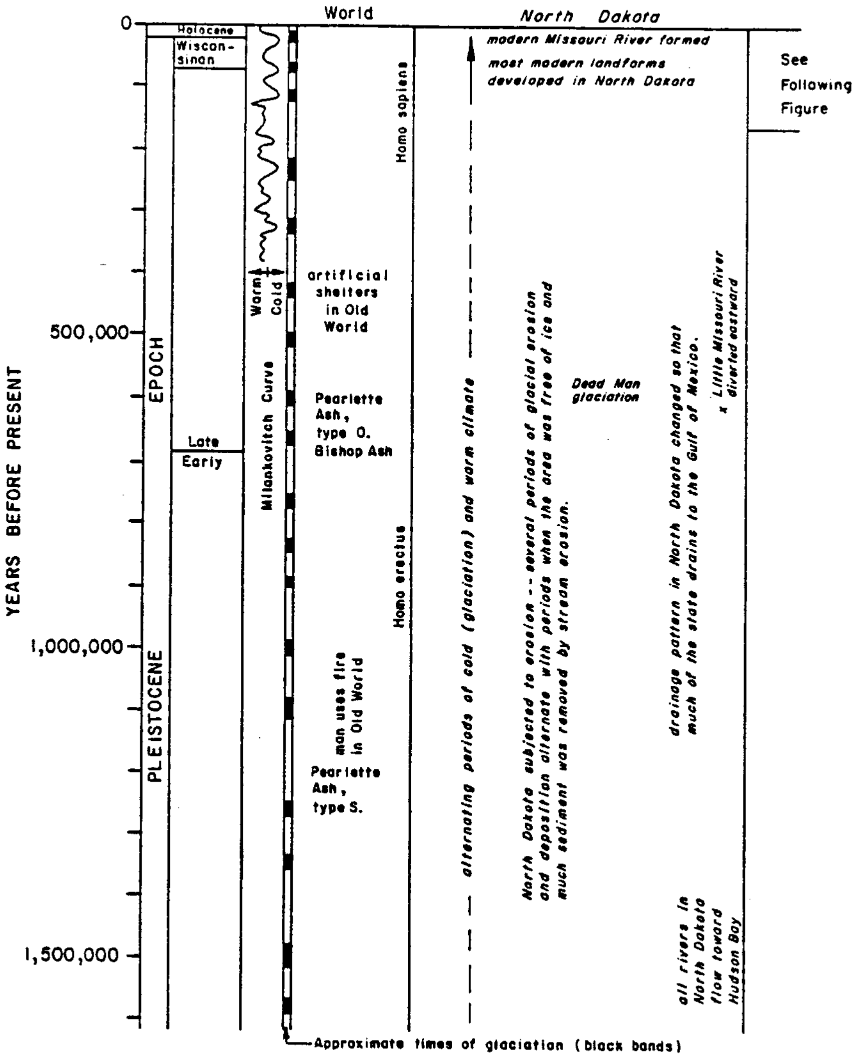

Figure 5. The last 1.5 million years of the Earth's history. During this period of time North Dakota was glaciated a number of times. The vertical bar shows periods of glaciation (the black bands).

