# NEWSLETTER
# NDGS

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### COVER PHOTO

North Dakota Geological Survey field assistants, T. T. Quirke (L) and unidentified man (R) at Pedestal Rock in the Killdeer Mountains, Dunn County. The photo was taken by State Geologist A. G. Leonard sometime between 1910 and 1913.

## BISMARCK MEETING GETS ACCOLADES

--Norman H. Foster

[Editor's Note: The following article appeared in the AAPG EXPLORER in October, 1988. It is reprinted here with the permission of the EXPLORER].

On the eastern banks of the beautiful Missouri River in central North Dakota lies the city of Bismarck, home of the North Dakota Geological Society and site this year of the Rocky Mountain Section of AAPG. Located on the eastern flank of the giant intracratonic Williston Basin, Bismarck provided an excellent setting for an outstanding convention held from Aug. 21-24.

President of the Rocky Mountain Section, Steven H. Harris, secretary/treasurer Gordon Hasket and Roger N. Borchert, general chairman and president of the North Dakota Geological Society, headed up the meeting. An especially strong technical program was put together by Cooper Land (AAPG), Richard LeFever (SEPM) and Terry Rowland (EMD). Many good comments on the technical sessions were heard. David A. Moore, after emerging from the session on Middle Devonian of the Williston Basin, said, "I wasn't coming to the meeting until I saw the list of papers. I haven't been disappointed. I'm going to find more oil as a result of these presentations."

Jim Lewis of Houston, president-elect of AAPG said, "I'm very impressed with the papers; that session of 'Sequence Stratigraphy and Oil in the Rockies,' was as good as I've ever heard. The slides were especially well done."

The field trip committee consisted of Kelly Carlson, Richard LeFever, Terry Zich, Sid Anderson, Randy Burke, Allen Kihm and James Martin. A trip to southern Manitoba led by Don Kent and Hugh McCabe, recognized authorities on the Devonian, visited outcrops of the middle Devonian section. A core workshop and poster session were headed by David Fischer. Cores were displayed on Winnipegosis and Dawson Bay of both Saskatchewan and North Dakota.

Other activities were headed by Nancy Borchert and Linda Johnson, spouse entertainment; David Bickel, publicity; C. B. Thames Jr., awards; Cooper Land, short courses; Steve Harris, logistics/transportation; Doren Dannewitz and Dave Hvinden, registration; Robert Post Johnson, entertainment; and Robert Hogland, finance/budget. All these people worked long and hard, and it showed--the convention was a great success!

Larry Funkhouser has pointed out how important the section meetings have become over the years, and that companies should take the opportunity to send their people to attend oral presentations, continuing education courses, poster sessions, field trips, exhibits (which are very educational) and other functions. It is the best way to learn about an area, keep abreast of new developments, and get stimulating creative insights into exploration and development. Over the years it has been my observation that the ones who attend local, sectional and national geological meetings are frequently consistent oil and gas finders.

A special treat included a trip down the Missouri on the 1876 paddle wheeler The Far West. The boat traveled downstream to Fort Abraham Lincoln for a "pitchfork fondue" (Texans take note!). The steaks were put on the tines of pitchforks and thrust into a large pot of boiling cooking oil. The North Dakota corn-fed beef was delicious. Afterwards, tours were given in beautifully restored antique cars. Janet and I had a ride in a 1914 Ford and the rumbleseat of a 1931 Ford.

Next year's meeting will be held in Albuquerque, N.M., a perennial favorite, with Bruce A. Black as president of the Rocky Mountain Section and John C. Lorenz as secretary/treasurer. The 1990 meeting will return to Denver where John H. Dolloff will serve as president.

## NEW NDGS PUBLICATIONS

Miscellaneous Series 72 -- "Oil Exploration and Development in the North Dakota Williston Basin: 1986-1987 Update," was written by David W. Fischer and John P. Bluemle. This report reviews North Dakota's history of oil and gas discovery and production. It analyzes the several exploration cycles the Williston Basin has undergone and reviews the development of significant oil reservoirs. The authors analyze current conditions and offer their best prognosis of future possibilities.

The report includes 20 illustrations and two tables to help the reader better understand the role of oil and gas in North Dakota's economy. Graphs of wildcat wells drilled annually since oil was discovered, the number of new oil pools discovered each year, annual crude oil production, average number of drilling rigs operating in the state, and the amount of oil and gas tax revenues collected by the state are included along with many other illustrations. Tables are included detailing all the new-pool discovery wells for 1986 and 1987.

This 40-page report is available from the Survey for $3.00.

Miscellaneous Map 29 -- "Geologic Highway Map of North Dakota," drawn by John P. Bluemle, is a colored map drawn at a scale of one to a million (about an inch to 26 miles), essentially the same as the official North Dakota State Highway map.

The Geological Highway Map is intended to be used as a general reference map to familiarize the user with North Dakota's diverse and interesting geology. It identifies major geologic features, materials, and landforms that can be seen by people travelling around the State. An east-west cross-section through the Williston Basin shows the major geologic formations that underlie the State.

The reverse side of the Geological Highway Map includes illustrated discussions of such topics as glaciation in North Dakota, the geologic history of the area, and the geologic features that can be seen in North Dakota. Inset maps show other aspects of the State's geology. One of the inset maps identifies points of geologic interest around the State.

The Geological Highway Map of North Dakota is provided folded to a size of 7 inches by 12 inches, and the map can be conveniently used in the same way as a standard highway map. It is available for $1.00 from the North Dakota Geological Survey.

Revised Reissues: Educational Series 17, 18, 19, and 20 -- "Guide to the Geology of Northeastern North Dakota," (Educational Series 17) by Mary E. Bluemle, and "Guide to the Geology of Southeastern North Dakota" (Educational Series 18), "Guide to the Geology of North-Central North Dakota" (Educational Series 19), and "Guide to the Geology of South-Central North Dakota" (Educational Series 20), are by John P. Bluemle.

The four guides are revisions of earlier guidebooks. Each is about 40 pages long and includes a simplified, colored geologic map of the area. Each guidebook also includes several field trips, at least one per county, that the reader can follow to observe the geology of the area.

The guidebooks are useful for teachers or for other people interested in learning more about the geology of the area. They are available in single copies, without charge, from the North Dakota Geological Survey.

"Williston Basin Stratigraphic Nomenclature Chart," was recently released by the Geological Society of America as part of its **Decade of North American Geology** series. This chart was included with volume D-2 of the series (The Geology of North America--Sedimentary Cover of the Craton: U.S.).

The chart was compiled for the Geological Society of America by J. P. Bluemle, S. B. Anderson, and C. G. Carlson. It includes correlations of the formations present in six North Dakota locations, four eastern Montana locations, three northwestern South Dakota locations, and one location each in southern Saskatchewan and Manitoba.

The chart is printed in color, the colors representing rock type. A representative wireline log from the center of the Williston Basin is included to show typical log response. The chart also includes a generalized, colored, west-southwest to east-northeast seismic profile, with several key locations identified.

Although this correlation chart was not published by the North Dakota Geological Survey, we do have a limited supply of them that we can provide, without charge.

## NDGS-NCIC STATE-AFFILIATE FACTS

--David Brekke

A previous newsletter article (June 1988) introduced our readers to the concept of a National Cartographic Information Center (NCIC) State Affiliate Office at NDGS. This article will be an expanded description of what NCIC is, what information is available at the NDGS-NCIC, and how to obtain it.

In 1919 the Map Information Office was established in the United States Geological Survey (USGS) by Presidential order. This was to be a central source of information on US maps. The focus of the information tended to be limited to USGS products rather than products from other agencies or the private sector. After a task force review, the USGS established NCIC in 1974 to serve as the public's primary source for information concerning the availability of cartographic, geographic, and remotely sensed data from all federal agencies and contributing state agencies and private concerns. Currently, more than 30 federal agencies collect and prepare cartographic and geographic materials for distribution (table 1). NCIC collects, sorts, and describes all types of cartographic information from these agencies and makes it available to the public. As part of the program, NCIC began in 1976 to develop a network of state-affiliated offices to provide local access to this information. Offices are now located in every state to assist the public.

