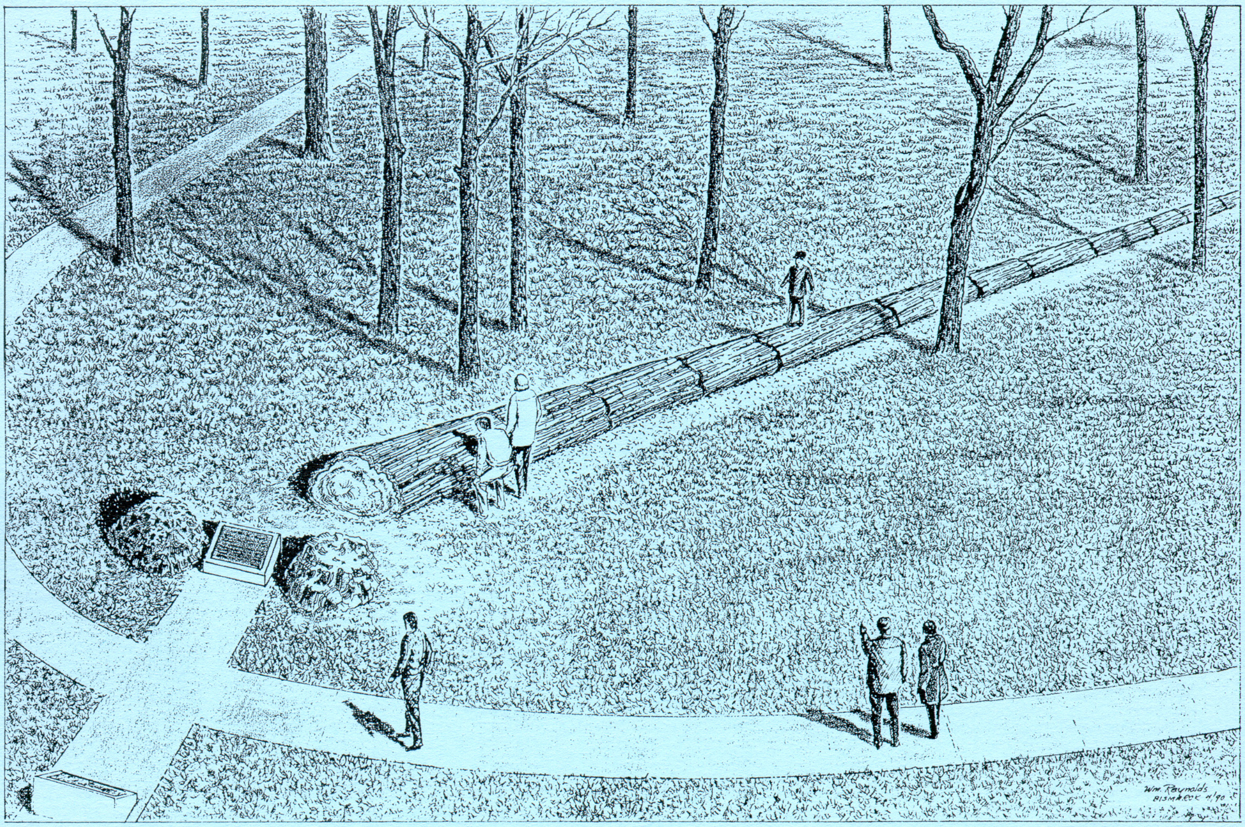
NEWSLETTER

NDGS

John P. Bluemle, Editor



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CONTENTS

COVER PHOTO

Low water levels of Lake Sakakawea have exposed several well preserved Paleocene age (about 57 million years old) petrified logs of probably the dawn redwood Metasequoia. The Central Gem and Mineral Society and several other sponsoring groups have received permission from the State Capitol Grounds Planning Commission to display one of the logs along the Arboretum Trail near the present location of the petrified tree stumps. Depiction by artist William Reynolds of Bismarck visualizes the exhibit in this drawing.

CURRENT SURVEY ACTIVITIES

--**John Bluemle**

Our geologists are involved in a variety of projects. **Sid Anderson**, who is Acting State Geologist, has been attending a number of meetings across the country. Sid was North Dakota's official delegate to the American Association of Petroleum Geologists (AAPG) annual meeting in San Francisco, where he chaired the meeting of the Core and Sample Preservation Committee. The San Francisco AAPG meeting marks the first time the Core and Sample Preservation Committee was given a booth in which to display core. By displaying core, as well as by other means, the Committee hopes to encourage individuals and companies to preserve cores and samples. Preservation of these materials is of the utmost importance in developing future exploration and also for enhanced recovery.

At the 82nd annual meeting of the Association of American State Geologists (AASG) in Madison, Wisconsin, the State Geologists were briefed on a number of federal and other programs that the various state geological surveys may be participating in, either now or in the future. Some of these include: the National Geologic Mapping Program, Oil & Gas Assessment Program, Radon Program, COCORP (see article in this Newsletter), and Clean Air and Clean Water Programs. The AASG meeting also allowed state and federal people to renew acquaintances and to discuss goals and problems common to the state surveys.

Sid was in Albuquerque on May 4, attending a meeting sponsored by the Department of Energy. The purpose was to focus on a new Fossil Energy Federal/State Partnership Program designed to share costs on a 50/50 basis between the states and federal government. Priorities are in the areas of oil, gas, and coal, with the focus on obtaining as much oil and gas as possible from existing reservoirs and on the utilization of coal, including new uses and aggrading existing uses, in an environmentally safe manner.

Tom Heck is working on an update of oil and gas activity, a report we publish every two years. The upcoming issue will cover 1988 and 1989 and should be available this fall. Tom is also finishing an appraisal of Forest Service lands to better enable them to determine which land to lease for drilling. The results of the study will be available as an open-file report from our office, and also from the Forest Service office in Billings, hopefully in August. Tom has been working with Randy Burke on some Devonian cross sections; these are nearly finished. He has been picking tops on logs of wells in the salt-solution area of north-central North Dakota and he hopes to update Sid Anderson's 1966 paper on that area. During his study, Tom plans to investigate the Devonian through the Triassic section.

Mark Luther has been devoting much of his time to setting up the Survey's topographic maps sales system. We are now in the map sales business (see article in this newsletter). In conjunction with this, Mark was in Rolla, Missouri in March to familiarize himself with the capabilities and products we can now offer as an ESIC (Earth Science Information Center) affiliate.

Much of Mark's field work has involved helping archaeologists around the state. He directed a drilling and coring project along the proposed route of a pipeline planned to be built through Fort Lincoln

State Park. The purpose was to provide stratigraphic data for the area and look for buried cultural deposits. This project was initiated by a request from the State Historical Society and the North Dakota National Guard. At the request of the Bureau of Reclamation and North Dakota Parks and Recreation, Mark helped determine the integrity of cultural deposits in Grahams Island State Park at Devils Lake. Mark continues as a member of the North Dakota Water Quality Task Force for Nonpoint Source Pollution. His main activity on the task force has been to provide input for the development of the Barnes County abandoned-well pilot project (see article elsewhere in this newsletter). Mark (along with Ed Murphy and Russ Prange) took cores and water samples near Denbigh in McHenry County, looking for Tordon and 2-4D. Mark is currently mapping in northeastern North Dakota, working on the Atlas Sheet for that part of the state.

Ed Murphy is in the process of wrapping up two three-year groundwater studies: the first is of groundwater quality at selected landfills in the state, and the second is of the movement of pesticides in shallow groundwater. Ed (along with John Hoganson) is currently in his fourth year of fieldwork on our COGEOMAP project (see article in this newsletter). If funding from the USGS continues, this mapping project will continue for another seven years. Recently, Ed finished drafting proposed rule changes to the state's geothermal program, which is regulated by the geological survey. Ed is overseeing the closure and site clean-up of the AKZO salt plant in Williston. The plant produced salt from the Devonian Prairie Formation for about 30 years. The NDGS has jurisdiction over the plant as part of our Subsurface Minerals Program and the Class III Underground Injection Control Program.

John Hoganson, the survey's paleontologist, is involved in a number of projects, most of them having to do with the state's fossil resources. He is working on three projects with Alan Cvancara (geology professor at the University of North Dakota), one on fossil fishes from the Cannonball Formation, another on fossil mollusks from the Alkali Creek Archeological Site in Dunn County, and a third on Cretaceous shark fossils in North Dakota. John is working with Allan Ashworth (geology professor at North Dakota State University) on the use of fossil beetles to determine Quaternary climatic changes.

Some of John's other projects include his continued development of the State Fossil Collection; his work with the Heritage Center, developing a display of North Dakota fossils to be exhibited starting in October, 1990; and his work with the State Parks and Recreation Department on placement of fossil sites on the State's Registry of Natural Areas (the Obritsch Ranch ceremony was held on May 16, 1990). John continues to evaluate oil and gas lease tracts for potential impact on paleontological resources and he is working on a Memorandum of Understanding with the Corps of Engineers for cooperation in managing paleontological resources on Corps lands in North Dakota. John has drafted proposed rules for fossil collecting on state lands. During the past six months, John was co-author on four technical articles: "Vertebrate Fauna of the Cannonball Sea: The Last (Paleocene) Transgression into Central North America," "Fossil Beetle Analysis: Monte Verde -- A Late Pleistocene Settlement in Chile," "Late Pleistocene (Illinoian?) Molluscs from the Loraff Farm Site near Milbank, Northeastern South Dakota," and "Glacial/Interglacial Change and Biodiversity." Finally, John is acting as technical advisor on a project to place a large petrified log on the state capitol grounds (see cover picture and article in this newsletter).

Randy Burke is continuing his work on Devonian System electric-log cross sections. He is mapping the Ratcliffe Formation in parts of Burke and Ward Counties. Randy is working on a report on the Geology of the Duperow Formation in southwestern North Dakota. He recently had a paper accepted, which he will present at the American Association of Petroleum Geologists Rocky Mountain Section meeting in Denver in September. The paper is titled "Porosity Development in Evaporite Dissolution Breccia." In February, Randy spoke to the Saskatchewan Geological Society and also at the University of Regina. The topics were "Lower Devonian Formation, southwestern North Dakota: depositional environments and modern analogs" (to the Society) and "Reefs to mounds: a sedimentologic and semantic continuum requiring a dynamic classification" (at the University).

Since the first of the year, **John Bluemle** has written two articles, one with Mark Lord and Nate Hunke on the Hogback Ridge and the other on glaciotectonic features; both of these are being submitted to geologic journals for publication. He has worked with several groups of teachers (for the UND Center for Teaching and Learning--see article in this newsletter--and for the Game and Fish Department's Project WILD), talking to them about North Dakota geology and helping familiarize them with their local geology so that they can better take their own students on field trips. He gave several talks on North Dakota geology, in Bismarck, Fargo, and Devils Lake. John also wrote nontechnical articles on the Turtle Mountains and (with Ed Murphy) on Theodore Roosevelt National Park. John attended the Montana Geological Society Bakken Symposium in Billings in March. During times when Sid Anderson has been out of town, John has filled in as director of the NDGS.

Finally, for those of you who haven't yet stopped by our offices in Bismarck, I've included a picture of the building we share with the Oil and Gas Division at 1022 East Divide Avenue. We are located just northwest of the capitol grounds. Use the door on the north side of the building. And again, to clarify, our location is 1022 East Divide; our mailing address is 600 East Boulevard Avenue. And you can call us at 701-224-4109 (the geological survey) or 701-224-2969 (the oil and gas division).

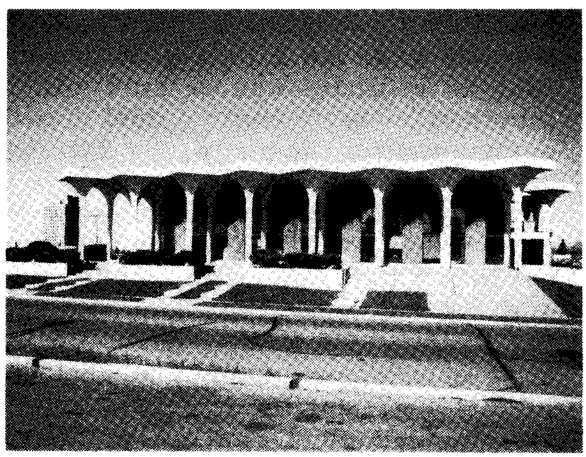

Figure 1. Geological Survey and Oil & Gas Division offices are located in this building at 1022 East Divide Avenue, just northwest of the Capitol. Entrance to the building is on the north side.

A CHANGING FOCUS FOR THE GEOLOGICAL SURVEY

--John Bluemle

Historically, the mission of nearly all of the state geological surveys has focused on developing the mineral resources of the states and serving the mineral industries. The enabling legislation for the North Dakota Geological Survey in 1895, for example, called for the Survey to investigate, "with a view to a complete account, the geology of North Dakota, which forms the framework for North Dakota's energy and mineral resources and natural environment." The survey was to "identify mineral resources and help to exploit them for the benefit of the state."

During the last 20 years or so, the services provided by the North Dakota Geological Survey have shifted gradually, but substantially from "exploiting the mineral resources" to what might loosely be called "environmental geology." More and more of our time is being devoted to providing information to solve a variety of environmental situations.

As part of the most recent Earth Day recognition, in April, Ed Murphy gave me a listing of projects that he recently was or currently is involved in that deal with environmental geology. Ed was noting the large number of environmental protecton projects the survey has undertaken (either alone or in cooperation with other state and federal agencies) since the first Earth Day, 20 years ago. I'll list some examples of cases he cited that involved requests of the North Dakota Geological Survey for help in solving environmental problems:

1) We conducted two studies of the effects of buried oil and gas drilling fluids on groundwater. These were the first detailed studies of their kind in the United States, dealing with the land disposal of oil and gas drilling fluids. Our first study was in the badlands and the second in north-central North Dakota. Both of these studies concluded that, while drilling fluid is not necessarily a hazardous waste, its improper disposal can cause significant contamination to the surrounding groundwater. The results of the studies have been widely used to improve disposal practices in North Dakota as well as in other parts of the United States.

2) We've studied the environmental effects of reclaiming abandoned surface lignite mines in North Dakota. In this study we investigated groundwater quality in and around four unreclaimed mines and determined what the effects would be to the groundwater if the sites were reclaimed. We concluded that the reclamation (or the leveling) of the spoil piles at some of the old mines scattered across the western part of the state would degrade the groundwater in those areas. These sites currently offer cover to wildlife and, in addition, no topsoil was stockpiled when the lignite was mined. We recommended that these old surface mines be left as they are.

3) In 1987 we began a study of contaminants within groundwater at six municipal landfills in North Dakota. We detected leachate (contaminated water) in the groundwater at distances up to 1000 feet from one of the landfills. The contaminated groundwater contains moderate to high increases in concentrations of the major ions (salts) and organic contaminants, and only slight increases in trace metal concentrations. The greatest threat to human health appears to be from organic compounds such as used oil, paint thinner, gasoline, etc.

A number of things need to be done in North Dakota to reduce the health risks imposed by landfills. New landfills must be sited in the proper geologic setting, well designed and operated correctly. The volume of waste going into these landfills should be reduced by the exclusion of yard wastes, household hazardous wastes, and the recycling of glass, paper, metal, etc.

4) In 1987 we began a three-year study of the concentrations of two herbicides (Tordon and 2,4-D) in groundwater in McHenry County. The study, which is targeted at an area of heavy leafy spurge infestation, has been hampered by the low moisture conditions during the past three years. However, concentrations of these herbicides, ranging from trace amounts up to extremely high levels, have been found in some of the groundwater samples. The results so far indicate that these herbicides may be flushed down and into the groundwater in areas with sandy soils and in places where the water table is within 25 feet of the surface.

In addition to the four examples I've just listed, I might add such things as the occurrence of radon gas, which is a geologic hazard in North Dakota. We have not been able to do the detailed studies we would like in order to enable us to better understand how this radioactive gas occurs in North Dakota's near-surface sediments. Questions and concerns like those I've just listed come to the attention of our geologists with increasing frequency. In addition to these kinds of requests for our services, we continue to get as many inquiries about mineral resources as we always have. We are also responding to a growing number of "educational" requests, from teachers, students, and public organizations asking for publications and other information, for speakers on North Dakota geology, field trip leaders, etc. Requests for such environmental and educational information now amount to about half of our service requests, with the remainder still largely mineral-resource requests.