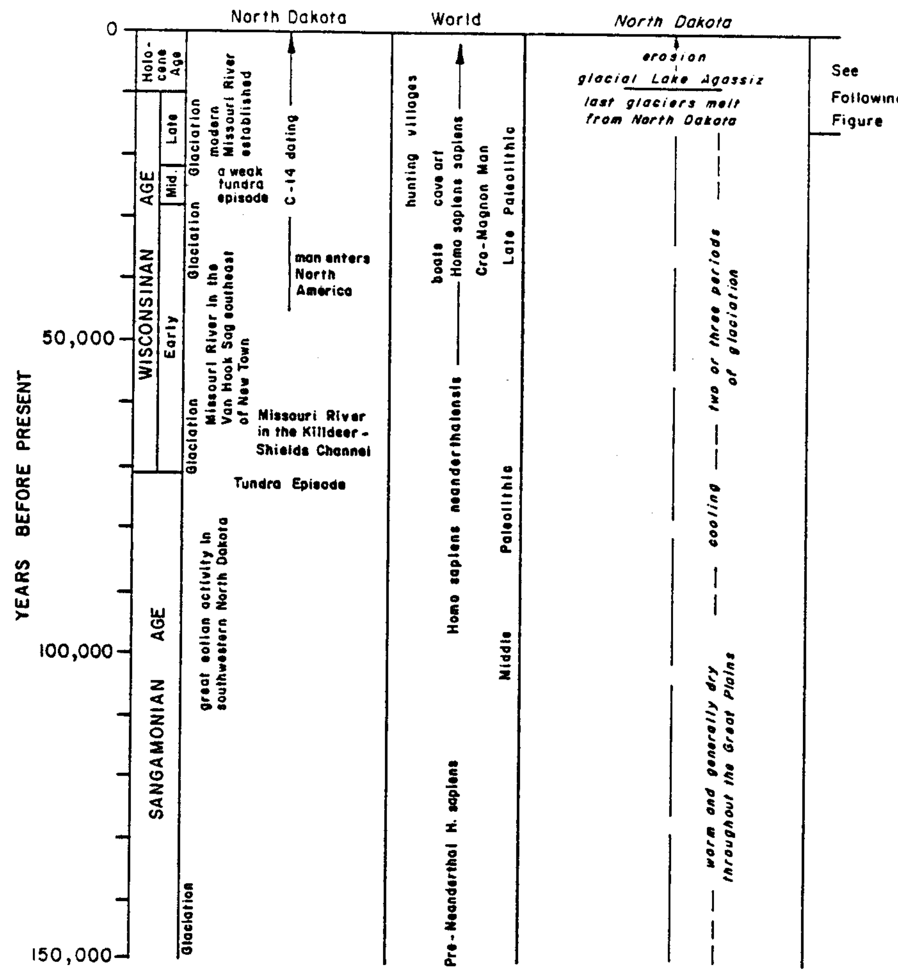

Figure 6. The last 150,000 years of the Earth's history.