Part of the mission of the NDGS is to collect and disseminate information on the geology and natural resources of North Dakota. The concept and goals of NCIC conform to that mission. In this cooperative effort, we are able to provide a wealth of information to the public (table 2). At this time NDGS is not able to actually sell topographic maps or any other cartographic and geographic products produced by federal agencies. However, we can provide ordering information and assistance in locating the desired product and specific area of interest. Of course, we can provide our own maps and publications as always.

Our NCIC materials include microfiche catalogs, map indexes, and informational brochures on most of the available products. The public can browse through the material individually at our office, contact us by telephone, or get assistance by writing the Survey. We can send out order forms and other information. In addition, anyone can get assistance from the USGS National Cartographic Information Center in Reston, Virginia, by calling 1-800-USA-MAPS.

Table 1. List of Federal agencies on which NCIC can provide information.

| | |
|---|---|
| US Geological Survey | US Forest Service |
| Bureau of Land Management | Bureau of the Census |
| Water and Power Resources Service | Library of Congress |
| Central Intelligence Agency | Corps of Engineers |
| National Oceanic and Atmospheric Adm | National Ocean Survey |
| Federal Highway Administration | Federal Power Commission |
| International Boundary Commission | Tennessee Valley Authority |
| National Archives and Records Service | Soil Conservation Service |
| Mississippi River Commission | Defense Mapping Agency |
| Agricultural Stabilization and Conservation Service | NASA |

Table 2. List of types of information available.

<u>Maps and charts</u>
Historic, current, and in progress
Topographic and planimetric
Mapping byproducts
Bathymetric
Geologic
Geophysical
Hydrologic
Land use/land cover
Aeronautical charts
Nautical charts
Utility maps
Transportation maps
County highway maps
Recreational maps
River charts
Atlases
Orthophoto map byproducts
Soil survey maps
Mineral and resources maps
Climate maps

<u>Aerial and space photos</u>
High altitude photographs
Low altitude photographs
Space photos
Space exploration photos

<u>Geodetic data</u>

<u>Digital Cartographic data</u>
Elevations models
Line graphs (planimetric)
Geographic names data
User guides
Sources of applications software

<u>Radar and satellite images</u>
Side-Looking Airborne Radar
Landsat
SPOT

## HORIZONTAL DRILLING UPDATE

--Marv Rygh

Possibly the most encouraging news in the North Dakota petroleum industry is the initial success of Meridian Oil, Inc's horizontal drilling program. I had initially reported on the horizontal drilling technique a year ago, in the December 1987 NDGS Newsletter. Meridian Oil (MOI) presently has four horizontal wells on production in North Dakota. The first horizontal well drilled, the Meridian Oil, Inc. Elkhorn #33-11, was completed September 25, 1987. The well has already produced over 90,000 barrels of oil. The average daily production for the Elkhorn #33-11 was 305 barrels of oil per day in October. This rate is actually greater than the initial flowing test of 258 barrels a day. Conoco, Inc. has also completed one horizontal well in North Dakota.

The producing formation for these horizontal wells is the Bakken Formation. The Bakken is not usually a primary target for drilling because it is a "tite" or impermeable shale and siltstone that produces primarily through natural fractures within the shale.

Horizontal drilling into the shale maximizes the possibility of intersecting these fractures, allowing more efficient drainage of the reservoir. An inherent advantage to the Bakken Formation is the low water productivity associated with it. The Elkhorn #33-11 well has produced only 222 barrels of water compared to the 90,000+ barrels of oil cumulative.

These factors, along with the general thin-bedded nature of the Bakken, make the formation an optimum target for horizontal drilling.

Meridian has plans for more horizontal wells and is cautiously optimistic that sustained production from these horizontal wells will offset the increased drilling costs associated with the new technique.

As a result of Meridian's horizontal drilling program, the company has set several industry records, including:

(1) the longest horizontal displacement for a medium-radius hole, 3372 feet.

(2) the longest continuous string of 5 1/2-inch casing run in a medium radius horizontal hole, 14,550 feet.

(3) the deepest kick-off point for a medium radius well, 10,260 feet.

(4) the longest medium radius hole drilled without first drilling a vertical well through the zone and logging prior to kick-off.

Meridian has other horizontal drilling programs in Montana and the company has reported that it has successfully drilled 15 horizontal wells in 15 attempts.

Meridian's success points the way to possible further use of horizontal drilling in other formations. This new technique could result in renewed drilling activity in North Dakota.

## SUCCESS IN WABEK FIELD

--Dave Fischer

Wabek Field (Mississippian/ Sherwood interval production) is located in remote portions of Mountrail and Ward Counties, over 15 miles from the closest production. Discovered in 1982 by Nortex Oil, the initial Wabek Field well received little attention until 1987 when Home

Petroleum Corporation (HPC) began a very successful development received little attention until 1987 when Home Petroleum Corporation (HPC) began a very successful development program. The oil accumulation discovered by the Nortex well is now from the Wabek Field proper and consequently has been re-named Prairie Junction Field.

Wabek Field is located in a large Mississippian re-entrant. Production is found on northeast-trending structural noses, with porous carbonates being replaced updip by anhydrites. Nothing new, exciting, or unexpected for "east flank" Mississippian players. What is significant about Wabek Field is that it is located in a portion of the basin that was once thought by many to be capable of only marginal production.

Initial production in the Wabek Field area was from the lower Sherwood. In February 1982, the Nortex #1-13 Kok (13-152-88) was completed pumping 11 BO and 49 BWPD from approximate 7350-foot perforations. Subsequent drilling in the area resulted in five dry holes. In 1985, HPC successfully completed another well approximately one mile northwest of the Nortex well. The #42-11 Rovig-Ness-State was completed flowing 49 BO and 47 BWPD from upper Sherwood perforations. Although not an impressive initial producer for a Sherwood, production was stable. Two years after the #42-11 Rovig-Ness-State went on line it was still producing a consistent 40 BOPD. A northwest offset to the #42-11 met with tremendous success. The HPC #31-11 Rovig-Ness was completed flowing 314 BO with no water from the Sherwood. Home immediately began a major development program in August of 1988. Home reported monthly production of 88,509 BO and 1054 BW from 18 wells. Additional locations are staked.