The North Dakota Geological Survey is not alone in dealing with these burgeoning environmental and educational requests. All state surveys are faced with this trend. Although we welcome it, this changing demand for our services is alarming for two reasons. First, the large increase in requests for educational and environmental services is <u>not</u> cushioned by a decrease in requests for information about mineral resources. In fact, the <u>total</u> number of requests for studies and information is growing by leaps and bounds. Second, the time spent by survey geologists answering the requests cuts deeply into the time planned for geologic mapping and development of the basic geologic framework. As our basic mapping and study of the geologic framework suffer for lack of time and manpower, so will our environmental responses. Without complete and accurate geologic mapping, the survey's response to environmental requests cannot be complete and accurate.

The North Dakota Geological Survey, like other state agencies, is faced with serious budgetary problems and limited human resources. Even though requests for information have increased markedly, our professional staff has actually decreased, from a total of ten geologists and one engineer three years ago, to a current level of eight geologists. As noted, in view of growing environmental concerns, our agenda is rapidly changing, and greatly increased demands are being placed on our remaining geologists' time. We face a difficult dilemma.

Even so, we are determined to continue to provide the geologic information required by government officials and other state agencies. We need to provide the essential, basic geologic information desperately needed by our mineral industries, which are working hard to develop North Dakota's oil and gas and other mineral resources. But we must also provide the essential geologic information needed to make sound environmental decisions. In short, we are in a position of having to respond to more demands for information, studies of specific problems, and basic geologic data with less staff than we had several years ago. It isn't always easy.

OIL AND GAS ACTIVITY IN NORTH DAKOTA DURING 1989 --Tom Heck

Once every two years for the past 12 years, the NDGS has published a review of North Dakota's oil and gas activity as part of our Miscellaneous Series. We have also included a briefer annual review in this Newsletter. The summary of 1989 activity included here will be incorporated into our more inclusive report later this year.

During 1989, North Dakota's 3,558 oil wells produced a total of 36,737,516 barrels of oil for a daily average of 28.28 BOPD/well. This represents a 6.7% decline from 1988 total production.

Drilling activity also decreased during 1989 with 230 wells permitted and 188 eventually drilled. Wildcat well attempts also dropped, from 67 to 35, a 48% decrease. Essentially, 1989 activity matched 1986-1987 levels, the lowest in over a decade. A bright spot was the horizontal Bakken play, which is continuing to gather momentum. A total of 29 horizontal wells were completed in North Dakota in 1989. Of these, one was a wildcat well, two were extension wells, and the remainder were development wells. The leasing phase of 1988 and 1989 in the "Bakken Fairway" has changed to a drilling phase.

A total of 13 new pools were discovered during 1989. Half of these were Madison completions with the remainder split among the Bakken, Birdbear, Duperow, and Red River Formations. Table 1 lists discoveries recorded in 1989.

One landmark event occurred in 1989. On October 23, North Dakota's billionth barrel of crude oil was produced. Appropriately, the barrel came from the Clarence Iverson #1 well, the discovery well for oil in North Dakota. The event was celebrated in Williston.

TABLE 1. 1989 NEW POOLS

Pennzoil Exploration and Prod. Co.-Pennzoil-Depco Federal #1
#7535 Case # 4711 Order # 5426 Comp. 2/17/89
Bull Moose-Birdbear
Sec. 14, T147N, R101W IP 11 BO + 10 MCF + 125 BW

D. C. Dudley & Assoc.-Gjorven #14-21
#7712 Case # 4702 Order # 5416 Comp. 3/10/89
Brooklyn-Nesson
Sec. 21, T155N, R98W IP 85 BO + 95 MCF + 145 BW

Raymond T. Duncan-Rivers #1
#12085 Case # 4750 Order # 5473 Comp. 4/6/89
Dolphin-Nesson
Sec. 29, T161N, R95W IP 720 BO + 563 MCF

Home Petroleum Corp.-Van Eeckhout St. 21-16
#12625 Case # 4777 Order # 5535 Comp. 5/22/89
Plaza-Bluell
Sec. 16, T152N, R88W IP 272 BO + 112 MCF

Conoco Inc.-Ketterling 21 No. 1
#9860 Case # 4801 Order # 5538 Comp. 6/8/89
Dore-Madison
Sec. 21, T151N, R104W IP 7 BO + 10 BW

Comdisco Exploration Co.-Foster #1-32
#12030 Case # 4800 Order # 5537 Comp. 7/18/89
Todd-Nesson
Sec. 32, T154N, R101W IP 118 BO + 59 MCF + 5 BW

BWAB Inc.-Ibarra #11-13
#9083 Case # 4810 Order # 5573 Comp. 7/25/89
Garnet-Duperow
Sec. 11, T161N, R99W IP 256 BO + 100 MCF + 3BW

Wyoming Resources Corp.-Yellowstone #1
#12648 Case # 4811 Order # 5574 Comp. 7/29/89
Hay Creek-Duperow
Sec. 16, T150N, R104W IP 80 BO + 32 MCF + 42 BW

Meridian Oil Inc.-#43-7H MOI
#12619 Case # 4812 Order # 5620 Comp. 8/15/89
Four Eyes-Bakken
Sec. 7, T143N, R100W IP 49 BO + 47 MCF + 4 BW

Amerada Hess Corp.-McKeen #30-23
#12589 Case # 4832 Order # 5580 Comp. 9/11/89
Antelope Deep-Red River
Sec. 30, T153N, R94W IP 113 BO + 1452 MCF + 28 BW

DeKalb Energy Co.-#22-24 McCoy
#11893 Case # 4910 Order # 5684 Comp. 10/13/89
Temple-Bakken
Sec. 24, T159N, R99W IP 28 BO + 45 MCF +7 BW

JN Exploration & Prod. Co.-#43-17 Mau
#12771 Case #4924 Order #5703 Comp. 12/14/89
Culver-Bluell/Sherwood
Sec. 17, T160N, R86W IP 165 BO + 40 MCF + 3 BWPD

Meridian Oil Inc.-#31-33 MOI
#11847 Case # 4948 Order # 5734 Comp. 12/24/89
Hay Draw-Ratcliffe
Sec. 33, T147N, R102W IP 96 BO + 87 MCF + 125 BW

NORTH DAKOTA MINERAL INDUSTRY STATISTICS

--John Bluemle

[*Editor's Note: Most of the information on nonfuel resources included in this article was obtained from Mr. Leon E. Esparza of the U.S. Bureau of Mines*]. The previous article dealt with oil and gas activity in North Dakota during 1989. The 36.7 million barrels of crude oil produced in North Dakota during 1989 had a value of approximately $651 million and the value of natural gas (58.1 billion cubic feet was produced) was about $87 million, although due to market conditions, much of the gas could not be sold and was placed in storage. According to the North Dakota Lignite Council, the state had lignite coal production of 29 million short tons in 1989. Although it is difficult to place an accurate value on that amount of lignite--a value of $10 per ton has been suggested as a reasonable figure--about 18,000 North Dakotans are employed directly or indirectly by the coal industry so the importance of lignite to North Dakota cannot be overemphasized.

Although oil, gas, and lignite account for most of North Dakota's mineral production value, the state does have a small nonfuel mineral industry. The U.S. Bureau of Mines recently released statistics on nonfuel mineral production in North Dakota during 1989. The value of North Dakota's nonfuel mineral production was about $14 million in 1989, a decrease of about 27 percent from that of 1988 when it was $18.8 million. The decreased value is attributed largely to a drop of 27 percent in value of lime production and the 1988 termination of salt solution mining operations. North Dakota ranked 48th nationally in nonfuel mineral production, accounting for less than one percent of the U.S. total. Construction sand and gravel contributed the greatest amount to the State's nonfuel mineral value, accounting for 59 percent of the total. Other commodities produced, in order of decreasing value, included lime, crushed stone, clays, peat, and gem stones. Elemental sulfur was recovered from natural gas processing. Most of the State's nonfuel mineral production was used in construction.

The amount of construction sand and gravel produced in 1989 was down about 5 percent from 1988 levels, but value was essentially unchanged (please refer to Table 1). Crushed stone production remained at the level estimated for 1988, but value increased about 200 percent. Clay production and value were at the same levels reported in 1988.

In March, Lafarge Corp. acquired wholesale cement distributer Beyer Cement Co. Inc. of Valley City for an undisclosed price. Beyer will continue to operate under its own name. The wholesaler distributes cement in North Dakota through outlets in Bismarck, Grand Forks, Minot, Valley City, Wahpeton, and Williston. Beyer buys cement for resale from, among others, Lafarge and South Dakota cement.

Dakota Gasification Co., a subsidiary of Basin Electric Power Cooperative and owner of a coal gasification plant near Beulah, signed a 15-year contract in July to sell all the krypton and xenon produced at the plant to the Linde Division of Union Carbide Industrial Gases, Inc. The two chemical elements, byproducts of coal gasification, are used in manufacturing halogen and long-life bulbs.

TABLE 1. NONFUEL MINERAL PRODUCTION IN NORTH DAKOTA

Mineral	1987		1988		1989p/	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Clays -------------------- short tons --	50,101	$100	84,787	$147	84,787	$147
Gem stones ----------------------------	NA	2	NA	2	NA	2
Lime ------------ thousand short tons --	127	11,912	108	7,094	108	5,185
Sand and gravel (construction) --- do.--	e/4,900	e/10,200	3,772	8,079	3,600	8,100
Combined value of peat, salt (1987-88), sand and gravel (industrial, 1987), stone (crushed miscellaneous) --------	XX	4,097	XX	3,485	XX	320
Total------------------------------	XX	26,311	XX	18,807	XX	13,754

e/Estimated. p/Preliminary. NA Not available. XX Not applicable.
1/Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

According to information supplied by the State Soil Conservation Committee, a total of 29 surface mining operations were reported for 1989. Table 2 (adapted from the annual report of the Soil Conservation Committee), shows the total acres affected by surface mining (except lignite) and the total amounts of mineral commodities mined, in cubic yards. A total of 77 pits, ranging in size from .125 to 46 acres operated in the state during 1989.

TABLE 2. VOLUME OF SURFACE COMMODITIES MINED IN NORTH DAKOTA

1.	Acres affected:	277
2.	Commodities mined:	
	Gravel and sand	2,023,555 cubic yards
	Clinker	139,750 cubic yards
	Clay	64,992 cubic yards
	Rock	6,740 cubic yards

IOCC MEETS IN BISMARCK

--John Bluemle

The midyear meeting of the Interstate Oil Compact Commission (IOCC) was held in Bismarck, June 17-20, the first time in 19 years that the meeting has been held in North Dakota. The IOCC is made up of the Governors of the oil-producing states, plus representatives appointed by the Governors. North Dakota's representatives are Nicholas Spaeth, State Attorney General and Wes Norton, Director of the Oil and Gas Division. Governor Sinner is immediate past Chairman of the IOCC. The present Chairman is Governor Mike Sullivan of Wyoming. Between 300 and 400 people attended the meetings in Bismarck.

Keynote speaker at the General Session, held on Monday at the Bismarck Sheraton, was Paul J. Hoenmans, President of Mobil Oil's Exploration and Producing Division. Significant remarks were made by Governor George Sinner, immediate past Chairman of the IOCC and host Governor, and by Governor Mike Sullivan of Wyoming, current IOCC Chairman.

Robert Gentile, Assistant Secretary for Fossil Energy at the U.S. Department of Energy, spoke before the Energy Resources committee on Monday afternoon on "The Role of Fossil Energy in the National Energy Strategy." Mr. Gentile, in his remarks, explained that DOE is proposing to devote a large proportion of its funding to develop better reservoir knowledge and better recovery technologies. He stated that the IOCC can play an integral role in the technology transfer component of the DOE program. Mr. Gentile stated that he believes that the future of the U.S. oil industry will not be determined by how much new oil we find in this country, but by how creative we are in getting out what we have already found.

Other programs included R. Patrick Thompson of the New York Mercantile Exchange, before the Legal Committee; an update on the Alaska oil spill by C. M. Harrison, Executive Vice President of Exxon; the status of EOR (enhanced oil recovery) research, and a report on the alkaline-surfactant-polymer process before the Research Committee; presentations by Texas Railroad Commission Oil and Gas Interim Director David Garlick and Mitch Foushee of Senator Jeff Bingaman's staff before the Enhanced Recovery Committee; a program on the regulatory and operations aspects of horizontal drilling in the Regulatory Practices Committee; and a discussion of the MOA on wetlands permitting in the Public Land Committee.

A pre-meeting trip to the Great Plains synfuels plant and the Antelope Valley Station, both near Beulah, was held on Saturday, June 16. Social events included a reception at the Capitol on Sunday evening and a "Pitchfork Fondue" at Fort Lincoln State Park, featuring rides in antique cars to the restored Custer House on Monday evening. The outdoor fondue picnic ended just as the first drops of Bismarck's heaviest rain in years--an inch and a half--began falling.

COCORP DEEP PROFILING IN THE WILLISTON BASIN

--Sid Anderson

During the late summer and early fall of this year, a research group called the Consortium for Continental Reflection Profiling (COCORP) hopes to run a major deep seismic reflection survey across North Dakota and adjacent northeastern Montana (fig. 1). The intended route begins on Montana Route 13, approximately 17 miles south of Scoby, Montana, and extends due east from there to near the town of Barton in Pierce County, North Dakota.

COCORP is a geological research project involving earth scientists from a number of universities around the country. It is based at Cornell University in Ithaca, New York, and is funded by the U.S. National Science Foundation. Since the program began in 1975, COCORP has collected several thousand miles of deep seismic reflection data at sites throughout the United States. The data collected have added substantially to the store of basic scientific knowledge about the structure and composition of the crust of the earth.

COCORP's goal is to look deep into the crust, far beyond the depth where oil or natural gas could be economically produced. COCORP does not prospect for oil or other economic mineral deposits; their interest is purely scientific. Rather, the purpose of the COCORP survey is to study the structure of the crystalline crust and upper mantle beneath the Williston Basin.

The Williston Basin is an example of an "intracratonic basin," a broad, sediment-filled depression in the continental crust that formed slowly over a period of hundreds of millions of years. The Williston Basin began forming about 550 million years ago. It is

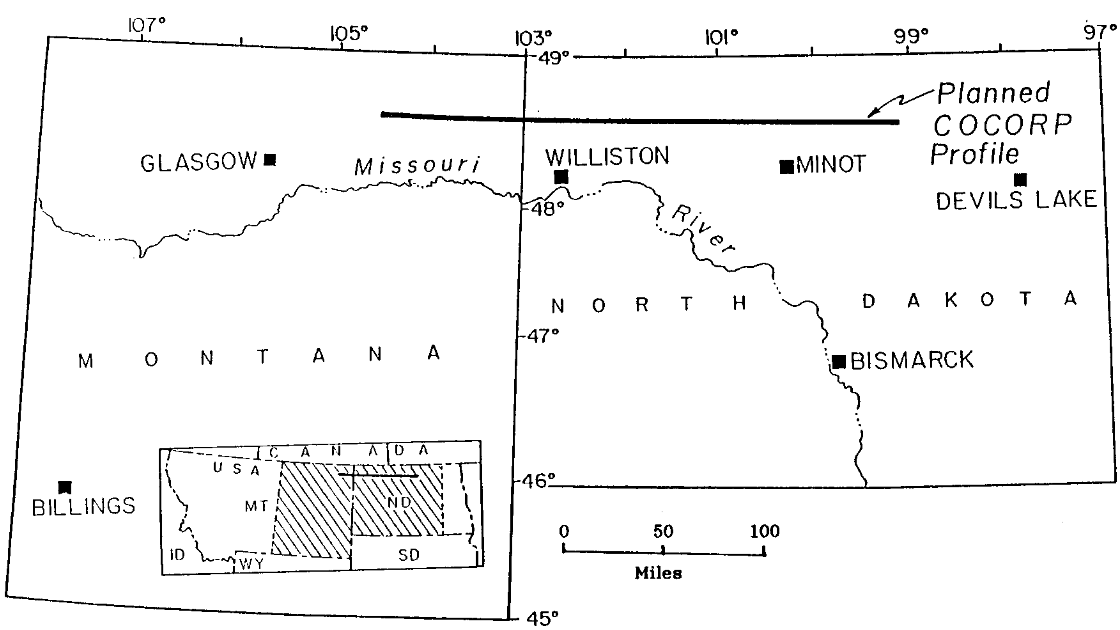

Figure 1. Map of part of North Dakota and Montana (see insert) showing the location of the planned COCORP seismic profile.

approximately 250 miles across and covers parts of western North Dakota, eastern Montana, northwestern South Dakota, southern Saskatchewan, and southwestern Manitoba. The thickest sediments in the Williston Basin occur near Watford City, where about 16,000 feet of sedimentary strata overlie the crystalline basement. These sedimentary strata contain North Dakota's oil and gas resources and, for this reason, they have been studied in detail--oil companies have drilled more than 10,000 holes in western North Dakota in search of hydrocarbons. Great amounts of data have been collected during the drilling of these holes: geophysical logs, rock samples, cores, and other information.