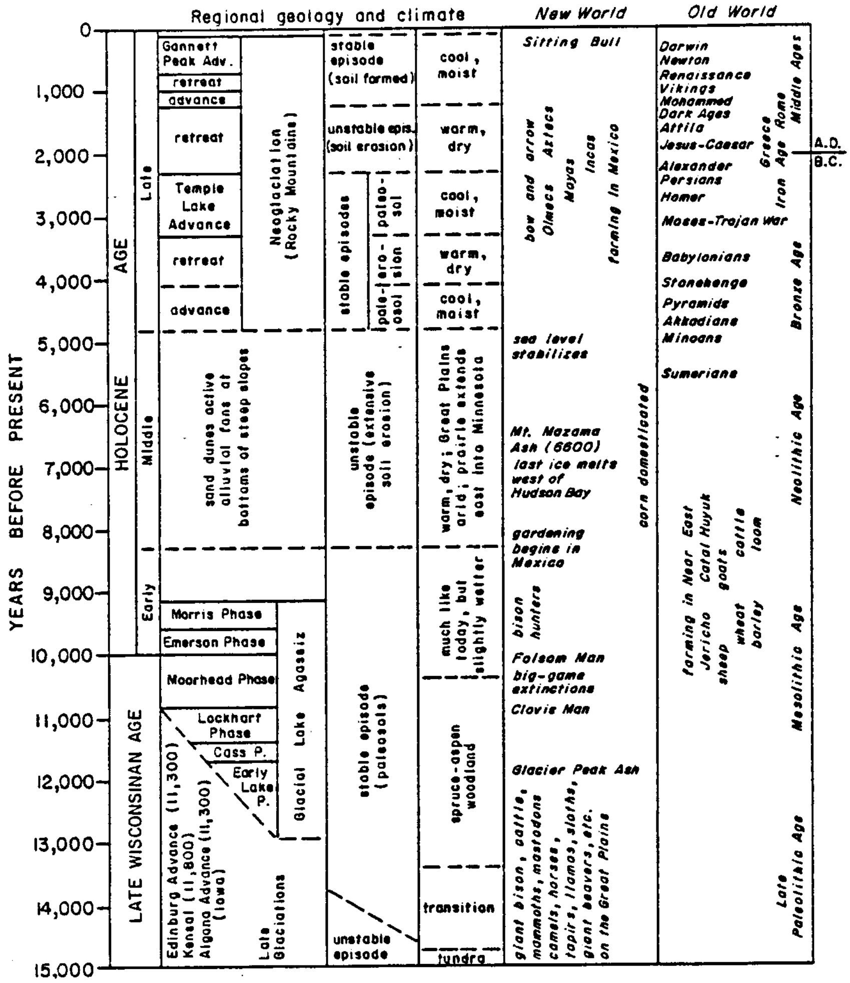

Figure 7. The last 15,000 years of the Earth's history.

NEW RULES ADOPTED TO PROTECT PALEONTOLOGICAL RESOURCES ON STATE LANDS

--John Hoganson

North Dakota Century Code Chapter 54-17.3 (ratified during the last legislative session) gives the North Dakota Industrial Commission, acting through the office of the State Geologist, the responsibility to manage and protect significant paleontological resources located on land owned by the state of North Dakota or its political subdivisions. Previously, the State Historical Board had this responsibility. The legislation to accomplish the change was introduced by the Committee on Natural Resources at the request of the State Historical Board and the Geological Survey to allow for more efficient management of the state's fossil resources because of paleontological expertise available through the Geological Survey.

Prior to this change, fossils were categorized as cultural resources and were included under regulations designed primarily to protect Indian artifacts and other archeological materials. That is why the State Historical Board initially had the responsibility. In the early phase of development of the Survey's Fossil Studies Program, I proposed that the responsibility to manage and protect the state's fossil resources should be with the Geological Survey (paleontology is generally considered a subdiscipline of geology). In addition, fossils should be considered natural rather than cultural resources and one of the Geological Survey's primary missions is to identify, investigate and help manage our natural resources. The Historical Board also recognized a need for change because they did not have a paleontologist on their staff to effectively deal with issues pertaining to fossils. As a result, in 1984, the Geological Survey and Historical Board signed an agreement wherein the Survey would advise the Board on issues regarding the state's fossil resources and evaluate permit applications submitted to the Board for permission to collect fossils on state lands in North Dakota. It was eventually jointly decided by the Historical Board and Geological Survey to totally shift that responsibility to the Survey and that transition was accomplished during the last legislative session.

As a result of the law change, fossils were removed from under the umbrella of cultural resource protection and new rules were needed for effective management and protection of the resource. The Industrial Commission was given the authority to adopt rules and issue orders to effectuate the provisions of sections 54-17.3-01 through 54-17.3-08 of the new law (see page 39 for a copy of the law). As paleontologist for the Geological Survey, I was given the responsibility to formulate rules that would assure that the scientific and casual (hobby) collecting of fossils from state-owned lands in North Dakota is conducted under conditions that adequately protect and preserve those public lands and the significant paleontological resources found on them. These rules were also meant to provide a mechanism to monitor paleontological activities on state lands so that information gained about North Dakota's fossil resources from those areas could be incorporated into North Dakota's overall resource management plans.