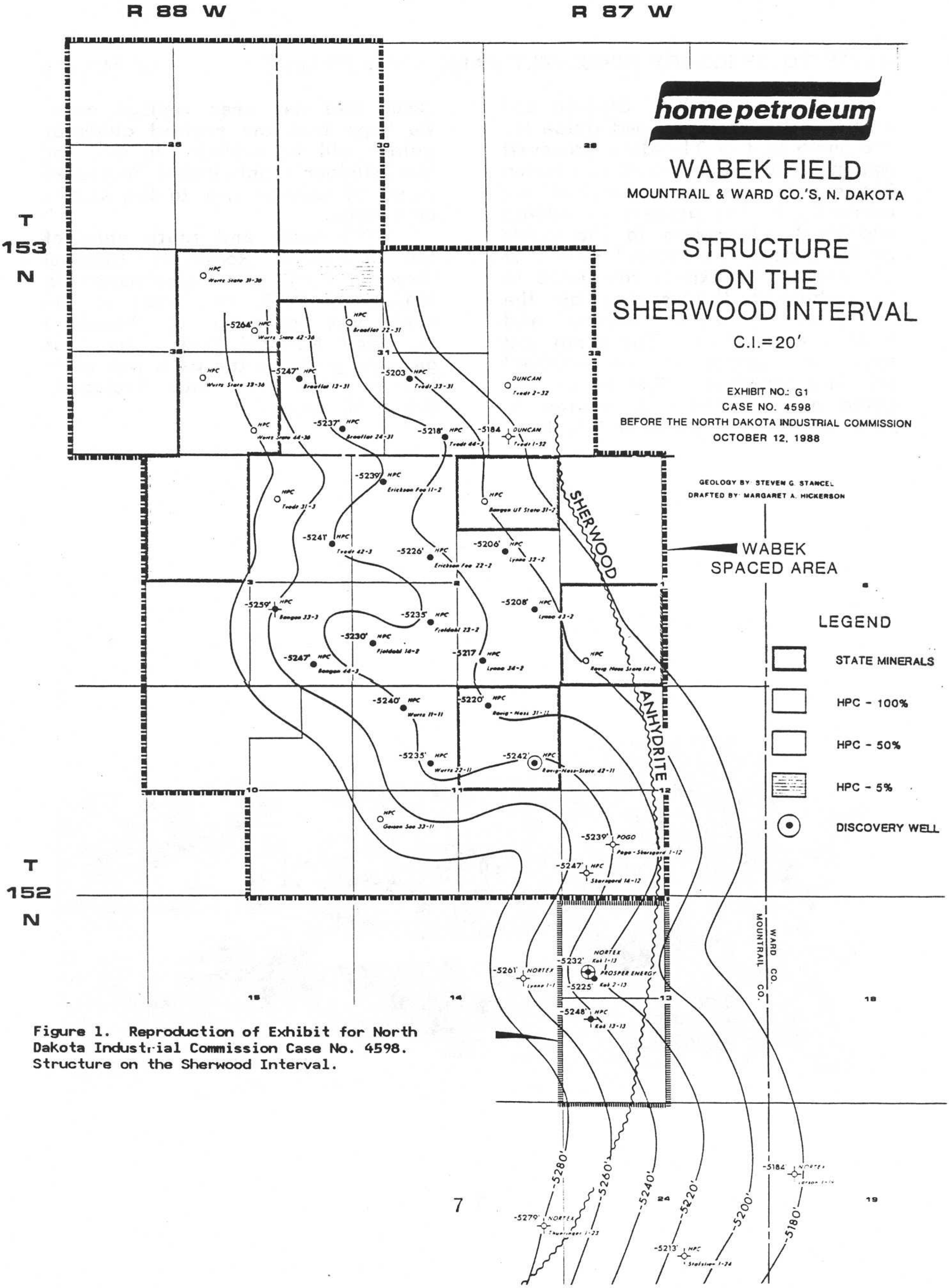


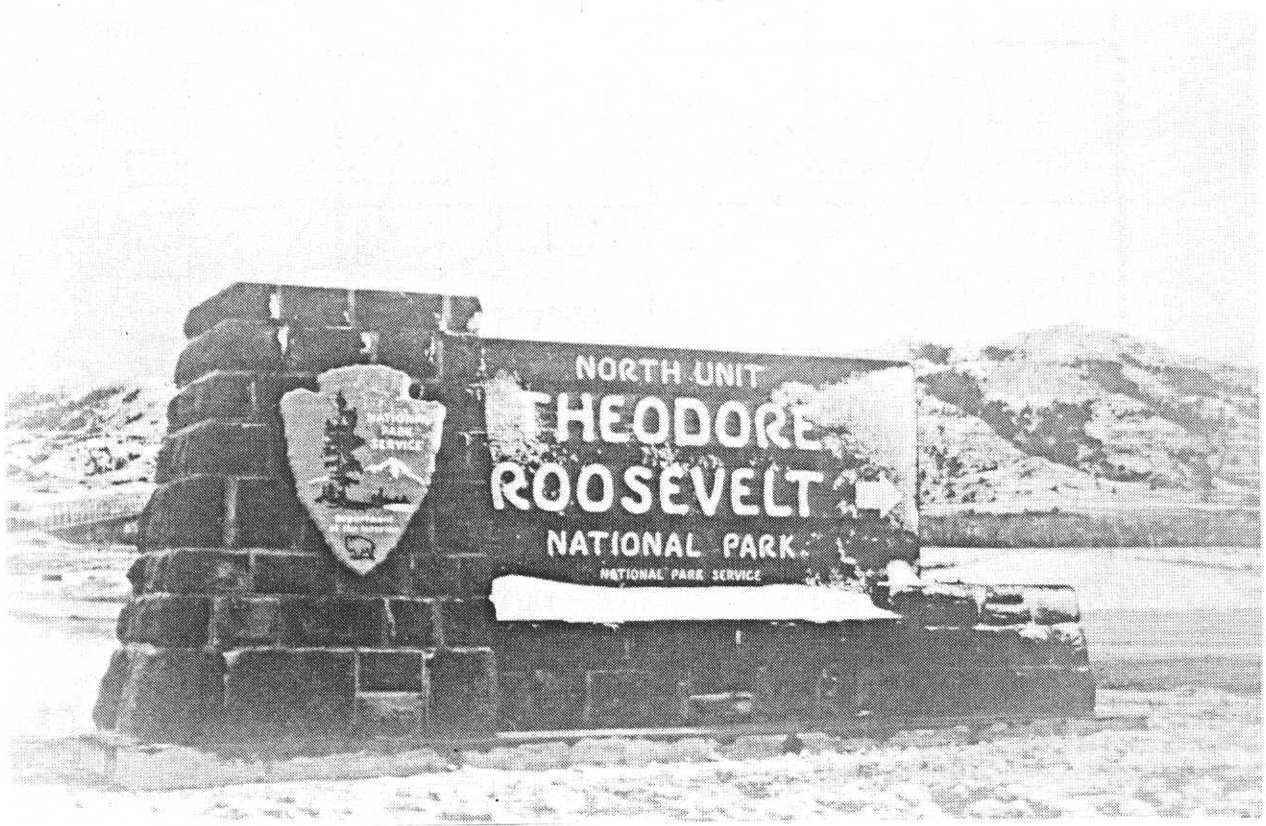

Figure 1. Reproduction of Exhibit for North Dakota Industrial Commission Case No. 4598. Structure on the Sherwood Interval.

## GUIDE TO THEODORE ROOSEVELT PARK - NORTH UNIT

--Ed Murphy

This summer John Bluemle and I compiled a geologic road guide for the north unit of Theodore Roosevelt National Park. Beth Ward and Karen Semerau (of the Park Service) are currently in the process of adding additional information to the guide on the biology and natural history of the park. We expect the guide to be published this spring by the Theodore Roosevelt Nature and History Association. The north and south unit guides may be combined into one pamphlet. The south unit guide now in use was written in 1973 by John Bluemle and Arthur Jacob and has been revised once. We hope that the revised guide or guides will be available in time for this summer's anticipated increased levels of tourism due to the state's centennial.

The north and south units of the Theodore Roosevelt National Memorial Park were established in 1947. In 1978, the name of the park was changed to Theodore Roosevelt National Park. The first geologic guide to the park was written in 1956 by State Geologist, Wilson M. Laird.



## NDGS PARTICIPATES IN STATE'S CENTENNIAL

--John Bluemle

The North Dakota Geological Survey is cooperating with the North Dakota Geological Society and the North Dakota Centennial Commission in a project involving placing informational geologic signs around the State. The Centennial Commission is helping to fund the statewide project, which was applied for by Dr. Eric Clausen, science professor at Minot State University and past president of the Geological Society. I am providing the NDGS' input into the project by writing descriptions and helping to design copy for most of the signs in the eastern half of the State; Dr. Clausen is handling the signs in the western part of North Dakota.

We hope to place about 25 signs in rest areas along the major highways in the State. Most of these will be along the two interstate highways, but signs will also be placed in rest areas along U.S. Highways 2, 52, 85, and 281. Work to date has consisted of visiting all of the potential sites and writing draft copy for most of the signs. Many of the signs will include illustrations, such as maps, diagrams, etc.

Members of the Geological Society will install the signs next spring. The project is scheduled to be completed before the end of June 1989.