In contrast to the detailed information we have amassed on the oil-and-gas-bearing sediments, we have relatively little information about the crystalline crust that underlies the Williston Basin; in particular, the mechanism by which the basin actually formed is not really known. Various ideas have been proposed by geologists to explain the basin's origin: cooling (contraction) of a thermal anomaly in the continental lithosphere; a metamorphic phase change in the lower crust; localized stretching of the crust; and even extraterrestrial impact (a meteor). The main purpose of the COCORP survey is to gain information about the deep crust and upper part of the earth's mantle beneath a typical intracratonic basin, so existing theories can be evaluated and new ones developed.

Along with its primary aim, which I've just described, COCORP researchers also want to know more about the structure of the Early Proterozoic "Trans-Hudson" orogen ("Western Dakota Mobile Belt" on figure 2). The Trans-Hudson orogen is the remains of a mountain belt that formed about 1.8 billion years ago and extended through western North Dakota. It is a belt of deformed metamorphic and plutonic rocks. The Trans-Hudson orogen is exposed in northern Manitoba and Saskatchewan and, based on scattered drill hole penetrations and gravity and magnetic data, it is thought to extend southward in the subsurface, comprising part of or all of the crystalline crust beneath the Williston Basin in western North Dakota. Canadian geologists plan to collect a deep seismic profile across the exposed Trans-Hudson orogen this summer and COCORP researchers will be comparing results with them. Among other things, they want to find out whether mountain belts formed in Precambrian times had structures similar to those found in mountains formed more recently, such as the Alps or Rockies, and what, if any, effect the older Trans-Hudson crustal structure had on the formation of the Williston Basin.

COCORP uses an adaptation of the seismic reflection method used by the petroleum industry to search for oil and, as with all COCORP surveys, the data will be collected by a commercial seismic reflection crew (in this case Amoco Corp.) working under contract to Cornell University. The crew will employ vibroseis and a limited number of shot-hole detonations, and will record the echoes produced by these seismic sources on a 600-channel receiving array. The seismic data collected by the crew will be sent to Cornell University for initial processing and interpretation, after which it will be available to researchers throughout the country, as well as personnel at the North Dakota Geological Survey and Montana Bureau of Mines and Geology.

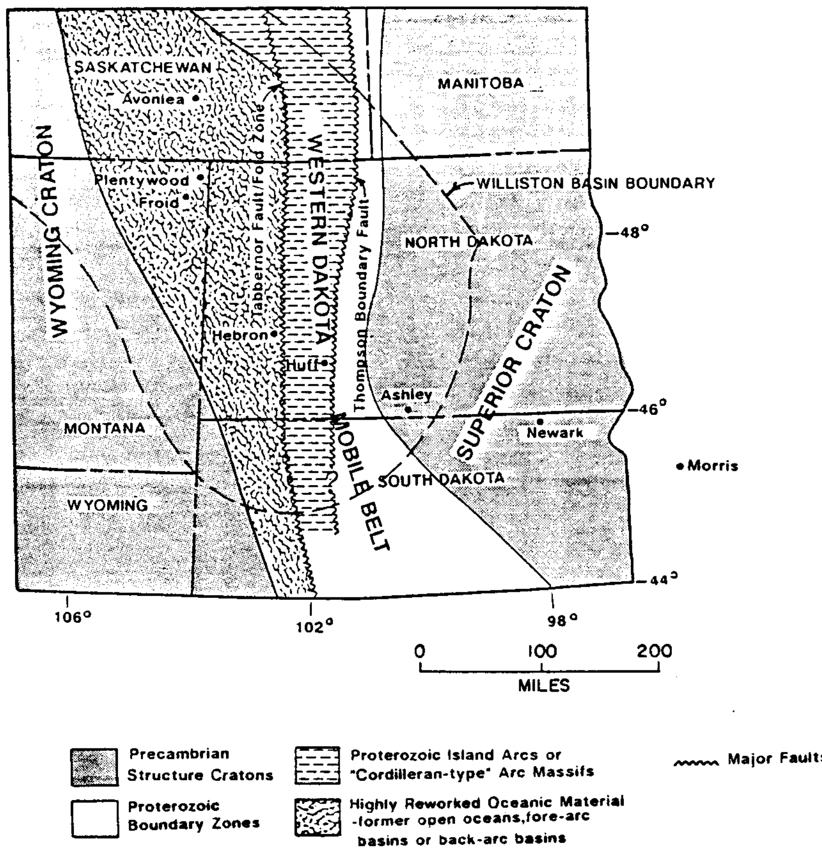

Figure 2. Structural geologic map of North Dakota and surrounding areas showing the outline of the Williston Basin and the Western Dakota Mobile Belt, or Trans Hudson Orogen.

THE INTERNATIONAL JOINT TRANSECT

--Sid Anderson

The International Joint Transect is a joint project of the United States Geological Survey and the Canadian Geological Survey with the cooperation of the state and provincial surveys.

The transect extends across North America from coast to coast and includes a strip of land 100 kilometres wide on either side of the border. The transect is part of a much larger Global Geoscience Transects Project. It is intended, along with other similar transects around the world, to increase our understanding of the structure and evolution of the earth's crust and provide us with knowledge of the relationship between mineral and hydrocarbon resources as they relate to crustal evolution, as well as aiding in the assessment of geologic hazards.

MANITOBA-NORTH DAKOTA CROSS SECTION

--Sid Anderson

The North Dakota Geological Survey and the Manitoba Department of Energy and Mines are cooperating on a geologic cross section that zig zags across the border. The reason for this is that, even though the geologic features and formations cross international and state borders indiscriminately, geologic information does not always flow freely across these same political boundaries. This often results in serious discrepancies that are known as "international boundary" or "state line" faults. The cross section that NDGS and Manitoba Mines Branch geologists are working on is an attempt to rectify this problem. The geologic formations often have different names on either side of these boundaries and they are sometimes picked at slightly different markers. We feel that a unified cross section will help geologists on both sides of the border to better understand the geology of the Williston Basin.

PETRIFIED LOG TO BE PERMANENTLY DISPLAYED ON STATE CAPITOL GROUNDS

--John Hoganson

Many interesting geologic sections and fossil sites are being exposed along the shore of Lake Sakakawea because of the low water levels. At one of these sites, Paleocene petrified logs, about 57 million years old, believed to be from the dawn redwood Metasequoia, are weathering out of the Bullion Creek Formation (figs. 1 and 2). These logs are not agatized like those found at Petrified Forest National Park in Arizona, but petrification is complete in many specimens and preservation is so exquisite that wood structures such as knotholes are preserved and annual growth rings are easily discernible. Although many large sections from several trees are exposed, one mostly intact log is 90 feet long. Some of the sections are

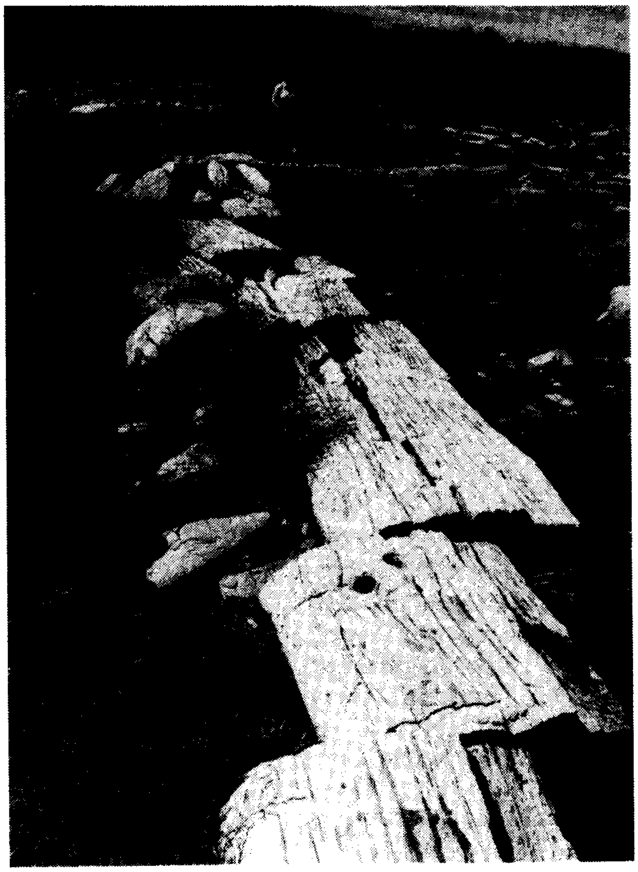

Figure 1. Long, petrified log that has broken and separated into several sections. This log is exposed along the shore of Lake Sakakawea in Mercer County.

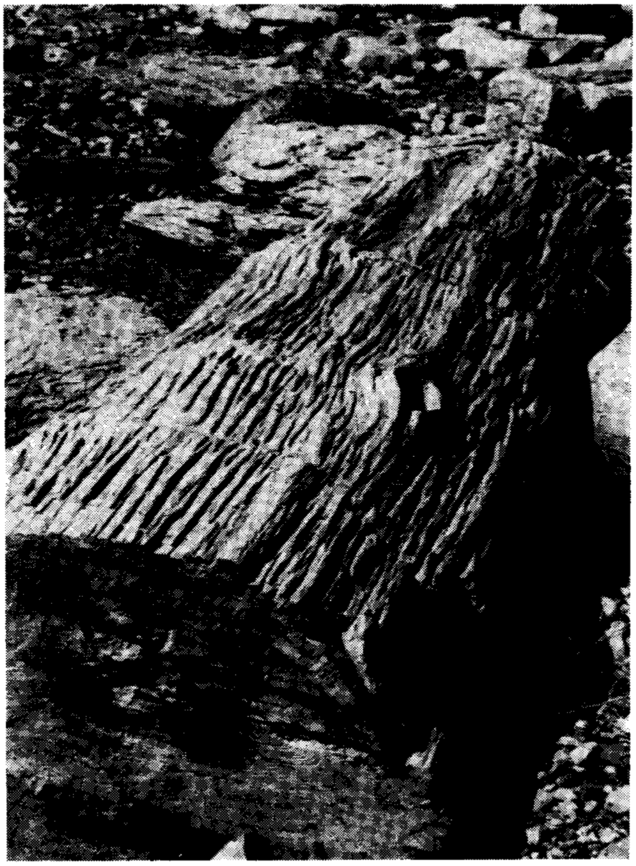

Figure 2. Section of a petrified log showing the structure of the outer surface and the annual rings on the cross section, a natural parting in the log.

6 to 8 feet in diameter. The only other fossils that have been found at the site are leaf imprints in mudstone.

The fossils were brought to our attention by Paul "Bud" Weiser of Hazen and E. L. "Buck" Worthington of Mandan, both deeply involved with forestry activities in their respective communities for many years. They and others have proposed moving several sections of one of these logs to Bismarck for permanent display on the state capitol grounds. On May 23, 1990, this project was formally proposed to the Capitol Grounds Planning Commission chaired by Lieutenant Governor Lloyd Omdahl. The principal sponsor of the project is the Central Dakota Gem and Mineral Society and Earl Campbell, treasurer of that society, made the formal proposal at the meeting. Because this project is entirely consistent with the Survey's directive to promote public awareness of North Dakota's paleontological resources, I attended the meeting to lend support and offer our advice regarding appropriate excavation and preservation procedures for the fossil specimens. The North Dakota Centennial Commission has endorsed the plan, and the North Dakota chapter of the Society of American Foresters, the North Dakota Nursery and Greenhouse Association, and the North Dakota Geological Society are also sponsoring the project. The Capitol Grounds Commission voted unanimously in support of the plan. The Corps of Engineers, on whose land the logs are located, is enthusiastic about the display and has consented to place the logs on permanent loan to the state.

Even though the specimens to be moved to Bismarck are in 4- to 8-foot-long sections, their excavation and transport will be no easy task. They are located in a fairly isolated area with no road access. The North Dakota National Guard has agreed to help as a summer engineering project. Their input will include building a short stretch of temporary road to the site, helping in excavation of the specimens, and transportation of the specimens to Bismarck. Additional help will be through volunteers, and I will be involved in a technical advisory capacity.

The log sections will be arranged as if the tree had just fallen (see cover of this newsletter) along the Arboretum Trail near the present location of the petrified tree stumps. An interpretive plaque will be placed with the stumps and tree. Relocation of the specimens will begin in late June or early July, and it is hoped that the display will be completed by fall, before the opening of the North Dakota fossil display at the Heritage Center.

IMPACT OF RECENT LEGISLATION ON THE GEOLOGICAL SURVEY'S FOSSIL STUDIES PROGRAM

--John Hoganson

Since its inception in 1983, the Geological Survey's Fossil Studies Program has evolved to include three primary objectives:

1. Conduct scientific investigations to determine the kinds of organisms that inhabited North Dakota at different times in the past and determine the types of environments and climates in which they lived.

2. Effectively manage North Dakota's paleontological resources, including:

   a. monitoring paleontological activities in North Dakota;

   b. identifying, mapping, and assessing the significance of fossil sites; and

   c. conserving and preserving significant fossil sites and specimens.

3. Promote awareness of the importance of North Dakota's paleontological resources through educational activities.

Two important bills that were passed during the last legislative session have a direct bearing on these objectives. This article summarizes my own thoughts on how changes in the law are affecting the program.

North Dakota Century Code, Chapter 54-17.4, reorganized the Survey and transferred responsibility for the agency from the Board of Higher Education to the Industrial Commission. This resulted in the relocation of the Survey from the campus at UND in Grand Forks to Bismarck. The transfer of authority for the Survey, from the

Board of Higher Education to the Industrial Commission, is having a positive effect on our Fossil Studies Program because of the Commission's interest in protecting North Dakota's fossil resources. Moving the Survey to Bismarck is having a mixed, but mainly positive, effect on the program.

In the area of paleontological resource management, the move has had a positive impact, primarily because we are now closer to most of the fossil-bearing formations. In addition, our goal of preserving significant fossil sites is being accomplished through a cooperative effort with the North Dakota Parks and Recreation Department and the Nature Conservancy. Both of these organizations are based in Bismarck and the Survey's move allows for more efficient interaction. Being located in the political center of the state is enhancing our paleontological resource protection effort because we now have more opportunities to communicate our concerns to state and federal legislators. Senator Kent Conrad, for example, has shown a keen interest in and concern for North Dakota's fossil resources. Because of Bismarck's central location, educational activities to promote public awareness of the importance of North Dakota's fossil resources will hopefully be more evenly distributed throughout the state. The Survey will be able to just as easily assist communities in the western part of the state develop exhibits of North Dakota fossils as it is for us to help communities in the east. In addition, we are currently working with the North Dakota Heritage Center staff on displays of North Dakota fossils to be exhibited at the Heritage Center beginning next fall. On the other hand, scientific investigations to learn more about North Dakota fossils will initially be somewhat hindered as a result of the Survey's move to Bismarck because we still have inadequate analytical equipment and geological library facilities. Access to these needs will be more difficult, but we are already developing a geological library in Bismarck. Hopefully, we will be able to obtain the analytical equipment we need.

North Dakota Century Code, Chapter 54-17.4, also specifically defines the Survey's mandate regarding fossils. That statute directs the Survey to conduct investigations designed to promote public understanding of North Dakota's natural (in this case paleontological) resources and to operate and maintain a public repository for North Dakota fossils. These activities were implied in the "old" Survey law, but are reaffirmed by the new legislation.