The rules (Administrative Code Chapter 43-04--see below) that I proposed and that were eventually adopted by the Industrial Commission were formulated after soliciting opinions from all of the professional paleontologists in North Dakota, from the North Dakota Geological Society (professional geologists) and from the North Dakota Paleontological Society (hobbyist fossil collectors). In addition, I reviewed the laws of all other states and federal laws concerning regulation of fossil collecting on public lands. The official positions regarding fossil collecting on public lands of the international societies of professional paleontologists, the Society of Vertebrate Paleontologists and the Paleontological Society, were also taken into consideration. As expected, a wide spectrum of thought concerning regulation of fossil collecting by resource management agencies was collectively expressed by these sources. I believe that there is enough flexibility in the new rules (see below) to accommodate both the professional and serious hobbyist fossil collectors and still allow effective management of the resource. I would like to take this opportunity to thank all of you who took time to provide your insights on this issue and I invite additional comments from anyone who would like to express them.

CHAPTER 54-17.3

PALEONTOLOGICAL RESOURCE PROTECTION

54-17.3-01. Definitions. As used in sections 54-17.3-01 through 54-17.3-08, unless the context otherwise requires:

1. "Commission" means the North Dakota industrial commission.
2. "Paleontological resource" means any significant remains, trace, or imprint of a plant or animal that has been preserved by natural causes in earth materials and the localities in which they are found.

Source: S.L. 1989, ch. 645, § 1.

Effective Date.
The act which added this chapter became effective July 6, 1989, 90 days after filing, pursuant to N.D. Const., Art. IV, § 13.

54-17.3-02. Jurisdiction of the commission. The commission, acting through the office of the state geologist, has jurisdiction and authority to enforce the provisions of sections 54-17.3-01 through 54-17.3-08. The commission has authority to make such investigations as it deems proper to determine whether facts exist which justify action by the commission. The commission has authority to adopt rules and issue orders to effectuate the provisions of sections 54-17.3-01 through 54-17.3-08.

Source: S.L. 1989, ch. 645, § 2.

54-17.3-03. Permit required. A permit must be obtained by any person, organization, institution, or company engaged on one's own behalf or on behalf of another to:

1. Identify or evaluate paleontological resources to satisfy state or federal requirements; or
2. Investigate, excavate, collect, or otherwise record paleontological resources on land owned by the state or its political subdivisions.

A permit may be issued upon filing of an application that contains information prescribed by the state geologist and upon the applicant's payment to the state geologist of the fee set by the state geologist. The state geologist may waive the fee requirement if the applicant is an instrumentality of the state. A permit may be issued only for the activities and at the locations described in the permit application.

Source: S.L. 1989, ch. 645, § 3.

54-17.3-04. Permit — Duration — Revocation. A permit issued under sections 54-17.3-01 through 54-17.3-08 expires on December thirty-first of the year in which it is issued. A permit may be extended upon written request to the state geologist before expiration of the permit and upon payment to the state geologist of the fee set by the state geologist. A permit may be revoked at any time if it appears the permittee secured the permit through false information or that any activities performed by the permittee are being conducted negligently or improperly, or without regard for the careful preservation and conservation of the paleontological resource.

Source: S.L. 1989, ch. 645, § 4.

54-17.3-05. Coordination of quaternary fossil finds. The state geologist shall notify the superintendent of the state historical board of all quaternary paleontological finds reported to the state geologist which potentially or actually contain cultural resources. The treatment of sites containing both paleontological remains and cultural resources will be handled in a manner jointly agreed upon by the state geologist and the superintendent. The term cultural resources has the same definition as the term is defined in section 55-03-00.1.

Source: S.L. 1989, ch. 645, § 5.

54-17.3-06. Protection of paleontological specimens and sites. Any paleontological resource found or located upon any land owned by the state or its political subdivisions may not be destroyed, defaced, altered, removed, or otherwise disposed of in any manner without approval of the state geologist. The state geologist shall determine the significance of the paleontological resource to the understanding of the paleontologic and geologic history of North Dakota. It is the responsibility of the state and its political subdivisions to cooperate with the state geologist in identifying and implementing any reasonable alternative to destruction or alteration of any paleontological resource.

Source: S.L. 1989, ch. 645, § 6.