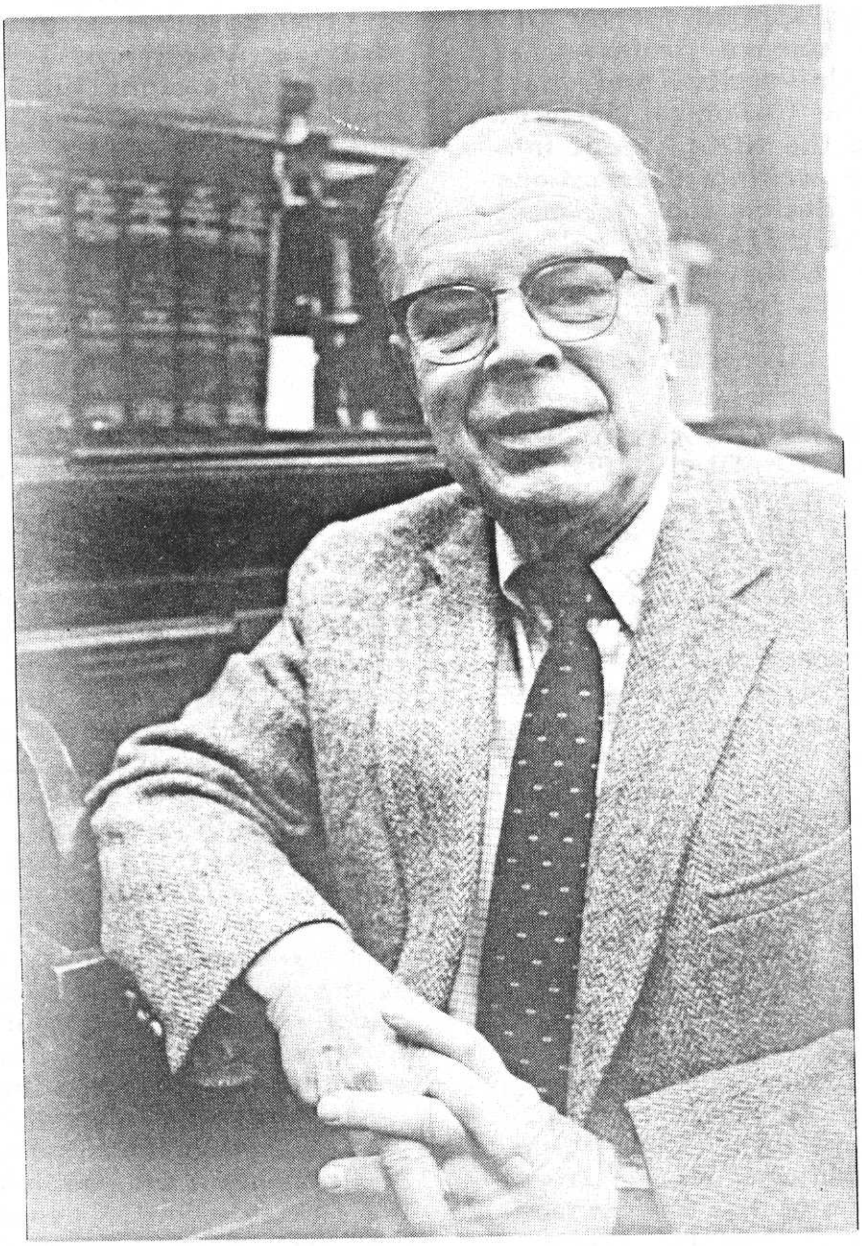
## GEOLOGICAL SYMPOSIUM HONORING PROF. F. D. ("BUD") HOLLAND, JR. SCHEDULED FOR APRIL 14, 1989

--John W. Hoganson

Dr. F. D. ("Bud") Holland, Jr. is retiring from the UND Geology Department after 35 years of dedicated service. Wilson Laird recruited Bud from the University of Cincinnati in 1954 to teach geology at UND. He has taught courses here, primarily in the areas of historical geology, paleontology, and stratigraphy and related topics since then, except for a two-year hiatus when he was Director of Education with the American Geological Institute based in Washington, D.C. (1970-1972).

As one of Bud's former students, I can personally attest to his dedication to student development, not only in the classroom, but also "after hours" and in the field. Bud has been advisor for hundreds of undergraduates and has supervised 20 Masters and 9 Doctoral geology students. His commitment to the need for professor/student interaction is exemplified by his long-term involvement with the UND chapter of the honorary earth science society, Sigma Gamma Epsilon. In addition to teaching, student advisement, and other professional university activities, Bud has compiled an admirable publication record, primarily articles pertaining to North Dakota paleontology. Bud was one of the principal designers of the outstanding UND geology facility, Leonard Hall and, largely because of his efforts, the UND Geology Library is one of the finest in the upper midwest. The impact of Bud's retirement will truly be felt in many ways by UND, its students, and those of us who have worked closely with him over the years.

A geological symposium, in Bud's honor, will be held in Room 100 (lecture bowl), Leonard Hall on the UND campus on April 14, 1989. About 20 of Bud's former students and colleagues will give presentations that day on their current research projects. The papers will be published in a symposium volume by the North Dakota Geological Survey. The symposium will be open to the public, and we hope that many of you will be able to attend to help us honor Bud. For more information, feel free to contact me, John W. Hoganson, Paleontologist, North Dakota Geological Survey, Box 8156, Grand Forks, ND 58202.



## NATURAL SCIENCE FIELD TRIP IS SUCCESS

--John Bluemle

The North Dakota Natural Science Society sponsored a field trip to the Killdeer Mountains on August 20, 1988. The Natural Science Society sponsors a public tour of natural North Dakota sites each summer. The sites are generally chosen for their biologic and geologic interest.

The August field trip was a definite success with about 200 people attending. With such a large group--much larger than we had anticipated--we had to divide the group into two parts after everyone reached the top of the South Mountain. Ed Murphy and I each took half of the group and gave an informal talk about the geology of the Killdeers, showing people some of the things that could be seen there. Alexis Duxbury, of the North Dakota Game and Fish Department, and Bonnie Heidel, North Dakota Parks and Recreation, discussed the botany of the area. John Schultz and Bill Schaller of the Game and Fish Department talked about the wildlife in the area.

After the trip to the Killdeer Mountains, most of the group went to Alick and Grayce Dvirnak's Diamond C Ranch, which is the site of the July 28, 1864 Battle of the Killdeer Mountains. Mr. Dvirnak talked to the group about the history of the area. In the evening, the group reassemabled at Little Missouri Bay State Park for a steak fry and then a talk by Gerard Baker, a park ranger in the Badlands, and a Hidatsa Indian. Gerard presented explanations of some of his tribe's beliefs.

Although most of the people left the tour on Saturday evening, part of the group that remained took a horseback tour of Little Missouri Park, led by Natural Science Society naturalists. John Schultz led another group of people on a walk up the west side of the South Mountain, a wooded area with numerous beaver dams and ruffed grouse habitat.

Plans for next summer are still extremely tentative, but they call for the group to visit the Sheyenne Dunes Grasslands area in southeastern North Dakota. If you want additional information on our upcoming trip, please let me know and I'll provide it as plans take shape.

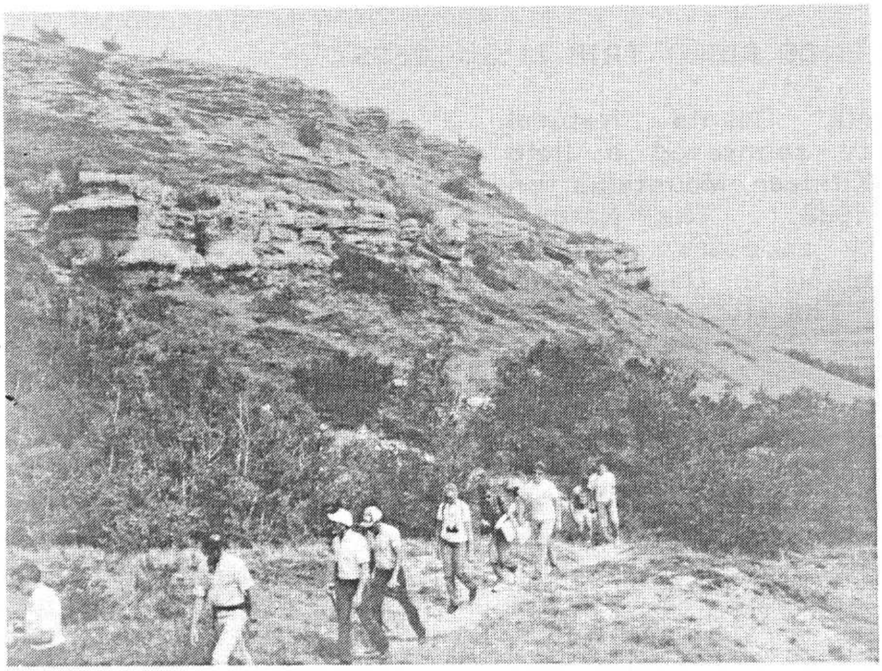


Figure 1. Some of the 200+ people who attended the North Dakota Natural Science Society Killdeer Mountains field trip make their way up the trail on the south side of the Killdeer Mountains.

Figure 2. Entrance to Medicine Hole, south end of the Killdeer Mountains.