We are accomplishing our directive to operate and maintain a public repository for fossils in our offices here in Bismarck. The state fossil collection is growing rapidly, and we will need to either expand our present quarters or acquire space elsewhere to effectively preserve North Dakota fossil specimens. On May 4, 1990, I proposed to the State Historical Board that they and the Survey work cooperatively to develop the state fossil collection. This proposal calls for most of the state fossil collection and permanent displays of North Dakota fossils to be housed at the Heritage Center, but curated by the Survey. This could eventually entail expansion of the Heritage Center, rather than constructing a separate facility for fossils. I believe it is appropriate and logical that North Dakota fossils should be housed in the state museum along with other reflections of our heritage. A cooperative effort between the Heritage Center and

Geological Survey to display, house, and curate North Dakota fossils would be the most efficient way to manage the state fossil collection and, therefore, be in the best interest of the citizens of the state. Nine out of ten of the voting Historical Board members endorsed the proposal and the Board directed the Superintendent to work with the Survey to design a plan to accomplish that goal. I hope to be able to relate the particulars of that plan in the next NDGS Newsletter.

The authority to protect paleontological resources located on land owned by the state or its political subdivisions was transferred to the Industrial Commission, acting through the office of the state geologist, by legislation (NDCC 54-17.3) introduced by the Committee on Natural Resources at the request of the State Historical Board and the Geological Survey. The authority was transferred to allow for more efficient management of the state's fossil resources because paleontological expertise is 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. In 1984, the Survey signed a Memorandum of Agreement with the Historical Board to advise them on issues regarding fossils and to evaluate permit applications submitted to them for permission to collect fossils on state lands. However, at the request of the Historical Board and Geological Survey, it was decided during the last legislative session to totally shift that responsibility to the Survey. As a result of the change in the law, fossils are no longer protected as cultural resources and new rules are currently being finalized to assure effective management and protection of our state's fossil resources. I believe that this second change in the law will have a positive impact on our Fossil Studies Program as it places the state's fossil resources under the jurisdiction of the NDGS.

CURRENT STATUS OF THE COGEOMAP PROJECT

--Ed Murphy

We are continuing our third year of work on the Cooperative Mapping Program (COGEOMAP), funded partially by the United States Geological Survey, with the field studies being done by North Dakota Geological Survey personnel. In 1986, we projected that the total project could be completed in ten years with 2 to 3 years spent studying the Oligocene and Miocene section, 4 to 5 years on the Paleocene and Eocene, and 2 to 3 years on the Cretaceous.

We expect to complete the first phase of the project (Oligocene and Miocene) this year and, at the suggestion of the USGS, we have decided to proceed directly to the third phase of the study and address the Cretaceous/Tertiary boundary before working on the Paleocene and Eocene. It may not be possible to properly study the Cretaceous/Tertiary boundary within the initially proposed three-year time period. We will confer with USGS personnel this summer to determine the appropriate interaction and timetable for this phase of the program.

We are attempting to more

accurately define and correlate the Miocene and Oligocene sedimentary rocks in southwestern North Dakota. Our search for fossils on the isolated buttes in western North Dakota has been somewhat disappointing. The Miocene/Oligocene rocks are often only poorly exposed on the buttes, which makes fossil collecting difficult. To date, three volcanic ash layers have been identified and sampled and these are being processed for finger printing and possible dating. Two of these ash layers, in the Little Badlands of Stark County, had not previously been discovered. The third layer is in the Killdeer Mountains. This layer was studied in detail by Nels Forsman (NDGS Report of Investigation 87, 1986).

A drilling project was begun last summer to obtain additional information on these rock units in areas where they are poorly exposed. The Geological Survey's Mobil B-50 auger truck was used to core holes on the different buttes in western North Dakota (figures 1, 2, and 3). A total of 441 feet of core was recovered during last summer's program. We are planning to core an additional 8 to 10 holes under our COGEOMAP program this summer (fig. 3). We recently received funding from the USGS for the fourth year of the study. As noted above, once we have completed our work on the Oligocene and Miocene part of the section, we plan to investigate the Cretaceous/Tertiary boundary in North Dakota.

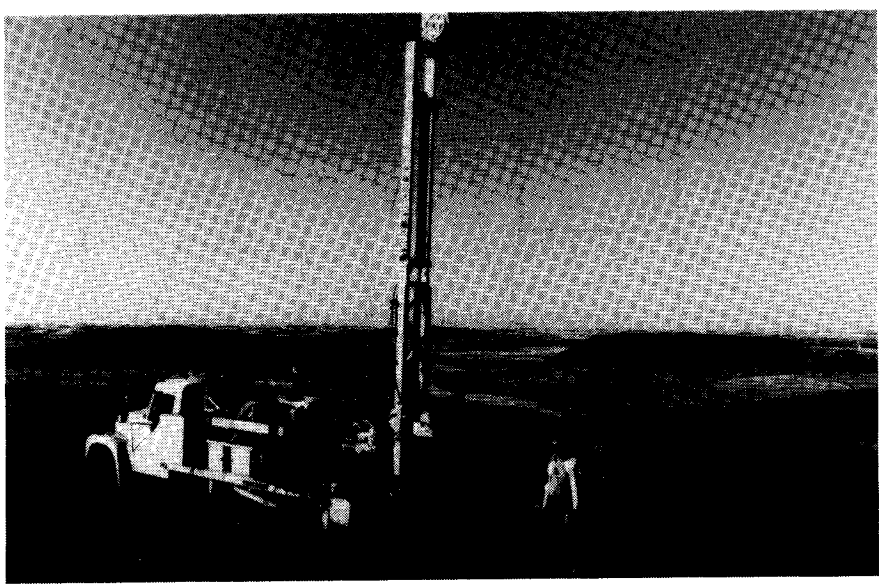

Figure 1. Coring on top of Davis Buttes, just east of Dickinson, Stark County. Dave Lechner (formerly with the NDGS) is in the foreground.

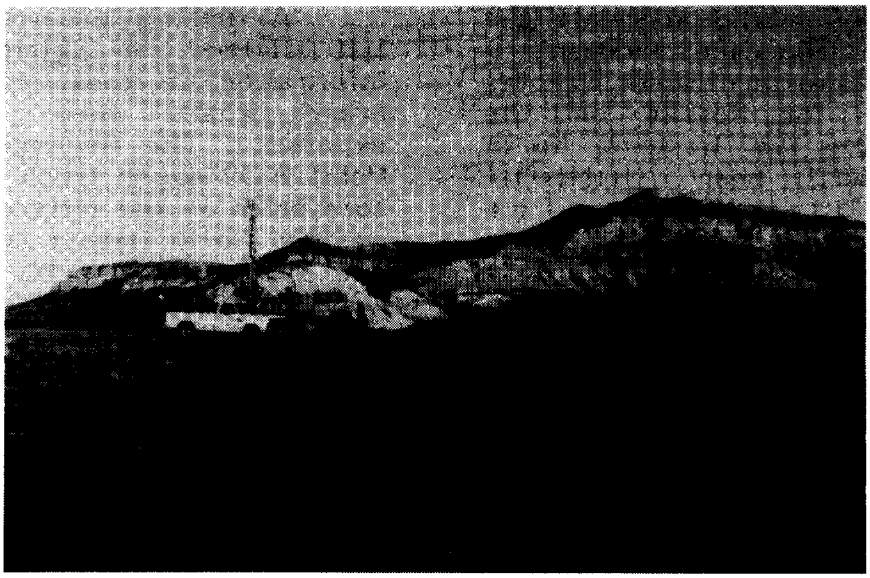

Figure 2. Coring a 90-foot hole at the base of a measured section at the Obritsch Ranch, Little Badlands, Stark County. Dr. Nels Forsman, a member of the COGEOMAP team is pictured.

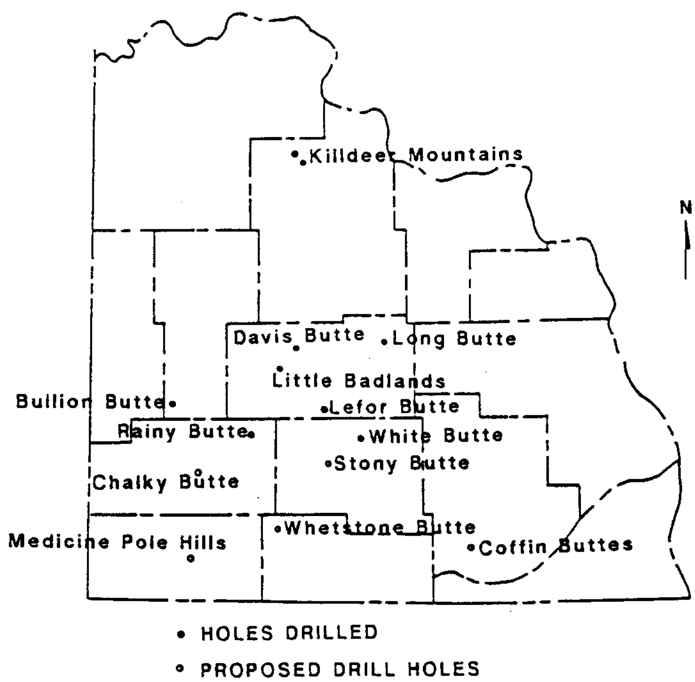

Figure 3. Location of holes drilled during 1989 and proposed for the 1990 drilling program for the COGEOMAP project.

FIELD GEOLOGY FOR TEACHERS

--John Bluemle

For several days early this summer, I had the opportunity to help as a resource person for the University of North Dakota's Center for Teaching and Learning, which has offered a course for North Dakota earth science teachers in various parts of the state. This year they offered the course twice, at Devils Lake and Bismarck, during June. The idea of the course is to help the teachers become more effective at teaching the earth sciences, mainly by introducing them to field methods and techniques they can use, both in the classroom and on field trips with their own students. In a state like North Dakota, with many small rural school districts, few earth science teachers have had significant college preparation in the field, and teaching is often textbook-based. In addition to geology, the teachers this year were introduced to methods of observing weather phenomena, basic meteorology, and ways to pass these observations on to their own students.

I've had the good fortune to participate in the course as a resource person a number of times over the past several years. My contribution usually consists of providing the teachers with a lecture on the geology of North Dakota and also taking the group on a field trip to show them the geology of their immediate area. After the teachers have gone on a geologic field trip, most of them feel more comfortable about taking their own classes of elementary students on similar field trips; a part of the requirement for the teachers, before they can receive credit for the course from the university, is that they take their students on a field trip they (the teachers) have designed themselves.

I like this approach at teacher training that the Center for Teaching and Learning is taking in these courses. When teachers become familiar with the geology of their own area, they are much more able and enthusiastic about teaching their own students about geology. Volcanoes and such things are fine and children like to learn about them, but they are usually much more interested in what they can see in their own back yard. At Devils Lake, for example, we took the teachers (all 14 of them were from the Devils Lake school system) along the shore of the lake to look at ancient beaches, up on Sully's Hill where they could better visualize (at least I hope they could!) the geologic processes that shaped that area, to a gravel pit in an esker, and to several other places (fig. 1). In Bismarck, we looked at old river-channel sands in the Cannonball Formation and collected fossils from exposures along the road north of Mandan.

Finally, near the end of the school year, in April or May, the same teachers will meet again as a group with their university instructors, to share the methods they used to teach earth science, and to report on the results of the field trips they led.

The methods the teachers have used in past years as they conducted their own field trips have varied greatly and some of them have been innovative. Two years ago, for example, one teacher's approach was to try to put the students in the position of a geologist. In preparation for their trip, students read textbook chapters on glaciation and studied the North Dakota Geological Survey roadlog for the sites they would visit. Each student had a map,

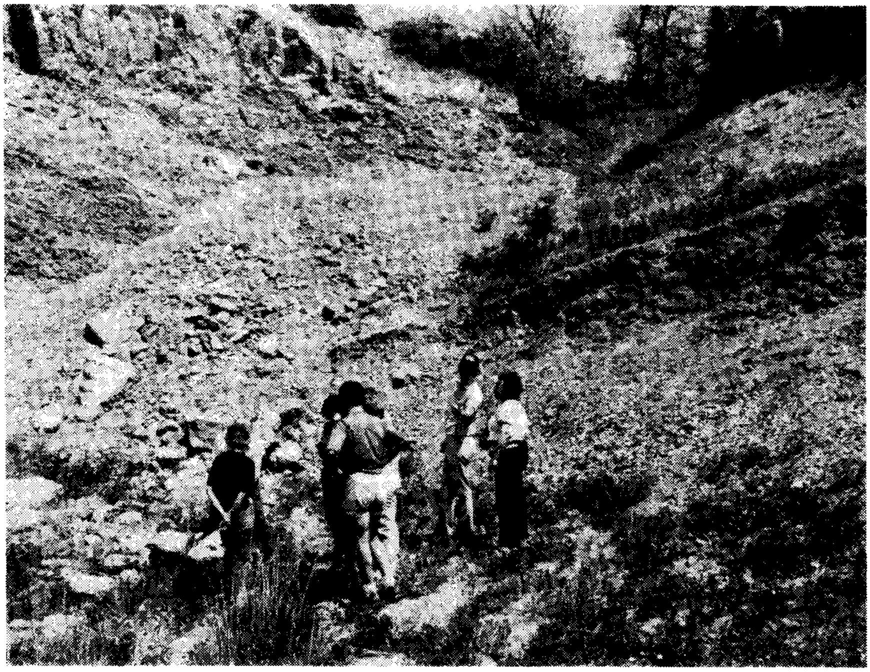

Figure 1. Group of teachers from Devils Lake looking at ice-thrust geology in an excavation on the north side of Sullys Hill.

notes on physical features they expected to see at each of the five stops, and a geology notebook. The students discussed each site and began to discover how features in their environment related to glacial action. They collected samples of shale, limestone, glacial till, and sand, then arranged displays in their school (Emerado, in this case). When they were interviewed, months after the trip, the students said that what most impressed them about the trip was learning that physical features they see every day are of interest to scientists.

Some of the teachers (the examples I'm using here refer to the course taught two years ago and all involved schools in the northeastern part of the state) ran a single "big" field trip; others preferred to run several shorter trips. Some of the topics of the more focused trips included soils, groundwater, kinds of rocks and minerals that can be found, river systems, and the geologic factors relating to how a landfill works. At least one of the teachers took his class out in mid winter, to an esker, so the students could experience the Ice Age first hand! In some cases, it was possible for teachers to take classes on short walks from school, without going to the hassle of getting a bus and driving a long ways, but not all teachers were so favorably situated.

My own involvement in this project has been rewarding to me. I've appreciated the chance to learn what earth science teachers need and how their students react to geology taught at a variety of levels of difficulty. Working directly with the teachers has also provided me with ideas about how to present written materials on the geology of North Dakota in ways that interest both students and adults.

EDUCATIONAL MATERIALS AVAILABLE FROM THE NDGS --John Bluemle

Even though most of the efforts of the North Dakota Geological Survey are directed mainly at solving technical geological problems and studying various aspects of the geology of the state, the NDGS also has definite commitments to educational outreach. In recent years, the demand for educational information and materials has increased considerably and the number of requests for field trips and workshops for both teachers and students has more than doubled in the last two or three years. This article is a description of some of the educational services and related materials that the Survey provides.

Publications on North Dakota geology--Several nontechnical publications on the geology of North Dakota are available from the NDGS. These include a set of guidebooks that include field trips for the various parts of the state, a brochure describing the geology along Interstate Highway 94, an auto tour guide to the Theodore Roosevelt National Park, a number of basic geologic maps of the state, and other informational materials. All of these materials are provided either at nominal charges or without charge (although we ask that requests be limited to a reasonable number of copies).

Geologic Highway Map--A colored geologic highway map is available from the Survey for $3.00. The backside of this map includes considerable additional information on the geology of North Dakota.

Rock and mineral sets--A set of 17 typical North Dakota rocks and minerals is available for $3.00. This rock set is used primarily by teachers and students. The specimens are mounted on a piece of cardboard with short descriptions of each sample on the reverse side of the card.

Slides of North Dakota geology--A slide program available from the survey describes the landforms that can be seen in various parts of the state. This set of 35 mm slides is provided in a Carousel slide tray (we hope to transfer the slide program to a television videotape soon). The program is loaned on request and is used mainly by teachers. It is available without charge; the only cost to the user is return postage.

NDGS Newsletter--The NDGS Newsletter, published in June and December, is available without charge. In addition to summaries of our current studies and activities, new publications, etc., we try to include at least one or two nontechnical articles in each issue of the newsletter on some aspect of North Dakota geology. Many of the articles that have appeared in past issues of the newsletter are now available as reprints.

Lectures and classes--Survey geologists are available to provide talks on various aspects of North Dakota geology (to technical and nontechnical groups, service clubs, classes, etc.). Arrangements can also be made for our geologists to lead field trips in virtually any part of the state.