54-17.3-07. Transfer of paleontological resources. The state geologist may exchange with or transfer to universities, colleges, governmental bodies, and scientific institutions duplicate paleontological resources it holds. The state historical board must receive preference for the receipt of duplicate paleontological resources.

Source: S.L. 1989, ch. 645, § 7.

54-17.3-08. Violation of sections 54-17.3-01 through 54-17.3-08 — Penalty. Any person violating any provision of sections 54-17.3-01 through 54-17.3-08 is guilty of a class B misdemeanor and shall forfeit to the state all paleontological specimens discovered by the violator at that site. Any such violation is considered to have been committed in the county where the exploration, collecting, or excavation for paleontological resources was undertaken.

Source: S.L. 1989, ch. 645, § 8.

ARTICLE 43-04

GEOLOGICAL SURVEY PALEONTOLOGICAL RESOURCE PROTECTION

CHAPTER 43-04-01
DEFINITIONS

43-04-01-01. Definitions.

1. "Large scale excavation permit" is a permit issued by the state geologist that allows large scale excavation or quarrying of paleontological resources (excavations that disturb a surface area of more than eighteen square feet [1.67 square meters] of material).

2. "Minimum excavation and surface collecting permit" is a permit issued by the state geologist that allows the collection of paleontological resources found at the surface or removal of specimens with hand tools without extensive excavation.

3. "Modified minimum excavation and surface collecting permit" is a permit issued by the state geologist to amateur collectors that allows collection only of paleontological resources that have completely weathered out of the rock or sediment.

4. "Paleontological resource" must be defined as in North Dakota Century Code section 54-17.3-01.

   a. Vertebrate fossils and the localities in which they are found are assumed to be paleontological resources unless they are determined not to be significant by the state geologist (bison remains would generally not be considered significant except when found in cultural context).

   b. Invertebrate, plant and trace fossils and the localities in which they are found are not considered paleontological resources unless they are determined to be significant by the state geologist (sites of unusually fine preservation and type localities, the places from which the first specimens of new fossil species were described would generally be considered paleontological resources).

History: Effective October 1, 1990.
General Authority: NDCC 28-32-02
Law Implemented: NDCC 54-17.3-03

CHAPTER 43-04-02
PERMIT PROGRAM

43-04-02-01. Qualifications of applicants. Permits will be issued only to applicants who can demonstrate that they are qualified and have experience in conducting those activities. The general standards for a qualified applicant will be determined by the state geologist.

History: Effective October 1, 1990.
General Authority: NDCC 28-32-02
Law Implemented: NDCC 54-17.3-03, 54-17.3-06

43-04-02-02. Procedure of application. Anyone wishing to collect paleontological resources on lands owned by the state or any of its political subdivisions must obtain a paleontological collecting permit. Whether or not a permit is required, the state geologist shall be contacted prior to paleontological mapping or collecting of fossils other than those defined as paleontological resources on lands owned by the state or its political subdivisions. Fossils found during those activities that are believed to be paleontological resources shall be reported to the state geologist.

Commercial collecting of paleontological resources from lands owned by the state or its political subdivisions is prohibited.

1. Information required on the permit application (available from the state geologist) is determined by the state geologist and may include, but is not limited to, the following:

   a. Name, mailing address, and telephone number of the applicant.

   b. Information to evaluate the qualifications of the applicant including a resume.

   c. Type of permit requested (modified minimum excavation and surface collecting permit, minimum excavation and surface collecting permit, or large scale excavation permit).

   d. Purpose of the proposed activity.

e. Location of the proposed activity.

f. Date (start and end of the proposed activity).

g. Names and affiliations of other individuals that will be involved in the proposed activity.

2. No permit processing fee will be charged.

3. The state geologist will review and respond to the permit application within thirty days after all the application materials have been submitted.