## NDGS GROUNDWATER STUDIES

--Ed Murphy

Farmers were not the only North Dakotans affected by last summer's drought. I had planned to take groundwater samples at all of our groundwater-monitoring sites during the spring of 1988. However, I have had to postpone this sampling until the spring of 1989 due to the extremely dry conditions.

Dry waste buried above the water table is devoid of moisture; leachate (contaminated water) cannot be produced without rainfall or snowmelt (fig. 1). In North Dakota, most leachate is normally produced during the spring when snowmelt and large amounts of rainfall create conditions that allow water to infiltrate below the surface and slowly make its way downward toward the water table. If this infiltrating water comes in contact with buried waste, it can produce leachate, which might continue to migrate downward to the water table and degrade the groundwater. The dry conditions during the spring of 1988 created a situation that allowed only small amounts of leachate to be generated at our study sites (fig. 1). Our extremely limited budget will allow us to take only one more round of samples. Had I sampled during a dry spring, and found little or no contamination of the groundwater around the study sites, I could only speculate what the effect might be to the groundwater during a normal spring. For this reason, I decided that I should delay all of the groundwater projects one year.

The following is a short summary of the projects:

### Landfill Project

A total of 103 piezometers have been installed at seven sites (Williston, Harvey, Wishek, Linton, Hillsboro, Devils Lake, and at the International Salt Plant in Williston).

Groundwater samples obtained from the landfill sites during the fall of 1987 indicate that the groundwater around these sites is being contaminated. However, the extent of the area of groundwater degradation was generally within 500 feet of the landfill boundaries and only moderate increases in the trace metals and major ion concentration levels in the degraded groundwater were noted beneath these sites. High concentrations of volatile organic compounds were found in both of the samples that were tested for organic contaminants. This coming spring, all 103 samples will be analyzed for major ions and trace metals and approximately a third of the samples will be tested for pesticides and volatile organic compounds.

### Sewage Lagoon Project

Three municipal lagoons (Linton, Harvey, and Devils Lake) are being monitored to determine how they affect the surrounding groundwater quality. The Linton and Harvey lagoons are located in sand and gravel and the Devils Lake lagoon is located in lacustrine clay (our study of the Devils Lake lagoon is a cooperative project with the State Water Commission).

### Pesticide Project

A total of thirteen piezometers were installed on four separate tracts of federal land in the Denbigh Sand Hills during May of 1987. To date, three rounds of water samples have been taken. These water samples were obtained in July of 1987 and in June and September of 1988.

Concentrations of both Tordon (picloran) and 2, 4-D (2, 4-Dichlorophenoxyacetic acid) have been detected in four of the wells. We hope to continue this project through 1989.

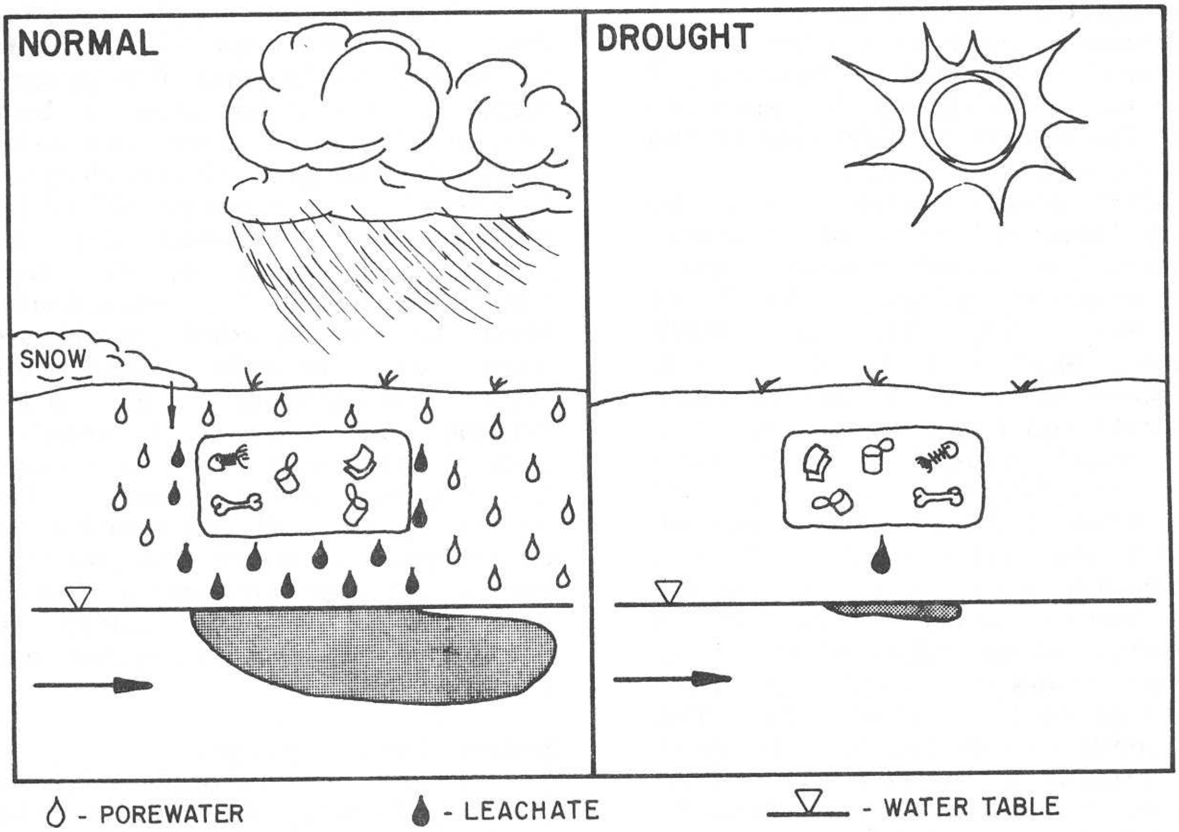



**Figure 1. Buried waste, if it remains dry, will not produce leachate. When water seeps through the waste, it produces leachate, which may reach the water table and contaminate the groundwater.**

## T. T. QUIRKE AND THE KILLDEER MOUNTAINS

--Ed Murphy

[Author's Note: I became interested in T. T. Quirke and his work on the Killdeer Mountains while I was mapping the Killdeer Mountain area for the Dunn County Geologic Bulletin.]

Terence Thomas Quirke was born on July 23, 1886, in Brighton, Sussex, England. He left England at the age of 17 and came to North Dakota to work as a ranch hand. He hoped that the open air would improve his myopic condition and allow him to enter officer training school for the British Navy. T. T. Quirke worked for one year on the Ed Lewis homestead near Baldwin in Burleigh County. He spent the following year (1906) as a clerk for a steamboat company which operated on the Missouri and Yellowstone Rivers. It was during this time that he became good friends with the famous riverboat Captain Grant Marsh. Quirke spent the next four years working at an assortment of

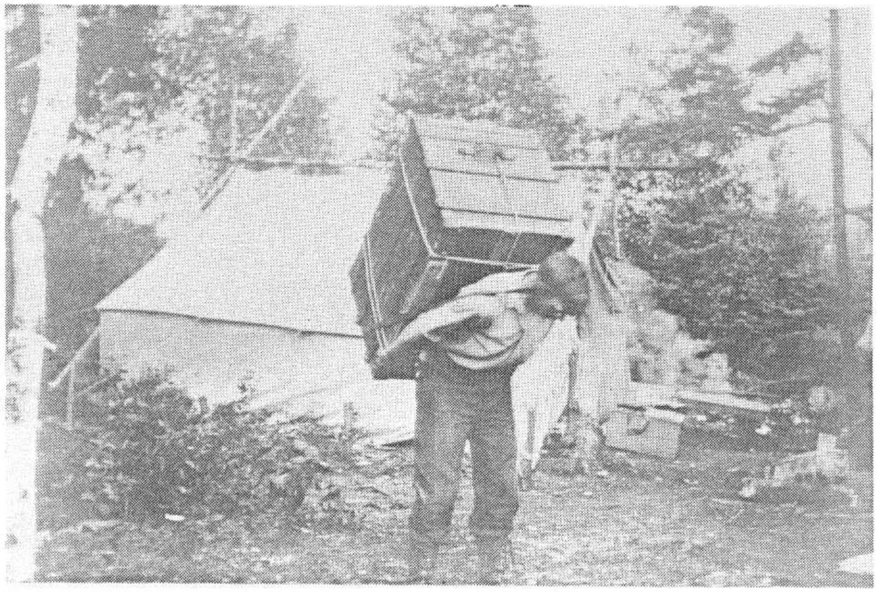


**Figure 1. T. T. Quirke hauling supplies at a base camp about 1910-1913. The photo may have been taken in the Killdeer Mountains.**

jobs in Bismarck. In 1909, he heeded the advice of his uncle, a mining engineer in New Zealand, and enrolled as a student in mining engineering at the University of North Dakota. T. T. Quirke worked for the North Dakota Geological Survey as a field assistant to the State Geologist, Arthur Gray Leonard, assisting Dr. Leonard in his field work in western North Dakota during the summers of 1910 through 1913. In 1912, Quirke received his engineering degree and enrolled in the geology department's graduate program--no doubt a result of his close association with Dr. Leonard. Quirke's genuine respect for Dr. Leonard is evident in his memorial tribute to him in the UND Quarterly Journal (vol. 23, nos. 3 and 4).