Map information and sales--The North Dakota Geological Survey is an affiliate of the Earth Science Information Center (ESIC) and can provide information on the availability of maps, air photos, etc. The Survey also acts as a retail sales representative for all USGS topographic and other maps. Copies of topographic maps of North Dakota, as well as other map materials, can be purchased at our publications office in Bismarck or ordered by phone or mail. *[Editor's*

Note: Please see article on Map Sales elsewhere in this Newsletter].

NORTH DAKOTA NATURAL SCIENCE SOCIETY FIELD TRIP WILL BE HELD IN TURTLE MOUNTAINS IN AUGUST

--John Bluemle

This year the North Dakota Natural Science Society (NDNSS) will hold its summer field trip and annual meeting in the Turtle Mountains. The tour will meet at noon on Saturday, August 18 at Lake Metigoshe State Park, leaving from the lakeside picnic shelter at 1:00. Registration begins at 12:00.

A tour bus will take tour-goers to each of the stops. The group will spend Saturday afternoon and Sunday morning looking at the diverse natural features of the Turtle Mountains and listening to informal discussions about a variety of topics. Leaders of discussions at the several stops include Dick Gilmore, who will speak on the vegetation in the Turtle Mountains; Allan Aufforth, who will discuss wildlife; and John Bluemle, who will discuss the geology. Sue and Cedrick Jacobson will discuss differing views on the origin of possible Viking ship mooring stones (a somewhat controversial topic). At one of the stops on the tour we will discuss the forest in its different stages of succession.

The program on Saturday evening will feature a talk by Jack Woods, who will give an overview of the Turtle Mountains, and by Linda Garner, who will discuss her research on the red-necked grebe. The Saturday evening program will also include a meal (a half-pound sirloin, baked potato, coleslaw, desert, cold pop, and hot and cold hors d'oeuvres). Sunday morning will feature a group inventory and field trip of Turtle Mountains vegetation and wildlife in Wakopa Wildlife Management Area. The Sunday morning session will run from 8 until 11.

The annual summer field trips sponsored by the NDNSS have been quite successful in recent years. The tours, which are open to the public, are not technical and they have appealed to a diverse group of people, virtually anyone interested in North Dakota's natural environment. Recent tours have attracted well over a hundred participants. Anyone is welcome to attend; membership in the Natural Science Society is not required (although we do welcome new members). However, since the tour organizers have to make advance arrangements for the Saturday evening meal, for transportation, lodging, and camping accommodations, etc. we will be requesting pre-registration.

The tour costs $2.00 for members and $4.00 for non-members. The dinner on Saturday, along with the evening program, costs $11.00. Pre-registration guarantees a place in the tour and is strongly recommended. The Park entry fee is a separate $3.00, payable at the entrance station. Camping fee at the Park costs $6.00, and lodging is also available nearby at Turtle Mountain Lodge at Lake Metigoshe (263-4206), Norway House Motel in Bottineau (228-3737), and Loveland Lodge in Bottineau (228-2296).

More information about the meeting will be published in local newspapers as the date nears. The July issue of <u>NORTH DAKOTA OUTDOORS</u> magazine will include articles on the Turtle Mountains and additional information on the field trip. Send your tour pre-registration fee by August 1 to: Natural Science Society Tour, c/o John Schulz, Rugby Game & Fish Office, Lunde Building, Rugby, ND 58368 or call John at 776-5185.

HEALTH DEPARTMENT WILL SPONSOR SOLID-WASTE SYMPOSIUM

The North Dakota Department of Health and Consolidated Laboratories Environmental Health Section, together with the North Dakota League of Cities and North Dakota Association of Counties, are sponsors for the North Dakota Solid Waste Symposium on October 4-5, 1990 at the Bismarck Radisson Inn. The theme, "Rural Solutions for the 1990s," will focus attention on solid waste management issues in rural states by using North Dakota as an example. Solid waste is a national and global issue, but remains a local government responsibility. "Rural Solutions" was chosen to bring together people who have a rural focus on "do-able" solid waste management programs and solutions. Funding is from a grant from the Environmental Protection Agency.

A preliminary list of topics to be discussed include: pending federal landfill regulations, waste reduction, materials recovery (recycling) and market development, landfill technology, transfer station technology, hard-to-handle wastes (tires, batteries, used oil and household hazardous materials), legislative proposals, composting, local government issues in waste management, waste combusters/ash management, waste paper (newsprint, cardboard, and bond paper), NIMBY/LULUs (facility siting issues of not-in-my-back-yard or local-unacceptable-land-uses), and public education. Ed Murphy, North Dakota Geological Survey geologist, will be giving a talk on the groundwater quality at six municipal landfills he has studied and also a talk on the state's geology relative to waste-disposal siting.

Symposium organizers hope to attract city and county decision makers and waste-management officials, waste haulers, recyclers, legislators and legislative candidates, representatives from business and industry concerned about waste management, and citizens concerned with this issue. The symposium will include an exhibition, with indoor and outdoor displays featuring professional services, waste-hauling equipment, recycling opportunities, and new technologies in the solid-waste field. The exhibition will give participants a first-hand look at a variety of waste-management options.

[Editor's Note: For more information or a detailed brochure describing the symposium, contact Dawn Botsford, University of North Dakota Division of Continuing Education, Box 8277, University Station, Grand Forks, ND 58202, phone (701) 777-2663 or 1-800-342-8230 (ND only)].

PARTS PER BILLION

--Mark Luther

We often see "parts per billion" or "parts per trillion" referred to in the newspaper or on the evening news, often with reference to trace amounts of chemicals found in water. In order to help people visualize how small a "part per billion" of something is, numerous analogies have been offered in a variety of publications. Common analogies: "one part per billion is the same as one penny for every $10 million" or "one part per trillion would be the same as one penny in $10 billion," or "one part per trillion is one second of time out of 320 centuries."

These analogies do help people to visualize just how small are the concentrations of chemicals found in water and reported in ppm or ppb or ppt, but they may also give a misleading impression. Because the concentrations are tiny, should they be considered insignificant? Not necessarily. Whenever one encounters reports of contaminants--chemicals or whatever--measured in parts per billion, etc., the figures must also be viewed in the context of just how toxic the specific chemical is that is being measured. Many chemicals have little or no toxicity to humans at several hundred parts per billion, while others (2, 3, 7, 8-TCDD (Dioxin) for example) will almost surely cause cancer in humans if regularly consumed in water at levels of only 200 parts per trillion. In addition, many chemicals that are not particularly toxic to humans may be extremely toxic to plants and other animals. Also, in some cases, when plants or animals or fish consume water containing certain contaminants, they may build up high concentrations of them in their bodies. When these plants or animals are, in turn, consumed by other animals higher on the food chain, the "dose" of contaminant may be magnified many times. It's not a simple problem, easily boiled down to "parts per billion," or whatever.

So, even though water contaminants are commonly found in very small quantities, people should not necessarily conclude that they are of no concern without first knowing the toxicity of the chemical involved, as well as a number of other factors. Small concentrations of contaminants may or may not be cause for concern, but they should never be ignored.

PLUGGING ABANDONED WELLS

--Mark Luther

A potential threat to groundwater aquifers across the entire state of North Dakota exists in the form of improperly abandoned wells. The exact number of abandoned wells scattered across the state is unknown, but it has been estimated that there may be as many as 100,000 of them. These estimates are based on the number of farms in the state during the peak years of the 1930's (85,000) versus the number of farms we have today (32,000). In many cases, as many as four farms were located on a single section of land, and each farm had one or more wells. The majority of the early farmsteads in the state are now abandoned, along with their well or wells.

Apart from the physical hazard

of improperly abandoned wells (falling into them), is there other cause for concern? The answer is "yes." Improperly abandoned wells may act as a direct conduit for surface pollutants (ie, pesticides, fertilizers, animal wastes, petroleum products, etc.) to move into and contaminate groundwater. They may also allow the mixing of waters from separate aquifers, possibly resulting in groundwater depredation. Another concern is that improperly abandoned flowing wells may result in depletion of the aquifer pressure, resulting in water level declines in other wells penetrating the aquifer. Steps have recently been initiated to address these concerns.

During the spring of 1989, the Barnes County Soil Conservation District (BCSCD) expressed interest to the North Dakota State Department of Health and Consolidated Laboratories (NDSDHCL) in initiating an abandoned-well-plugging project. Since groundwater pollution due to improperly abandoned wells is considered nonpoint source pollution, the project idea was forwarded to the North Dakota Water Quality Taskforce for Nonpoint Source Pollution (NPS Taskforce) for its consideration. The NPS Taskforce, of which the NDGS is a participant, approved the project, clearing the way for partial funding of the project with Environmental Protection Agency funds.

The Barnes County abandoned-well-plugging project is receiving partial funding through Section 319 of the Clean Water Act, administered in North Dakota by the NDSDHCL. This is considered a pilot project which, if successful, could be applied to the rest of the state. The project is in its infancy, with current efforts being directed toward developing educational materials and practical, inexpensive, well-plugging techniques. It is in the development of well-plugging techniques that the NDGS has had considerable input, striving to develop methods that do a satisfactory job of protecting our groundwater resources, while remaining as simple and inexpensive as possible.

The immediate goal of the project is to develop a teaching videotape, which shows step-by-step instructions to help landowners properly abandon their own wells with the use of materials that cost less than $200 for most wells. The NDSU Extension Service will produce the videotape which, when it is completed early this fall, should be available through County Extension offices. A brochure entitled "Plugging Abandoned Wells" that is already available from NDSU Extension provides a good overview of reasons for plugging abandoned wells, and proper plugging procedures. The techniques presented in the brochure will likely be modified somewhat as the results of the Barnes County pilot project become available.

To date, two abandoned wells have been properly plugged, and the plugging procedure videotaped, during two public demonstrations in Barnes County. At least two more public demonstrations will be conducted later in the summer, plugging wells of different diameters and depths so that landowners can learn how to properly plug any type of abandoned well that may be located on their own land. The NDGS has assisted personnel from the NDSDHCL and BCSCD in plugging these wells, hauling well-plugging materials to the site, participating in the plugging itself (figures 1 and 2), and providing geologic expertise and input as required.

The Barnes County abandoned-well-plugging project is just one of many examples of ways in which the NDGS works with local, state, and federal groups and agencies to both determine and promote the wise use and protection of North Dakota's resources.

Figure 1. Mark Luther (NDGS) guiding the removal of the pump from an abandoned well on the Peter Paulson farm, north of Valley City. Dean Fredrickson (NDSDHCL) assisting.

Figure 2. Dave Paulson (NDSDHCL) pouring sodium bentonite (clay) chips into a well bore. Mark Luther and Lynn Hill (BCSCD) assisting.

DRILLING AT FORT LINCOLN STATE PARK

--Mark Luther

A two-man crew from the NDGS--Mark Luther and Russ Prange, the Survey's technician--spent two days in early May working at Fort Lincoln State Park. We were there to help the State Historical Society by providing soil cores along the path of a proposed pipeline. The pipeline route crosses the southern end of the park, near the vicinity of the original fort's commissary. When installed, the pipeline will be used to supply water for irrigation at the Veteran's Cemetery, now under construction. Fortunately, the NDGS' hollow-stem auger rig was in Bismarck and ready for drilling at the time the request was made, and we were able to begin coring the day after we were asked. This allowed the North Dakota National Guard, which is constructing the pipeline and cemetery, to complete their project without costly delays.

Reasons for coring along the pipeline route were several-fold. First, the Historical Society wanted to know if any paleosols (ancient buried soils) underlay the site, and if so, if any evidence of cultural remains or human occupation could be found in the paleosols. Second, we wanted to know the depths from which historical debris dating from the fort's occupation could be found. Finally, the NDGS is interested in gathering shallow stratigraphic data for inclusion in our N-File--a near-surface data base, used in the creation of many of our surface maps.

Drilling went smoothly (figs. 1 and 2). We drilled and continuously cored fourteen holes in the two days we were at the site. The holes ranged from about 7 to 13 feet deep and the materials we penetrated appeared to consist mainly of fine-grained alluvial (stream-deposited) and, possibly, some eolian (wind-blown) deposits. We noted a possible thin paleosol in one hole, at a depth of approximately nine feet, directly over a gravel (river bar) deposit, but we didn't find any cultural material in that zone. We did find historical (fort) debris in the upper foot or so of most of the holes, indicating disturbance of the deposit to at least that depth. The

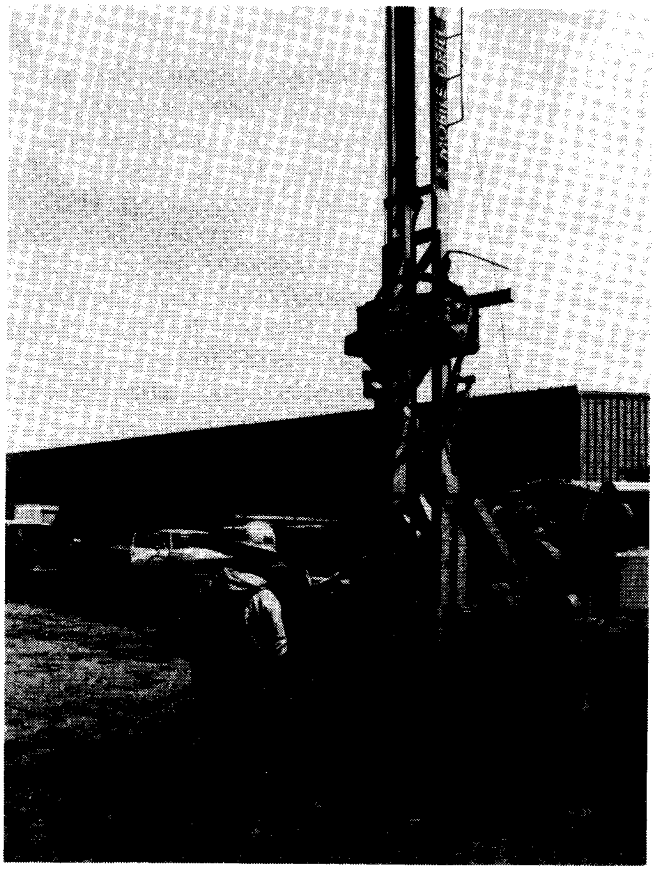

Figure 1. Mark Luther (left) and Russ Prange (right--Russ is the Survey's technician) coring at Fort Lincoln.

Figure 2. Mark and Russ extruding a soil core from a shelby tube, using the hydraulic ram on the drill rig.

holes we drilled near the river penetrated loose, noncompacted soil that contained a scattering of historical debris to a depth of at least seven feet, indicating that the area near the river is likely composed of relatively recent fill.

As a result of our coring at Fort Lincoln State Park, project archaeologists determined that no cultural deposits of significance would be disturbed by the proposed pipeline, thereby clearing the way for the project to be completed in a timely manner. We feel fortunate in having been able to assist several other agencies in the successful completion of their tasks, and to renew our commitment to working with the archeological community in the state.

NDGS STUDIES HAVE INFLUENCED OIL EXPLORATION --Marv Rygh

[Note: Marv Rygh was with the NDGS at the time he wrote this article in 1986. He is now employed by the Oil and Gas Division of the North Dakota Industrial Commission. The statistics included here have been updated to reflect current (1990) conditions].

Geologic studies by the North Dakota Geological Survey have provided an impetus to oil exploration and development in various ways. Some of the Survey's studies have identified new possibilities for oil exploration, while others have directly influenced exploration and created interest resulting in new oil plays in the state. Even studies that were done many years earlier often contain information that explorationists find valuable in their current studies.

An example of such a study is NDGS Report of Investigation 42, entitled "***A Look at the Petroleum Potential of Southwestern North Dakota***" by Sid Anderson. It was in this 1966 publication that the Billings Anticline, a major geologic structure, was first identified. At the time the report was published, only minimal production existed in the area, that from a few wells in the northern and southern parts of the study area (fig. 1) The Billings Anticline was recognized in the report as a prominent geologic feature and it was mapped by the Survey as a northward-plunging anticlinal trend approximately 24 miles wide and extending at least 60 miles from north to south. The Oil and Gas Journal reprinted this report in their August 15, 1966 issue, pointing out the potential oil-producing capability of the Billings Anticline.

Since it was identified in 1966, the Billings Anticline has become one of North Dakota's most important oil-producing areas. The first major discovery on the Billings Anticline was in 1978 and, since that time, 57 new oil pools have been discovered along the trend (fig. 2). Cumulative oil production through 1989 in the area exceeds 94 million barrels of oil. This production accounts for over 9 percent of all oil ever produced in North Dakota. In 1989, wells on the Billings Anticline produced 11 percent of North Dakota's annual oil production. These figures illustrate the importance of the discovery of the Billings Anticline to the oil industry and to the economy of North Dakota.