History: Effective October 1, 1990.
General Authority: NDCC 28-32-02
Law Implemented: NDCC 54-17.3-03, 54-17.3-06

43-04-02-03. Requirements for permitholders. Requirements for permitholders are to be determined by the state geologist and must include, but not be limited to, the following:

1. Permits will be effective until December thirty-first of the year in which they are issued.

2. Permits will generally be issued for paleontological activities in geographically restricted areas. Individuals affiliated with North Dakota institutions may obtain a statewide permit. The names of students or field assistants under supervision of these statewide permitholders must be reported to the state geologist.

3. All paleontological resources collected from state-owned lands remain the property of North Dakota.

a. Permitholders not affiliated with a North Dakota institution must return to the geological survey a representative sample of the paleontological resources collected after an appropriate period of study.

b. What constitutes a representative sample and an appropriate period of study will be determined upon proposal and request by the collector at the end of the field activity and approved by the state geologist.

c. The representative sample is to be permanently reposited in the state fossil collection or, if preferred by the collector, into the paleontological collection of one of North Dakota's universities.

d. Remaining specimens must be deposited in a suitable repository, presumably the institution where the permitholder is affiliated, where they will be available for study and public display.

e. North Dakota resident permitholders affiliated with state institutions having a paleontological collection will be expected to curate specimens into that collection but, if they so desire, can deposit the specimens with the North Dakota geological survey for curation into the state fossil collection.

4. Upon termination of field activity or expiration or revocation of the permit, the permittee shall restore the site (remove all collecting equipment, fill in excavations, and so forth).

5. The state geologist may revoke the permit at any time if it appears that the circumstances warranting revocation as stated in North Dakota Century Code section 54-17.3-04 exist.

6. The permitholder will not be released from the requirements of the permit until all the outstanding obligations of the permit have been satisfied even if the term of the permit has expired.

7. The state geologist or the state geologist's representative has the right to visit the permit area at any time and inspect all paleontological resources collected under the permit.

8. A paleontological resource site record form, supplied by the state geologist, must be filled out for each fossil site identified.

9. Six months after the termination date of the permit, a final report, containing at least the following information must be submitted to the state geologist:

a. Paleontolgical collecting permit number.

b. Names and affiliations of all individuals involved with the permitted activity.

c. Discussion of the purpose of the activity.

d. Description of the area where the activity took place, including the plotting of site locations on 1:24,000 United States geological survey topographic maps.

e. Methods employed during the activity.

f. Preexcavation and postexcavation photographs of the site in the case of large-scale excavation permits.

g. Discussion of the results of the activity.

h. Description of the paleontological resources collected during the activity. This includes specimen accession or catalog numbers or both.

i. All paleontological resource site record forms.

10. A copy of all publications, such as journal publications or reports, resulting from the activity conducted under the permit must be submitted to the state geologist.

11. Upon request, copies of all field notes and other data relating to the permitted activity must be made available to the state geologist.

History: Effective October 1, 1990.
General Authority: NDCC 28-32-02
Law Implemented: NDCC 54-17.3-03, 54-17.3-06

COMMENTS

Do you have questions, comments, or suggestions regarding the Newsletter, Oil and Gas Division services or North Dakota Geological Survey services? For additional information on any of the items mentioned in this Newsletter, please contact North Dakota Geological Survey, 1022 East Divide, Bismarck, ND 58501, (701) 224-4109.

CHECKLIST FOR NEW PUBLICATION

_______MS-74 ($3.00)	Oil Exploration and Development in the North Dakota Williston Basin: 1988-1989 Update

ADDRESS CORRECTION

( ) Please correct the address to read as follows:

Name ____

Address ____

______________________________ Zip Code______________

*** **My previous address was - Please include code number from upper right hand corner of mailing label:**

Name_________________________ Number on Label:__________

Address ____

______________________________ Zip Code______________

( ) Please add the following to your Newsletter mailing list:

Name ____

Address ____

______________________________ Zip Code______________

( ) Please remove the address shown on the label of this Newsletter from the mailing list. (Enclose label or current address - Please include code number from upper right hand corner of mailing label.)

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