At the start of each field season, Dr. Leonard and his assistants would travel from Grand Forks to Dickinson by train and then proceed to their field area by wagon. Field work during this period of time was rather spartan compared to today's comforts. The group stayed in tents and obtained their water from springs or hand-dug ranch wells (figs. 1 and 2). Food staples such as flour, corn meal, oats (for the horses), sugar, salt, coffee, and perhaps salted pork or beef were carried in the wagon; eggs and fresh meat were probably purchased from homesteaders or community stores (fig. 3).

Unfortunately, I was unable to locate T. T. Quirke's field notes. However, A. G. Leonard's field notes describe what conditions were like during the time that Quirke was one of his field assistants:

*June 30, 1912 - We went down to (the) Little Missouri (River) by way of Hay Draw and crossed (the) river at the Diamond C Ranch. The horses struck quicksand and we were stuck in mid-stream. Unloaded wagon, floated wagon box to shore, and pulled wheels out of sand. Spent over three hours in getting across. The road across the river flat had washed away so that we could not get up Cherry Creek, but*

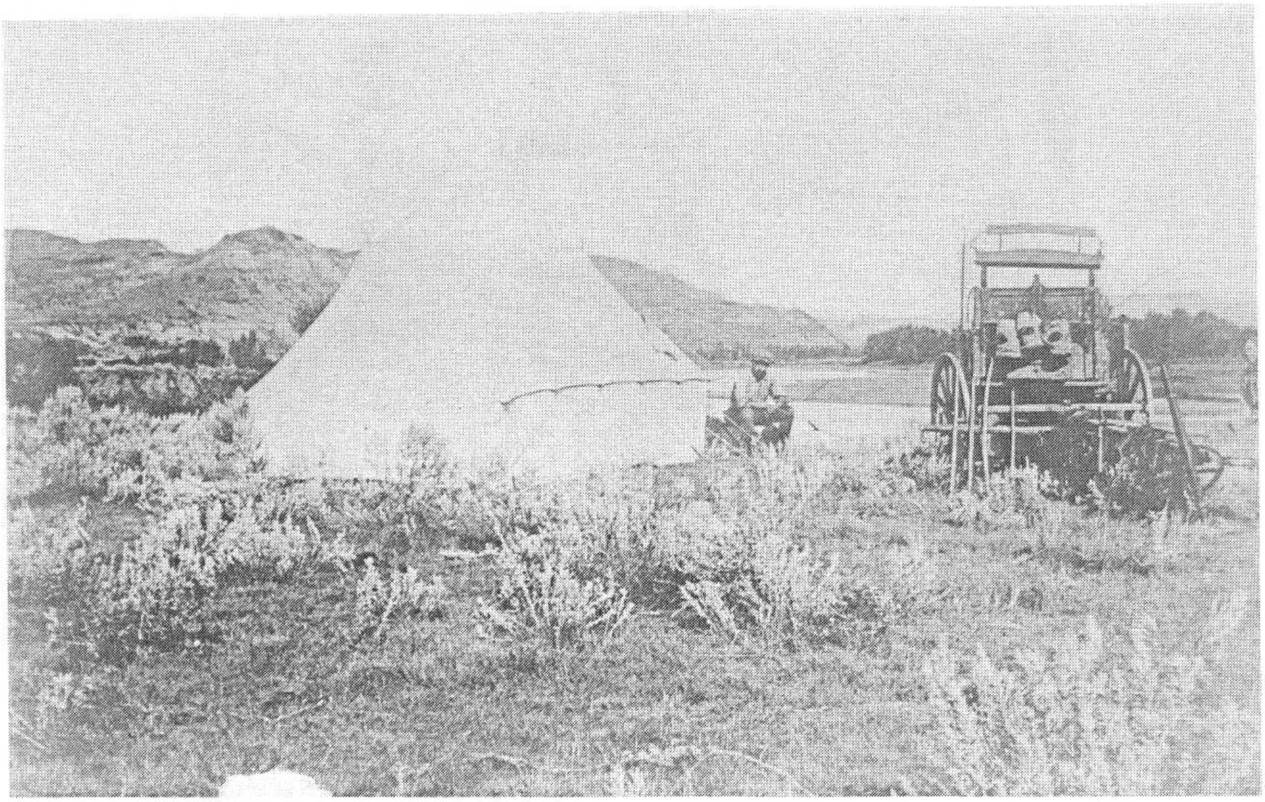


Figure 2. Base camp along the Little Missouri River in western North DaKota about 1910-1913.

Figure 3. T. T. Quirke flipping a flapjack somewhere in Dunn or McKenzie County (about 1910-1913). The photo may have been taken just west of Fayette along the Knife River in Dunn County.

*had to camp near the crossing.*

*July 1, 1912 - While Quirke and Roy were cutting a new road along beside the Little Missouri River, I went down the river to the bluffs below (the) mouth of Cherry Creek on north side of river...*

T. T. Quirke's Masters Thesis is entitled "The Geology of the Killdeer Mountains, Dunn County, North Dakota" (fig. 4). His paper was submitted in 1913 and was the first Masters Thesis to be completed through the geology department at the University of North Dakota. Prior to his report, little was known about the geology of the Killdeer Mountains. The Killdeer Mountains are two prominent mesas in western North Dakota. The mesas rise approximately 700 feet above the surrounding plains and occupy an area approximately nine miles long and six miles wide (fig. 5).

The earliest known reference to the geology of this area was by Babcock and Clapp in 1907 (Fifth Biennial N.D. Geological Survey Report). The earliest known geologic study of the Killdeer Mountains occurred on September 9, 1911 when Quirke and Leonard measured a section along the southeast edge of South Mountain (South Killdeer Mountain) near the village of Oakdale. This is probably when Quirke got the idea for his study. His thesis is the result of a month of field work during the summer of 1912.

Topographic maps of the area were not available to Quirke so he worked from township plats that he had obtained in Bismarck. The township plats that Quirke used did not accurately depict the outline of the Killdeer Mountains so he had to construct his own map using the compass and pace method. He also used an aneroid barometer to obtain elevation information. The map that Quirke produced in 1913, and the elevations on that map, match quite well the maps we use today.

T. T. Quirke set out to determine the lithology of the sedimentary rocks of the Killdeer Mountains, their environments of deposition, and if possible, their geologic age. He hoped to determine the age based on any fossils he might find. He found that the rocks along the edge of the mountains were generally poorly exposed. He measured geologic sections at eight localities throughout the Killdeer Mountains. Construction of his geologic map required that he cover virtually all of the 30-odd miles of the mountain perimeter. Quirke found that the Killdeer Mountains are capped by a 200-foot-thick carbonate, which is interbedded with sandstone and generally forms three distinct ledges throughout the mountains (fig. 6). Quirke correctly interpreted the environment of deposition of these sediments to be within a lake or series of lakes. He found pebbles in the carbonate along the southwest end of South Mountain and felt that this was the result of a river system entering the lake near this spot. The lower-most carbonate ledge-former is underlain by pale green clays and sand, which are devoid of carbonaceous material. These sediments are generally poorly exposed due to vegetation cover. These green sediments are approximately 200 feet thick and overlie the coal-bearing sedimentary rocks of the Fort Union Group. Quirke found the contact between these two groups of sedimentary rocks exposed at three localities throughout the mountains. In 1984, I was able to find the contact at only one of these sites due to soil and vegetative changes that have occurred over the last 70 years.