Studies of older, existing fields have also proven to be valuable. A study, performed by NDGS staff, entitled "***Mission Canyon Porosity Development, Glenburn Field, North Dakota Williston Basin***" was published in the 1978 Williston Basin Symposium volume. One of the important results of this NDGS study was the recognition of stacked porosity zones within the reservoir in the Glenburn Field. This recognition greatly influenced the inception of a major infill-drilling and recompletion program in Glenburn Field. As a result, substantial amounts of additional oil reserves have been discovered and recovered. The production rate of the Glenburn Field approximately doubled from 1979 to 1981, largely due to the 39 infill wells completed in the field during that time. The field had originally been drilled on 80-acre spacing and, with the infill-drilling program, the field is now effectively on 40-acre spacing. Similar successful infill-drilling programs were also initiated in other oil fields north of the Glenburn area.

A stratigraphic study in 1961, entitled "***Maps of the Frobisher-Alida Interval, North Dakota***" by then NDGS geologist W. P. Eastwood better defined the trapping mechanism for oil in north-central North Dakota. Wells drilled prior to the publication of this study normally penetrated only as deep as the Midale subinterval of the Madison Group. Subsequent wells were drilled to the deeper Frobisher-Alida interval in the Madison Group. The Frobisher-Alida interval proved to be a productive oil zone in many instances. The recognition of further potentially productive oil zones in older, developed areas has been an important result of NDGS investigations.

One of the basic responsibilities of the North Dakota Geological Survey is to promote, on a scientific basis, the mineral

1966

Billings Nose Area

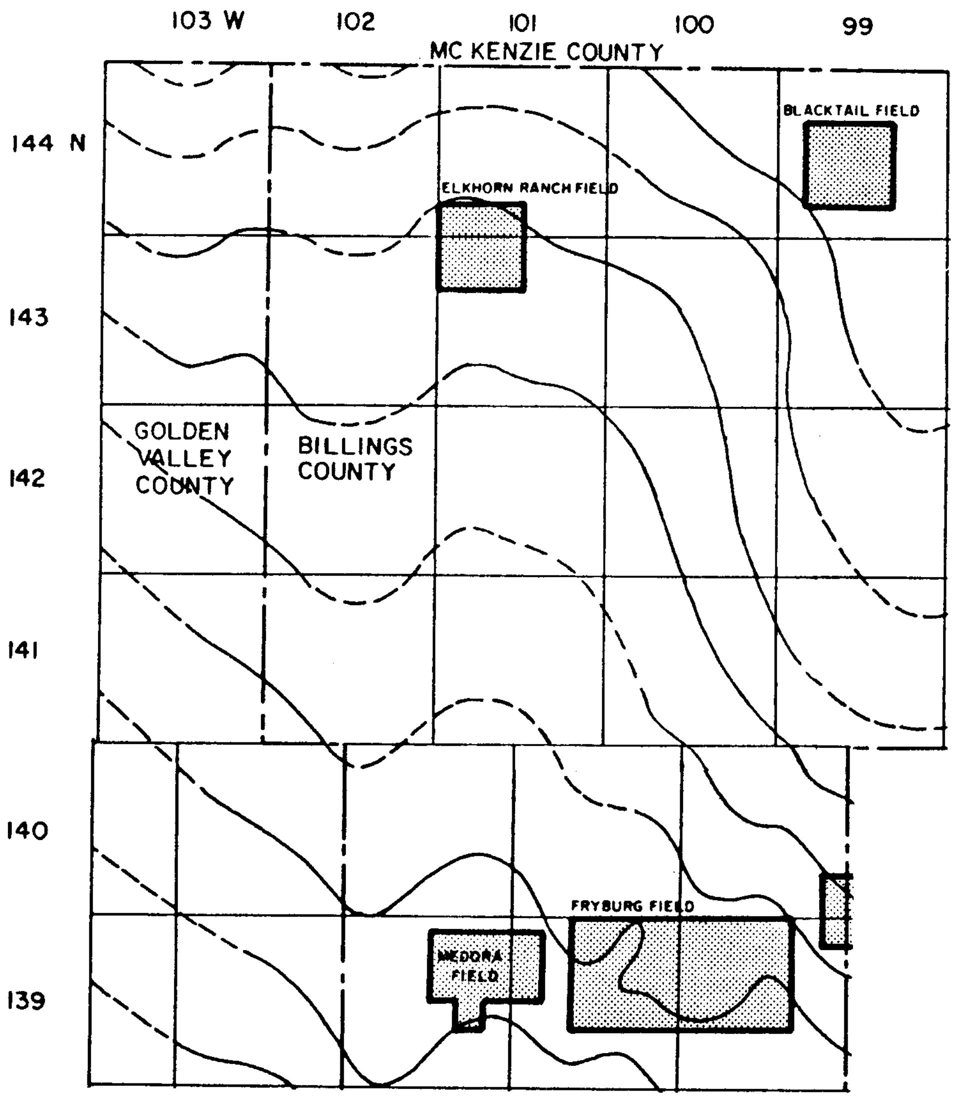

Figure 1. A part of the Billings Anticline area in southwestern North Dakota showing development in 1966, when the structure was first defined by S. B. Anderson.

Billings Nose Area

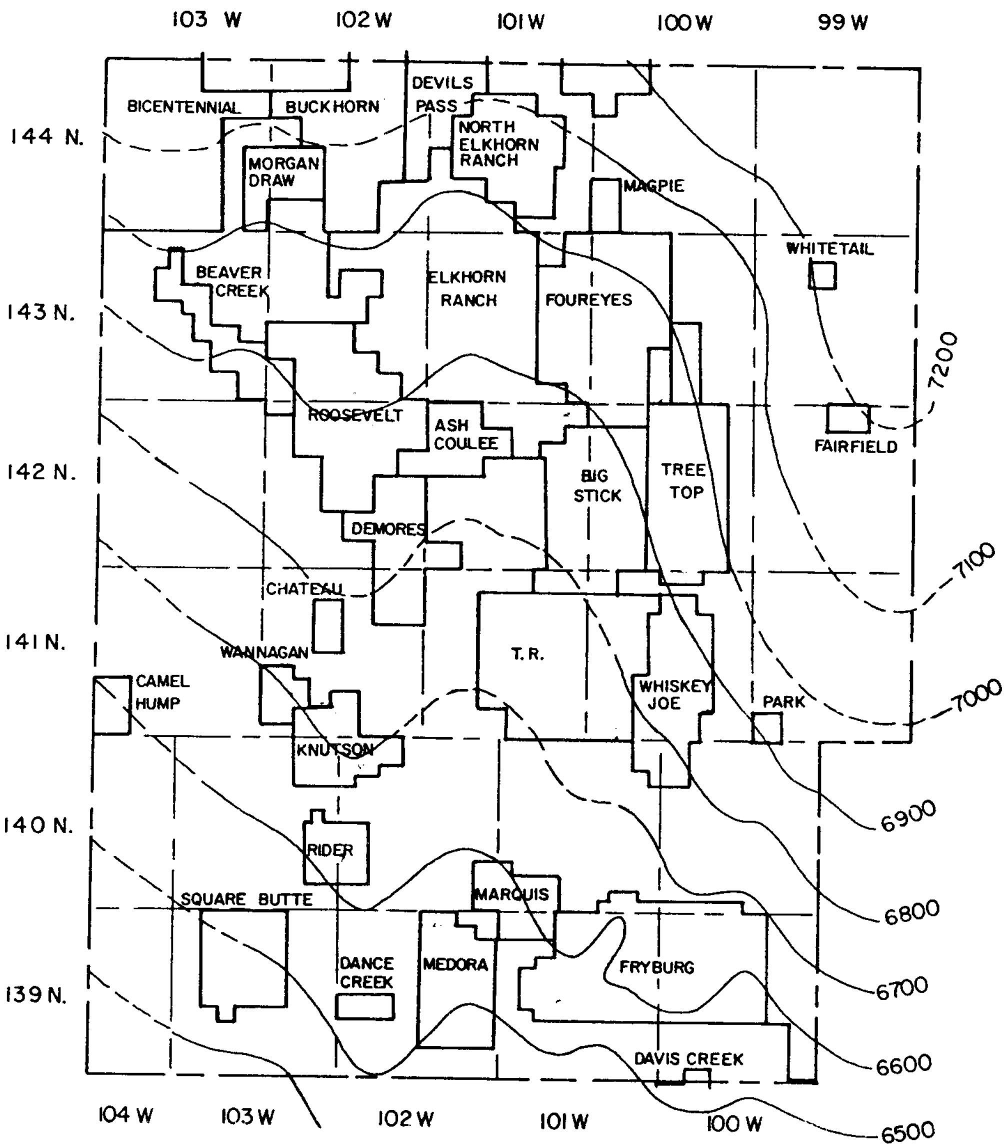

Figure 2. Billings Anticline (same area as that shown on figure 1) showing development in 1990. Structure contour lines on figure and preceding figure are drawn on the main Fryburg pay.

resources of the state. An effective approach to this, one which has proven to be successful in the past and should continue so into the future, is the broad-base study of lesser-known subsurface horizons and undeveloped geographical areas in North Dakota, areas that may have economic mineral potential.

The NDGS has a virtual storehouse of data, in the form of well core, well logs, and various well information, from which these studies are made. Studies like those described in this article provide a sound basis for encouraging more exploration and for future development of the state's mineral resources.

THE PEMBINA ESCARPMENT

--Allan Ashworth

[Editor's Note: Dr. Allan Ashworth is Professor of Geology at North Dakota State University in Fargo. This article is adapted from one that Dr. Ashworth wrote to accompany a field trip he helped lead on August 11, 1989, "Tales of the Tall Grass": the International Prairie Tour of the Lower Red River of the North. The lithographs reprinted at the end of this article were included in an article by Manton Marble that appeared in Harper's New Monthly Magazine, August, 1860].

The Pembina Escarpment, rising 300 to 400 feet above the Red River Valley in northeasternmost North Dakota, forms one of North Dakota's most dramatic landscapes. The hilly country, with cool ravines full of aspen and birch, stands in stark contrast to the flat lowlands to the east. The escarpment may have been one of the "mountains" referred to by the French fur trader, La Verendrye, in 1738. Certainly, by the time that the first geologist explored the region, the hills were reputed to be the source of silver ore. However, William Keating, geologist to the U.S. Government's first expedition to the Red River Valley, led by Major Stephen H. Long in 1823, wrote:

> *"We saw no ore of any kind. The prairies do not present any character that would leave us to anticipate the discovery of mines in this neighborhood."*

[Editor's Note: all of the quotations in this article are taken from a book entitled Roy Johnson's Red River Valley, edited by Clarence A. Glasrud and published by the Red River Historical Society, Moorhead, 1982].

Rumors persisted long after Keating's visit that coal and perhaps even gold existed on Pembina Mountain. David Dale Owen, geologist for the fledgling United States Geological Survey, visited the Red River in 1848. Owen, as Keating had discovered earlier, found no evidence for any deposits of economic significance.

In the more poetic language of the nineteenth century, Keating described the Red River Valley in a manner more vividly than any subsequent chronicler:

> *"The flatness of the surface that almost uniformly prevails throughout the Valley may be regarded as a defect in its natural character that cannot easily be remedied."*

Keating (in 1823) made the observation that the entire region had been covered by water: "...*The* *whole of the country may be considered to be an immense lake, interspersed with innumerable barren and rocky islands."*

Pembina Mountain is "...*in fact no mountain at all, nor yet a hill. It is the terrace of table land - the ancient shore of a great body of water that once filled the Red River Valley*" (quoted in Roy Johnson's Red River Valley, 1982; this statement was probably originally made by David Owen in 1848).

Interestingly, both Keating and Owen had anticipated the discovery of Glacial Lake Agassiz (fig. 1). The existence of Lake Agassiz was not formally proven until the survey of its beaches by Warren Upham and Horace Winchell in 1881. Neither Keating nor Owen could have guessed the origin of the body of water to which they alluded. The very existence of an Ice Age, to which the lake owes its origin, was not proposed until 1840, by the Swiss scientist, Louis Agassiz.

The materials exposed in the Pembina Escarpment have their origins several millions of years ago, during the Cretaceous Period, long before glaciers invaded the Red River lowlands.

The shales and carbonates of the Cretaceous formations, exposed today in the deep gullies and valleys of the Pembina Escarpment, were deposited in a seaway that connected the Arctic Ocean to the Gulf of Mexico about 90 million years ago. Bones and teeth of fish, mosasaurs, (large marine lizards), and pterosaurs (flying reptiles) are occasionally found in the Walhalla area and in the Morden area of southern Manitoba. The western shoreline of the Cretaceous seaway, in western North Dakota and Montana, was the habitat of duck-billed dinosaurs, Triceratops, and Tyrannosaurs.

The exposures of shale are interrupted in places by thin beds of yellowish-colored bentonitic clays. These bentonites are weathered volcanic ash beds. Clouds of ash, from volcanoes erupting in the developing Rocky Mountains, far to the west in Wyoming and Montana, blew eastward over North Dakota, settling in the shallow sea that covered the area.

After the Cretaceous seas drained, most of North Dakota and northern Minnesota underwent a long period of erosion during Tertiary time, between about 60 million years ago until about two or three million years ago. Although it is not known where or even in which

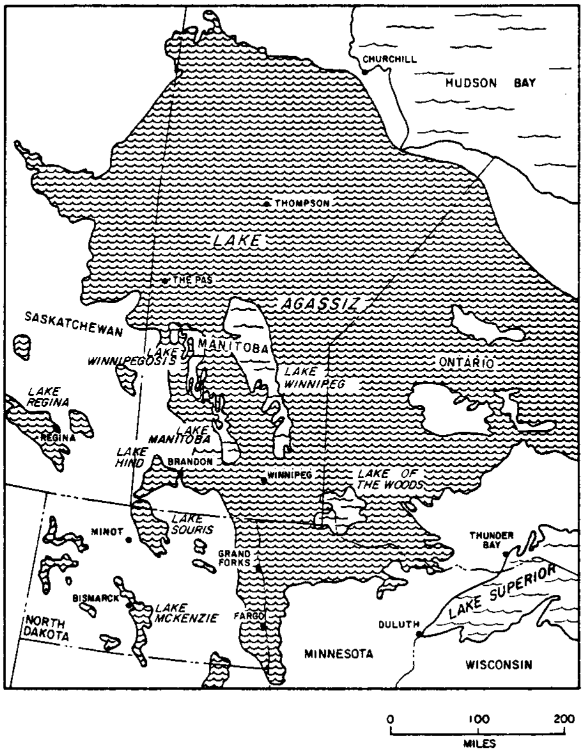

Figure 1. Extent of glacial Lake Agassiz. The lake extended south into northwestern Minnesota and eastern North Dakota, the area Keating and Owen visited in the first half of the 19th century.

direction rivers flowed in North Dakota during most of that time, by the end of the Tertiary Period North Dakota's drainage was through a series of major rivers that drained mainly to the north (fig. 2). The modern system of existing rivers in eastern North Dakota, such as the Sheyenne, James and Pembina Rivers, did not develop until the end of the Ice Age.

The formation of the Red River, and ultimately of the Pembina Escarpment, was due to springs emanating from the Cretaceous-aged Dakota Group sandstone; this sandstone formation came to the surface in northwestern Minnesota (fig. 3). It was in that area of springs that the north-flowing Red River originated. Undercutting of the Cretaceous formations by spring sapping, coupled with erosion by the early Red River, resulted in the westward migration of the route of the river and the formation of Pembina Escarpment.

The Cretaceous formations are preserved as an escarpment because the uppermost layer of rock, the Odanah Member of the Pierre Formation shale, is more resistant to erosion than the lower formations (fig. 4). Spring sapping may have initiated the escarpment, but it was the glaciers that steepened it to near its present configuration. Scouring of the face of the escarpment occurred on numerous occasions as glaciers flowed southward, up the Red River Valley. Later, when glacial Lake Agassiz flooded the valley, storm waves generated on the lake accentuated the steep face of the escarpment. Massive outbursts of flood water from ice-dammed lakes to the west--glacial Lakes Souris, Regina, and others--flowed along the Manitoba-North Dakota boundary, eroding the deep valley of the Pembina River. Finally, erosion since the end of the Ice Age has deepened the many small valleys in the face of the Pembina Escarpment and carved fresh exposures in the shale that can be seen today.