Despite a diligent search, T. T. Quirke found no fossil shells or fossil bone within the Killdeer Mountain strata. He theorized that the

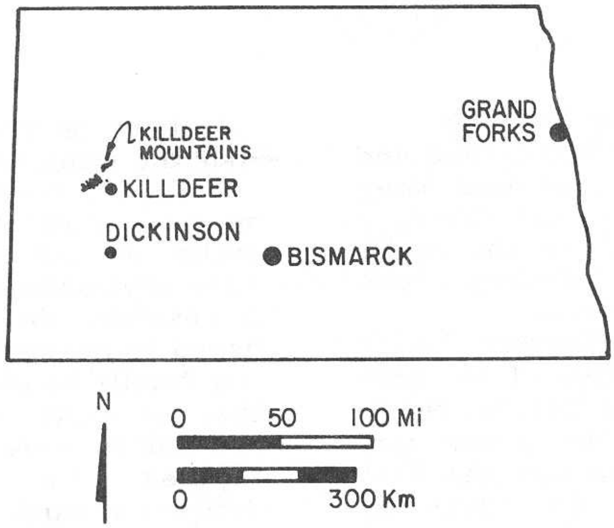



**Figure 4. Location map of the Killdeer Mountains, Dunn County, North Dakota.**

rocks comprising the mountains were Oligocene in age and belonged within the White River Formation (now recognized as a Group). He based this conclusion partly upon the petrographic similarities he noted between the Killdeer Mountain rocks and known Oligocene-age rocks (fossil-bearing) within the state. He also reasoned that these rocks were part of the White River Group because only this unit had been found to overlie the Fort Union Group within the state. He also determined that rocks of the White River Group were separated from those of the Fort Union Group by an unconformity, because the beds above the contact of these units were dipping at a different angle than those below.

Quirke indicated the location of four different caves on his map. Only one of these, Medicine Hole, can still be seen today. The other three have been filled in by dirt, either by a rancher concerned for the safety of his cattle or by workers constructing the numerous radio towers that occupy the mountains. The caves all appear to have been the result of slope movement and were not created by the dissolution of the carbonate rock by snowmelt or rainwater. Although area ranchers had gone down Medicine Hole before Quirke did in 1912, he was the first scientist to explore it and write a description of it. Medicine Hole is actually an east-west trending crack that is only a few feet wide but at least 70 feet deep. The crack resulted when a section of the carbonate caprock separated and tilted away from the mountain due to the undermining of the soft sediment below it.

T. T. Quirke went on from the University of North Dakota to have a distinguished career in the field of geology (fig. 7). He received a PhD in geology from the University of Chicago in 1915 and taught for the next four years at the University of Minnesota. In 1919, he accepted the position of chairman of the geology and geography department at the University of Illinois. He held this position until 1928. Quirke was a professor at the University of Illinois until his death in 1947. He spent the summers of 1919-1931 as Chief of the Survey Party for the Geological Survey of Canada. During his career, Quirke published numerous articles and textbooks on a variety of geologic topics. He further contributed to the understanding of North Dakota geology with his article on the

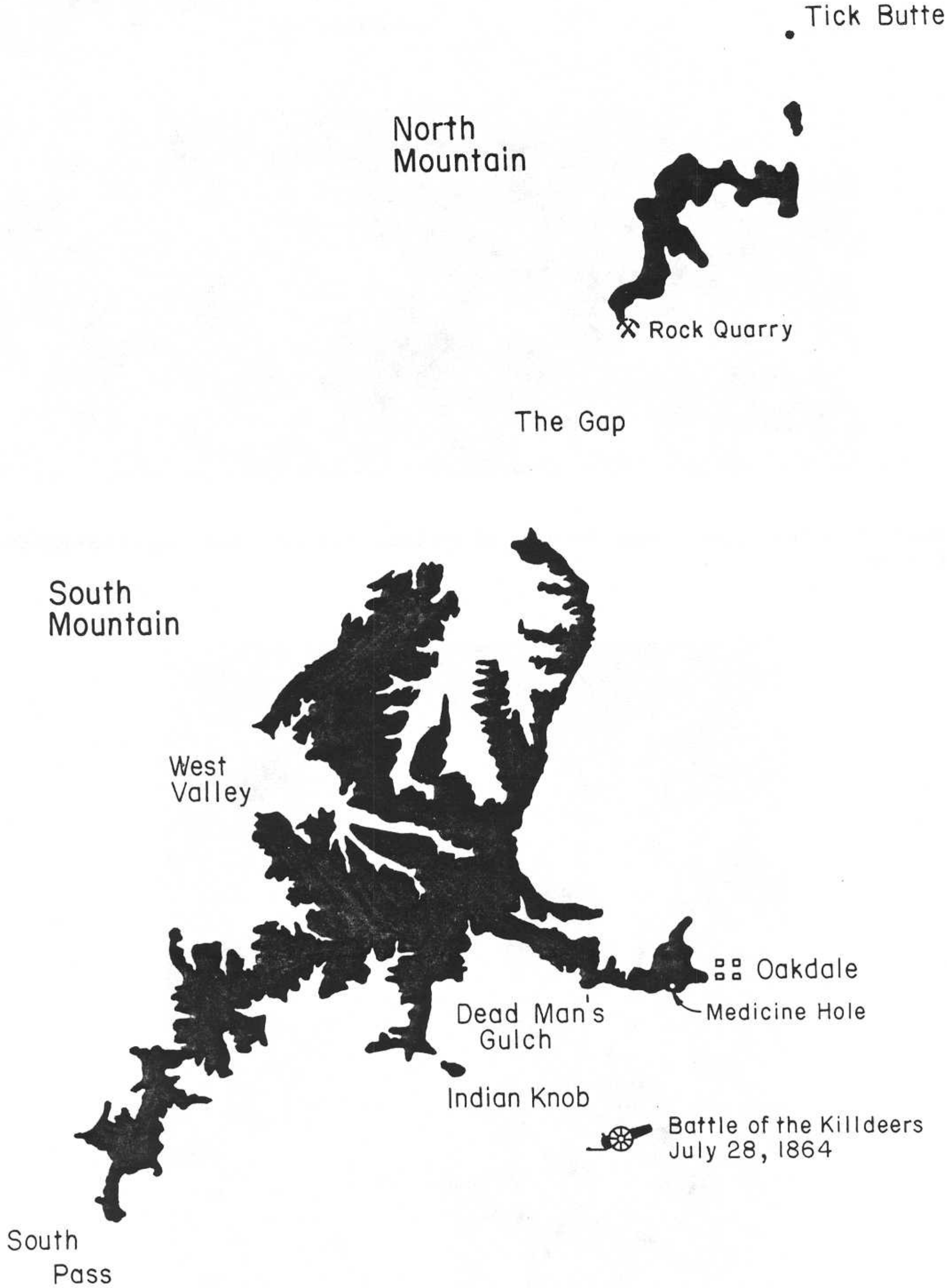



**Figure 5. A simplified version of T. T. Quirke's 1913 map of the Killdeer Mountains. The rock quarry began operations in the 1980s.**

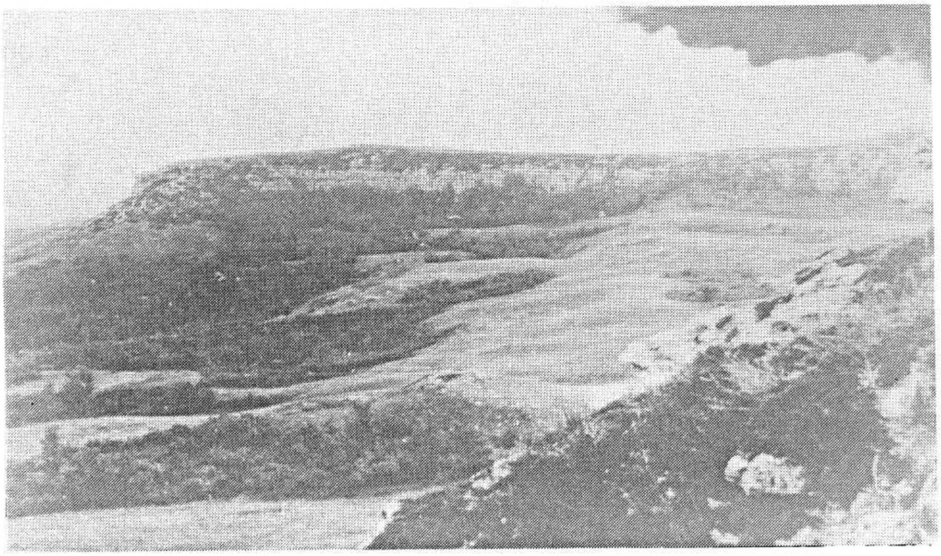


Figure 6. View looking west across Dead Man's Gulch on South Killdeer Mountain. Photograph taken by T. T. Quirke in 1912.