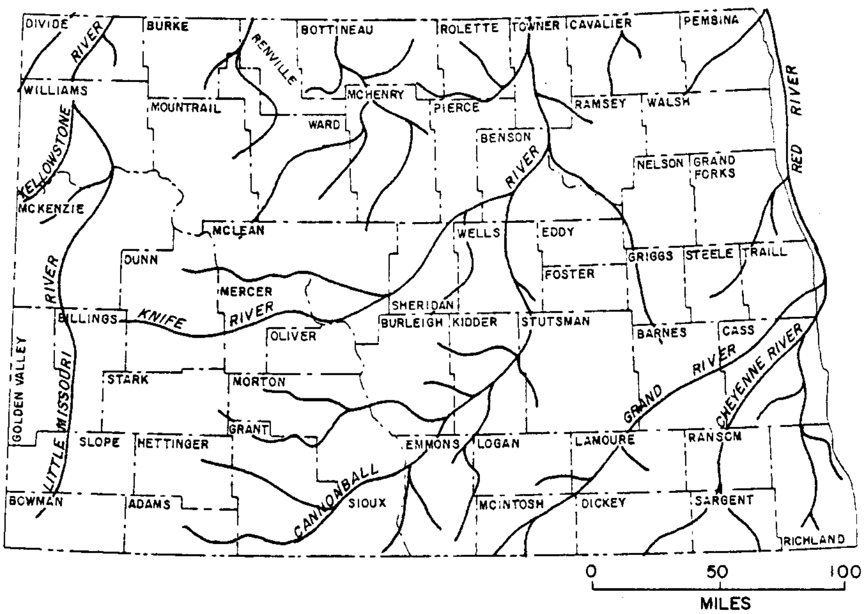

Figure 2. North Dakota's drainage pattern prior to glaciation. The entire state drained northward, ultimately to Hudson Bay.

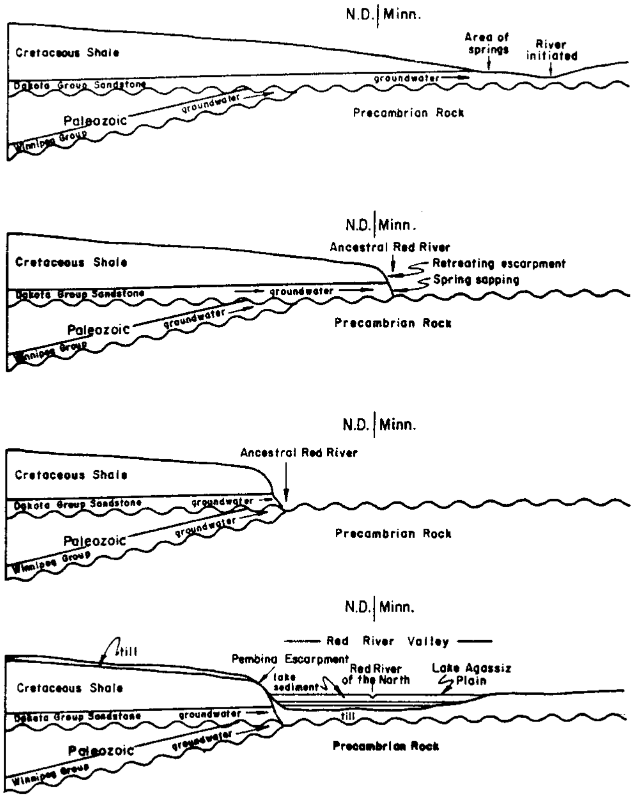

Figure 3. Steps in the formation of the Red River Valley and the Pembina Escarpment. Top diagram, a cross section drawn from west to east along the U.S.-Canada boundary, shows the early Red River when it was located east of its present location. As the river eroded its way downward to the Precambrian rock, it shifted its course to the west (next two diagrams). The modern escarpment (bottom diagram) has been further modified by glaciers, which flowed southward through the valley, and by sedimentation in glacial Lake Agassiz.

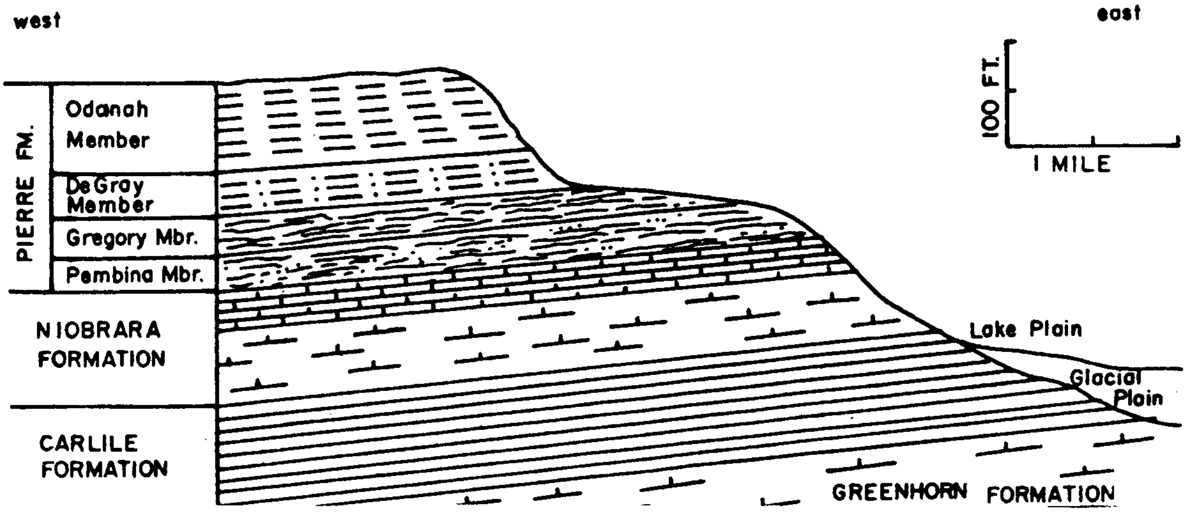

Figure 4. The Cretaceous formations exposed in valleys along the Pembina Escarpment area. The more resistant Odanah Member of the Pierre Formation shale serves to keep the escarpment from eroding to a gentler feature.

Pembina Mountain.

Red River Guide.

St. Joseph, from Pembina Mountain. St. Joseph was the former name for the town of Walhalla.

Our naturalist, studying grasses.

THE LITTLE MISSOURI BADLANDS

--John Bluemle

On first viewing the intricate shapes of the badlands, you might conclude that some great natural catastrophe has torn the earth apart, ripping it open and exposing its interior. But the hills and valleys of the badlands were formed by agents more relentless than earthquakes or volcanoes. Earthquakes certainly have not been a significant factor in forming our land and North Dakota has never had volcanoes. Rather, hundreds of thousands of years of erosion by running water have sculpted the terrain along the Little Missouri River, resulting in a rugged, colorful, and beautiful panorama.

The badlands are a hilly landscape, but when you approach them, you look down on the hills from above, not up at them. From the rim of the "*breaks*," as the drop into the badlands is called, you can see the strip of barren ridges, bluffs, buttes, and pinnacles along the river. Behind you, an unbroken, rolling plain stretches away to the horizon. This land along the Little Missouri River, which Theodore Roosevelt found "fantastically beautiful," was carved by running water from rain and melting snow, wind, frost, and other forces of erosion.

The Sioux Indians had a name for the badlands: "*makosika*" ("land bad"). Early French explorers translated this and added to it, referring to "*les mauvais terrers a' traverser*" ("bad land to travel across"). Today, modern roads make at least parts of the area easy to travel across, and the name "badlands" may not be as applicable as it once was.

In addition to the badlands expanses bordering the Little Missouri River, several other small areas of badlands topography are found in western North Dakota. Badlands are also carved from the Hell Creek Formation, which consists of materials that are Cretaceous in age, about 62 million years old. The Hell Creek badlands are found near Marmarth, in Slope County, and they extend to the south into Bowman County. Other isolated areas of badlands, a few acres or tens of acres in extent, are carved from layers of the Hell Creek Formation near the Missouri River in parts of Sioux, Emmons, and Morton Counties. Pieces of dinosaur bones can be found in the badlands near Marmarth and, occasionally, an entire bone, or even a complete skeleton, will turn up. Several years ago, a skull of the dinosaur *Triceratops* was taken from Hell Creek sediments in Slope County. This dinosaur skull is now on display at the University of North Dakota, but most of the dinosaur fossils collected over the years in North Dakota have ended up in museums in the eastern United States.

Badlands are also found near Dickinson, carved from sedimentary rocks that were deposited by rivers and in lakes during the Oligocene Epoch, about 30 million years ago. These rocks belong to the White River Group. Other rocks in the Dickinson area that have been eroded into badlands topography are part of the Golden Valley Formation, deposited during the Eocene Epoch, 50 million years ago. The badlands just south of Dickinson, sometimes referred to as the "Little Badlands," are carved from sedimentary layers that are equivalent, in part at least, to the strata found in the well-known area of badlands in western South Dakota (the "Big Badlands"), along the White River. The Little Badlands, like their counterparts in

South Dakota, are notable for their abundant mammal fossils.

The most extensive and spectacular badlands in North Dakota though, and the ones most North Dakotans think of when they hear the word "badlands," are those that occur along either side of the Little Missouri River, all the way from the South Dakota border to the point where the river flows into Lake Sakakawea in Dunn County (fig. 1). The Little Missouri Badlands are carved from sedimentary rocks of Paleocene age (about 55 million years old). The Paleocene rocks are not quite as old as the Hell Creek Formation rocks, but they are considerably older than the White River rocks.

The rock layers exposed in the Little Missouri Badlands were deposited mainly by rivers and streams flowing east to the Dakotas from the Rocky Mountains in Montana and Wyoming. The various layers are made of several different kinds of sediment. Most of the bluish gray layers consist of beds of silt and clay. Brownish gray layers are composed of beds of sand that contain orange, iron-rich bands a few inches thick. The black layers are mainly lignite coal.

During Paleocene time, near the newly-formed Rocky Mountains in Wyoming and Montana, swiftly flowing rivers and streams carried large amounts of coarse materials: cobbles, gravel, and coarse sand. At the point where the rivers flowed from the mountains, out onto the plain, they lost much of their carrying power as their velocity decreased and they deposited most of the coarser materials. These materials are still in Wyoming and Montana. The rivers carried the finer materials--the silt, clay, and fine sand--farther eastward to the Dakotas and deposited them as the Bullion Creek and Sentinel Butte Formations. These are the rock layers that are now exposed in most of the area along the modern Little Missouri River (rocks older than the Bullion Creek and Sentinel Butte Formations are exposed in the badlands along the river in Bowman and Slope Counties). The deposition of these sedimentary rocks was not uniform and blanket-like, but rather, as the rivers and streams meandered from side to side, they deposited materials on their floodplains in one area for a few years and somewhere else a few years later, gradually building up layers that were hundreds of feet thick. Forests and other vegetation that grew throughout the area were sometimes flooded and buried, resulting in accumulations of petrified wood and lignite.

At the time the Rocky Mountains were forming, during Paleocene time, volcanoes were erupting in western Montana and Wyoming. These volcanoes produced large amounts of ash, probably similar to the ash clouds produced by the eruption of Mt. St. Helens during May of 1980. The ash was carried by the wind to western North Dakota (but in much greater amounts than that which erupted from Mt. St. Helens). It washed into wet areas--lakes and lagoons--and with the passage of time it was transformed to bluish, bentonitic clay layers that can be seen today in the badlands areas (fig. 2). Bentonite is composed of extremely fine clay particles that swell when they get wet. The clay can absorb up to five times its weight in water and it is extremely slick and mobile when wet.

Although the layers of sedimentary rock exposed in the Little Missouri Badlands are about 55 million years old, the badlands themselves--the hills and valleys--are not nearly that old. The Little

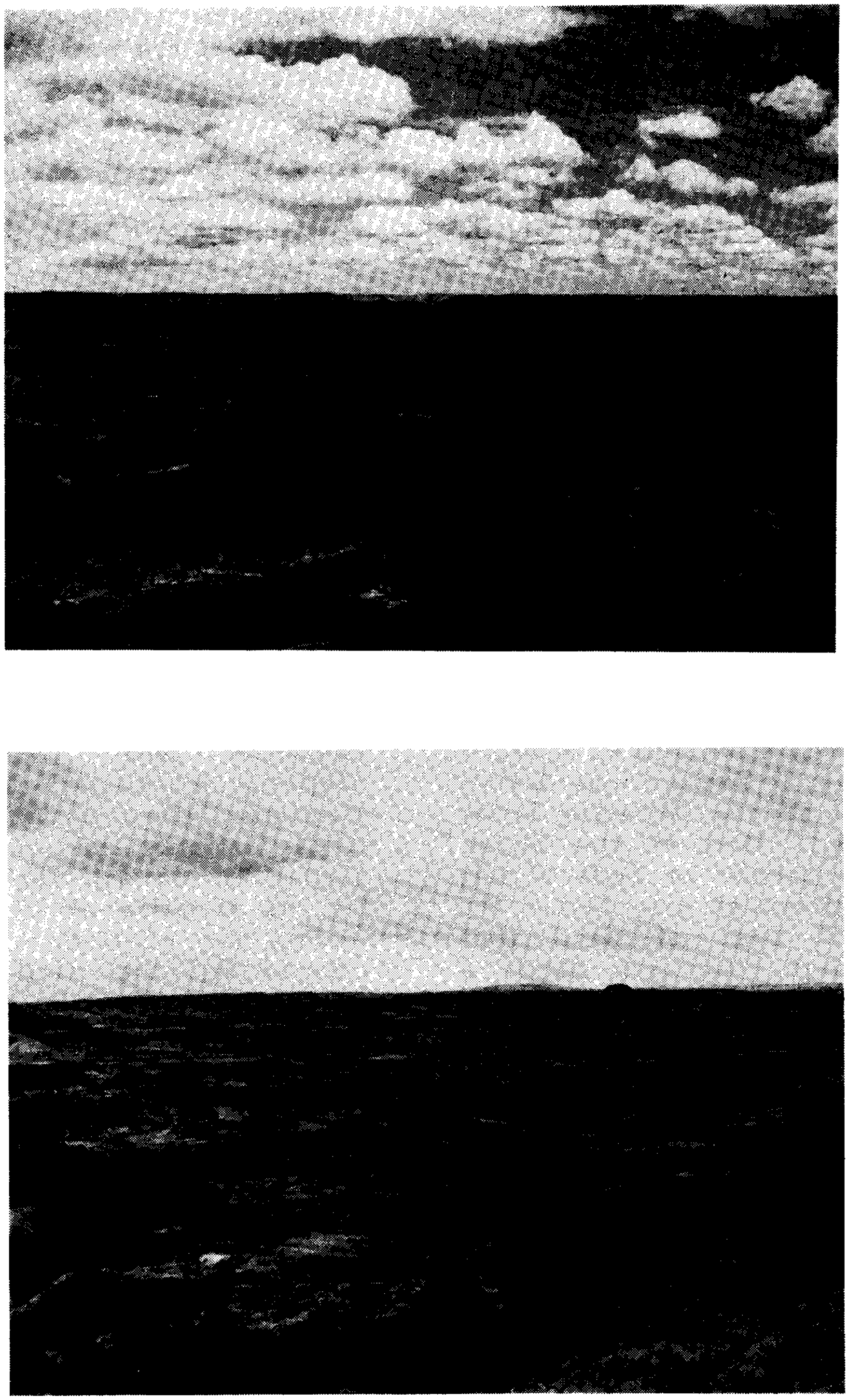

Figure 1. Little Missouri Badlands near Medora. Trees grow in draws and on some of the north-facing slopes.

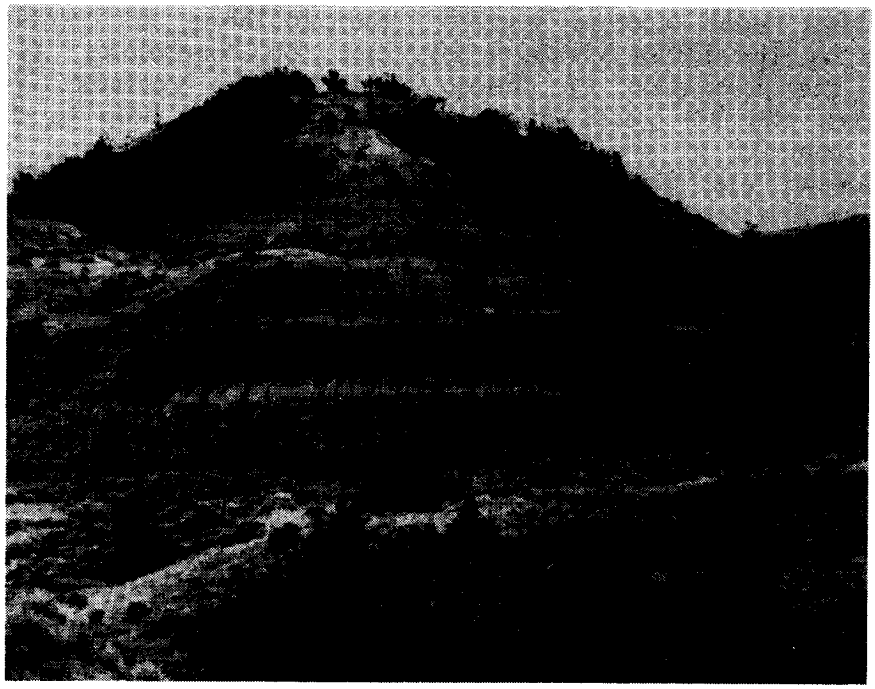

Figure 2. Exposure of layered sediments in the badlands. The black layers are lignite, dark-colored layers are clay, and most of the lighter shades are sandstone and siltstone.

Missouri River began to carve the badlands about 600,000 years ago, when a glacier diverted its course. Prior to that time, the river flowed northward, essentially following its present route to southern McKenzie County, to a point about 40 miles southwest of Watford City. From there, the river continued northeastward, past Watford City, and on into Williams County, eventually joining the early Yellowstone River a few miles north of Williston. The combined Little Missouri and Yellowstone Rivers flowed north into Canada and on to Hudson Bay.

As I said, 600,000 years ago a glacier diverted the Little Missouri River eastward through northern Dunn County forcing it to flow over a shorter, steeper route than before. As a result of the increased gradient on the river, a vigorous cycle of erosion and downcutting began, initiating badlands development.

Since the erosion of the badlands began, a great deal of sediment has been carried away by the river. In the southern part of the Little Missouri Badlands, near the headwaters in northeastern Wyoming, the river has cut down about 80 feet below the level it flowed at before the glaciers diverted it. Near Medora, the valley floor is 250 feet lower than the pre-diversion level. Still farther north, in the North Unit of Theodore Roosevelt National Park, the east-trending portion of the river flows in a valley that has been incised to a depth of more than 600 feet since glaciers diverted the river. Approximately 40 cubic miles of sediment has been eroded and carried away by the Little Missouri River since the formation of the badlands began 600,000 years ago. Given these amounts of erosion, it can be calculated that the average rates of erosion are (approximately):

North Unit area: 0.1 feet (one inch)/hundred years

Medora area: 0.04 feet (a half inch)/hundred years

Northeast Wyoming: 0.013 feet (less than 0.2 inch)/hundred years.

Although these rates of erosion seem tiny, they have been able to accomplish a great deal over the 600,000-year period of time that the badlands have been forming.

As I said, the erosion rates noted above are averages. Erosion of the Little Missouri Badlands has actually taken place at very irregular rates. Since their excavation began, the badlands have undergone numerous periods of erosion and deposition. Erosion is most intense during periods of drought because the vegetative cover is too sparse to protect the soil. Badlands are eroded mainly by hill slope processes, especially slopewash, not directly by streams and rivers. In places where vegetation is thin, the soil and rock materials are easily weathered, forming a loose surface that moves down slope easily--by slumping and sliding during showers or when the snow cover melts. Streams and rivers then carry the eroded materials away. During the past few hundred years, the badlands have undergone four separate periods of erosion and three periods of deposition. New gullies have been cut to their present depths since about 1936.

The individual shapes and configurations of the hills, buttes, valleys and other landforms in the badlands are not simply happenstance or coincidence; they can be explained (sometimes at least). Various factors and circumstances help to determine the shape of the topography. Differences in hardness of the materials cause differences in resistance to erosion. Variations in permeability have almost the same effect; rain and melted snow tend to soak into the more permeable sands, causing little or no erosion, but when water flows over the surface of less permeable sediments, such as clay, it erodes the materials it is flowing over. The presence and kind of vegetation can be important factors in retarding the rate of erosion.

The shapes and configurations of badlands landforms are also affected by the presence of such things as nodules and concretions, hard and resistant pods and lenses that are encased by less resistant materials (fig. 3). These are resistant to erosion and they sometimes cause small, rock-capped pillars (known as "hoodoos") to form. Some concretions and nodules are nearly spherical, some are long and tubular, and others have irregular shapes. In places, the land surface in the badlands is covered by nodules of siderite (iron carbonate or "ironstone"). As these nodules weather out of the surrounding materials, they may form an erosion-resistant layer of armor.

Among the more interesting of the various types of larger concretions are the "logs," elongate sand bodies, which at first glance might be mistaken for tree trunks that have been transformed to petrified wood. These logs, however, are not petrified wood, but rather they are sandstone bodies that have been cemented, most commonly, by calcium carbonate. The log-like concretions formed when

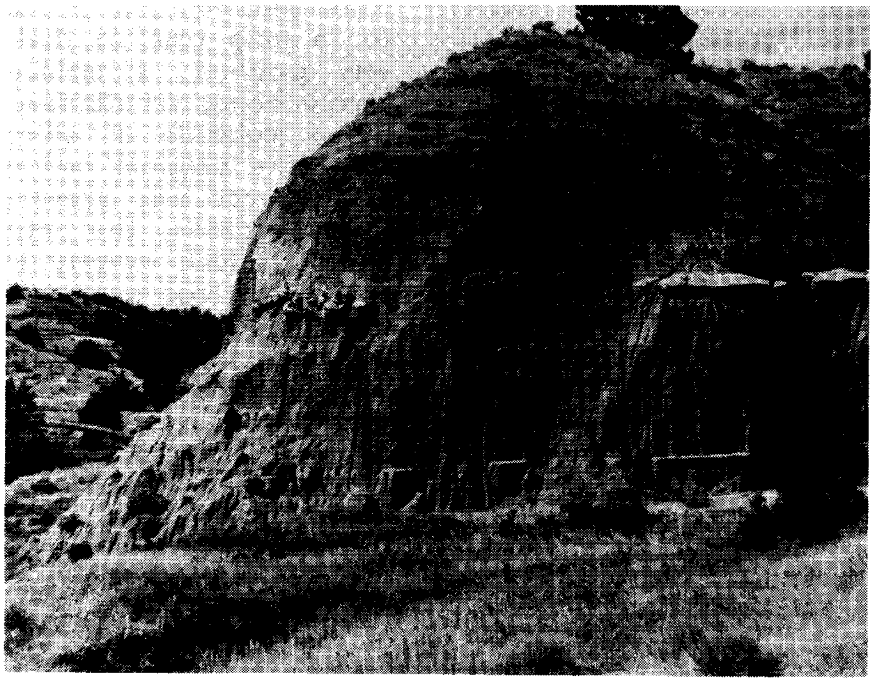

Figure 3. Exposure of sandstone with lenticular concretions. The concretions help to control the rate and configuration of erosion. In this area, concretions tend to remain standing as caps on pedestals of sand.

mineral-rich groundwater seeped through porous and permeable zones in the buried sediments, depositing the minerals it contained in the sediment pores. As a result, the sediments were cemented so that they became concretions.

The whole area that is now the Little Missouri Badlands was probably forested during the Paleocene Epoch. Trees similar to the modern cypress grew in swamps along the rivers. As the trees and other plants died and fell into the swamps, they began to decay due to the action of bacteria. However, before the plants could be completely decomposed, the bacterial action stopped because the bacteria "committed suicide" by filling the stagnant swamp water with their body poisons to such an extent that they died. As the swamps gradually filled with debris, thick layers of peat built up. When the streams changed course, as the Mississippi River does on its delta in the Gulf of Mexico at times, they deposited sand on top of the partially decomposed vegetation (peat), burying it. With time, the weight of the overlying sediment helped to transform the peat to lignite. Lignite is soft coal consisting of carbonized plant fragments. A one- or two-foot-thick bed of lignite might have resulted from a ten-foot layer of peat. Had the lignite been buried longer, or by thicker layers of sediment, it is possible that higher grades of coal--sub-bituminous or bituminous--would have resulted.

Sometimes, living trees and newly fallen logs were rapidly buried by sediments so that they escaped decay. These often were not transformed to lignite, but rather changed to petrified wood. This might have happened when a stream changed course or flooded its banks, depositing sand or silt on the trees, or perhaps when ash from the Paleocene volcanoes buried or partially buried some of the ancient forests. After trees were buried, groundwater began to circulate through them. With the help of bacterial action, the water dissolved out the softer cellulose material of the wood. The same water also carried dissolved minerals, among them silica. The silica was deposited in the spaces left when the plant tissues dissolved out.

This petrification process went on for a long time so that replacement was gradual, a molecule of plant tissue being simultaneously replaced by a molecule of silica. In this way, the original cellular structure of the wood was preserved so that, in many cases, the petrified stumps and logs look exactly like old wood stumps or logs except that they are stone. The petrified wood found in the badlands is not a highly colored variety such as is common in some areas; it is mostly very light brown or cream colored.

Among the most outstanding features of the Little Missouri Badlands are the layers of clinker ("scoria") (fig. 4). These are

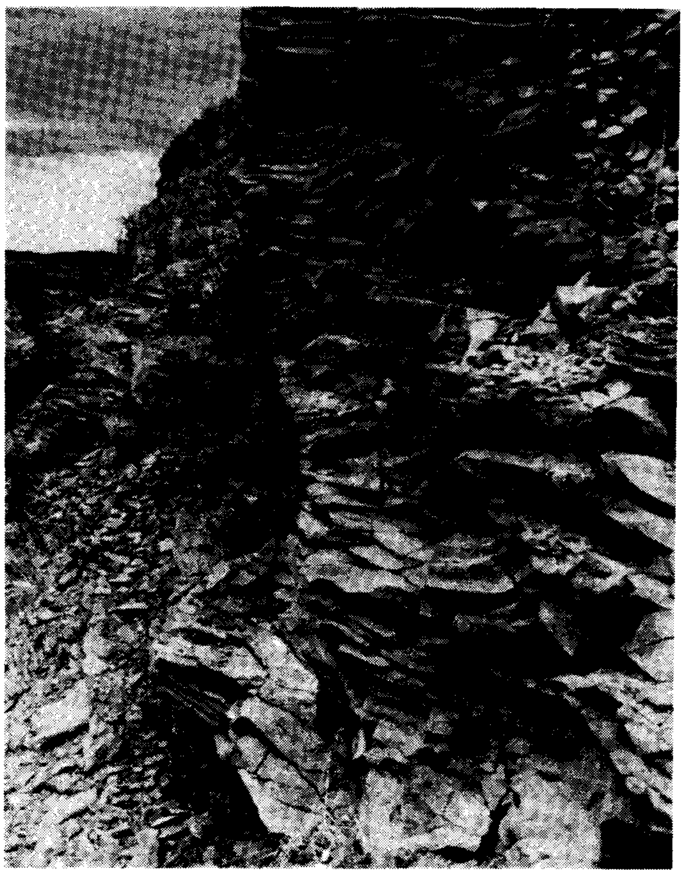

Figure 4. Clinker exposed near Buck Hill in the South Unit of Theodore Roosevelt National Park. The baked sand here has columnar shapes.

especially striking after a shower, which intensifies the typical reddish coloration. Clinker is a natural brick deposit, formed when lignite veins burned. The resulting heat baked the overlying sediments, hardening them and changing their color. The baking process goes on today, whenever a lignite seam is ignited. Exposed lignite seams may catch fire when they are struck by lightning or when prairie fires burn over them or, sometimes, they ignite spontaneously.

The colors of the clinker depend on the temperature reached at different localities during the baking process, and on the mineral composition and grain size of the baked materials. The most typical colors are shades of red. The red color is due mainly to the presence of the mineral *hematite*. Hematite is iron oxide, which is the same as common rust. All of the sedimentary rocks from which the badlands are carved contain iron-bearing minerals, although none are of commercial value in these concentrations. Iron is oxidized more easily at high temperatures than at normal temperatures, so when the sediment is baked, hematite forms.

In addition to changing their color, the baking process hardens the sediments, sometimes fusing them to glass if the heat is intense enough. The differences in hardness of the sediments has affected the way erosion has gone on in the badlands, in some places resulting in hills and buttes capped with hard, red layers of clinker.

It has often seemed to me that our North Dakota badlands are especially beautiful because wooded areas occur in many of the draws and on the north-facing slopes. The badlands along the Little Missouri River at Little Missouri Bay State Park near Mandaree in Dunn County are especially scenic because of the vegetation in the area. Evergreens, such as the Rocky Mountain juniper, and creeping red cedar, are interspersed with trembling aspen, cottonwood, and poplar. Limber pine is found in the badlands in places in the southwest corner of the state. Near Amidon, in Slope County, fumes from a burning vein of coal have altered the growth habits of the juniper trees, causing them to grow in tall, columnar shapes. After such fires go out, the descendants of these shapely trees revert to the typical, somewhat bush-like, juniper shape, common elsewhere in the badlands.

I've given only a short discussion about the geology of North Dakota's badlands. The details would require a book. Remember too, that the geology is only a part of the whole story--the climate, animals and birds, plants, insects--all of these need to be dealt with before the total badlands environment can be understood and appreciated. I've hiked and camped in the Little Missouri Badlands many times and, oddly enough, I think I enjoy them most at night. It's sometimes hard to accept that the stark, intricately eroded pinnacles are real. From a distance in the moonlight they appear like ruins of an ancient city rather than simply sand and clay. Evening rains accentuate the colors almost beyond belief--the clinker beds take on intense and unique shades of red and orange--and the fresh smells of wet sage and cedar have to be experienced, because I certainly can't describe them adequately.

If you haven't had a chance to spend some time in the badlands lately, by all means, do so! It's a rewarding experience.

MAP SALES AT THE NDGS

--Mark Luther

The North Dakota Geological Survey is now a dealer for USGS topographic maps. During its last session, the legislature authorized the NDGS to purchase cartographic products from the federal government, and resell them to the public. The NDGS replaces the State Water Commission as the state agency selling topographic maps in North Dakota.

The NDGS will carry 7.5 minute (1:24,000 scale), 30 x 60 minute (1:100,000 scale), and 1 x 2 degree (1:250,000 scale) maps, covering the entire state of North Dakota and adjacent areas of neighboring states. We also provide a variety of maps showing the entire state at a 1:500,000 scale--emphasizing differing features such as geology, topography, roads, boundaries, and shaded relief. Other federally produced maps that we have in stock or plan to carry include: grassland maps, atlas series maps of the U.S., and 1:500,000 scale maps of the adjacent states.

In addition to the maps we already have in stock, the NDGS has the information available to help you locate existing maps for almost every state in the U.S., and we can either assist in ordering them or include them in our regular map order (it takes about a month for us to receive map orders from the USGS).

The NDGS will accept orders by phone or mail, or you may visit us at our office (1022 East Divide Avenue) in Bismarck (however, please note that our mailing address, on the cover of this newsletter, is 600 East Boulevard, Bismarck, ND 58505-0840). When ordering by mail or phone, please be sure to indicate the map name and scale you want. If you are not sure, map indexes can be sent free of charge upon request. Please address all orders to the Publications Clerk.

PRICES

7.5 Minute maps	$ 2.50
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SHIPPING

1 to 5 maps	$ 2.75
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The NDGS has invested considerable time setting up the maps sales operation in the hope that we will be able to provide the best possible service to the public and to other agencies. With over 12,000 maps currently in stock and a computerized inventory system, we should rarely run out of any particular map; still, unforseen circumstances (ie., late orders, unusually large orders, etc.) may occasionally lead to temporary unavailability of a particular map. We will make every effort to minimize this inconvenience. Maps are available over the counter, or we can ship them the same day an order is received.

We began selling maps in March, although we were not fully stocked until the end of May. Despite the fact that we have not yet advertised, we have had a substantial number of map orders already. We hope that you will take advantage of our map sales service. Please drop by our office and see our operation when you are in Bismarck.

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.

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