Figure 7. Terence Thomas Quirke. Photograph was taken during the late 1930s.

Richardton meteorite, which fell on June 30, 1918 (Journal of Geology, vol. 27, no. 6). His most important contributions to geology have probably come from his work on Precambrian rocks in the province of Ontario.

Time has been kind to the work done on the Killdeer Mountains by Terence Thomas Quirke. Most of the observations he made and the theories he based upon those observations are still valid today -- some 75 years later. Some of the questions Quirke was asking in 1912 are still being asked today: "What is the relief on the unconformity below the White River Group?" "What is the age of the carbonate caprock?" "Are there any fossils?" -- such is the nature of geology. Today we have access to sophisticated analytical equipment; yet, as important as these tools are, they will never surpass the diligent field observations made on the outcrop by trained geologists like T. T. Quirke.

T. T. Quirke's son, Terence T. Quirke, Jr., also has North Dakota ties. A geologist like his father, T. T. Quirke, Jr. was an assistant professor of geology at the University of North Dakota from 1958 to 1960. He is currently Supervisory Senior Staff Geologist with American Copper & Nickel Company, Inc. in Golden, Colorado.

I would like to thank Mrs. Francis Quirke Washburn for her invaluable help with this article and for the photographs of her father that she sent me. Information was also obtained from the T. T. Quirke memorial tributes written by Carleton A. Chapman (Geological Society of America, 1948, Proceedings of 1947, p. 167-172 and American Mineralogist, 1948, vol. 33, no. 5, p. 178-184, and by Harold R. Wanless, Illinois Academy of Science Transactions, vol. 41, p. 118-119).

## KILLDEER MOUNTAIN STUDIES

Geologists have continued the study of the Killdeer Mountains, which T. T. Quirke began. The following is a list of the studies and a brief explanation of their contribution:

1. Quirke, T. T., 1913, UND Masters' Thesis
    a. First detailed map of the Killdeer Mountains
    b. First published measured sections (8 total)
    c. Assigned Oligocene age to the sedimentary rocks of the Killdeer Mountains
    d. First to note the absence of well-defined fossils
    e. Attributed the environment of deposition to be within a shallow fresh-water lake or a series of such lakes with a river system entering at the southwest corner
    f. First to describe Medicine Hole
    g. First to recognize distinct ledges or benches with the caprock

2. Skinner, Morris, 1950s (see Tedford)

3. Denson and Gill, 1965, U.S.G.S. Professional Paper 463
    a. First to recognize that the rocks of the Killdeer Mountains contain volcanic rock fragments
    b. Theorized that the carbonate caprock was part of the Arikaree Formation and is Miocene in age. They based this upon compositional differences between the carbonate caprock and rocks of known Oligocene age as well as on the partly volcanic origin of the sediment

4. Stone, W. R., 1973, UND PhD Dissertation
    a. Found similarity between sedimentary rocks below the carbon-

ate caprock in the Killdeer Mountains and Oligocene rocks in the badlands south of South Heart

b. Recognized a concretionary marker bed in the carbonate caprock

c. Detected volcanic glass fragments in thin sections of the sandstones between the carbonate bench-formers recognized by Quirke

5. Delimata, J. J., 1975, UND PhD Dissertation

a. Speculated that the rhyolitic composition of the tuffaceous (volcanic) sandstones within the carbonates pointed to these rocks being of Pliocene age

b. Measured 43 stratigraphic sections throughout the Killdeer Mountains

c. Determined that Stone's marker bed consists not of concretions but of numerous fossil burrows; renamed it the "wormy marker bed"

d. Detailed discussion of the sedimentary petrography

e. Found evidence for not only lacustrine (lake) and fluvial (stream) deposits, but also for eolian (wind) deposits

6. Forsman, N. F., 1986, NDGS Report of Investigation 87

a. Determined that at least two units in the Killdeer Mountains are volcanic tuffs

b. Noted that tuffs may consist of ash from one eruption or from a series of eruptions

c. Noted that glass within the tuffs is of sufficient quality to enable radiometric or fission-track dating

d. Noted that petrologic fingerprinting of ash units may eventually be used to correlate the Killdeer Mountain deposits to other units in the Great Plains

7. Tedford, R. H., 1986 - Correspondence

a. Fossil mammal bones collected from the carbonate caprock by Morris Skinner have been identified by the American Museum of Natural History as Early Miocene in age

8. Hoganson, Forsman, LeFever, and Murphy, on-going COGEOMAP project

a. Collected and prepared ash samples for age-dating and for petrologic fingerprinting

b. Hope to determine whether ashes in Killdeer Mountains represent a single or multiple eruptions

c. Hope to compare fingerprinted Killdeer Mountain ash or ashes to other such deposits in the Great Plains

## LITTLE BADLANDS AND FITTERER RANCH FOSSIL SITES PLACED ON NORTH DAKOTA'S REGISTRY OF NATURAL AREAS

--John W. Hoganson

One of the primary objectives of the North Dakota Geological Survey's Fossil Studies Program is to seek protection for North Dakota's significant fossil sites. One way in which we are achieving that goal is through a cooperative effort with the North Dakota Parks and Recreation Department wherein fossil sites receive protection through the North Dakota Natural Areas Registry Program. This program was created by and is administered jointly by the state Parks and Recreation Department and the North Dakota Chapter of the Nature Conservancy. In special cases, when fossil sites are involved, the Geological Survey becomes an active participant in the program. North Dakota's first fossil sites to be included in the program, Little Badlands and Fitterer Ranch, were placed on the Natural Areas Registry during a ceremony at the State Capitol on December 2, 1988.

The North Dakota Natural Areas Registry is part of the state's nature preserve plan. It is a program developed to recognize and honor citizens of the state who are committed to preserve outstanding natural areas under their stewardship. The program encourages the protection of privately owned, natural, undeveloped lands through citizen-based conservation. About 40 natural areas are currently on the registry. Most of these sites are recognized as natural areas because of their biological significance--habitats for rare plants or animals, etc. In recognition of the landowners commitment to protect part of our state's natural heritage, they are presented with a plaque and certificate bearing their name and the name of the registered natural area. The plaque is mounted on a map of North Dakota carved from our state tree, the American Elm. The certificate, expressing appreciation from the citizens of the state, is signed and presented by the Governor.

In the spirit of North Dakota tradition, the agreement between the state and landowner is based on a "handshake." It is a voluntary, nonbinding, and non-regulatory program. The landowners are provided with information about the uniqueness of their particular sites and why the areas were chosen as candidates for the registry program. Scientists employed by the state provide management advice to the landowners upon request and will assist the landowners in any way possible to carry out the conservation effort. Landowners of registered natural areas are asked to preserve and protect the sites to the best of their abilities, notify the state of any threats to the area, inform the state if the land is to be sold or ownership transferred, and allow registry representatives to periodically visit the area to determine if the sites are being threatened in any way. The commitment can be terminated by the landowner at any time although the state requests a 30-day notice of cancellation.

The Little Badlands and Fitterer Ranch are areas of sparsely vegetated badland terrain located southwest of Dickinson in Stark County where erosion has exposed fossiliferous, 30 to 50 million-year-old rocks. Most of the fossil-bearing rocks are about 32 million years old and contain remains of a variety of vertebrate animals. Snail, insect, and plant fossils are also found associated with these bones. The fossils, similar to those found in the Big Badlands of South Dakota, provide us with a unique glimpse of what life was like in western North Dakota millions of years before humans inhabited the state.

The Little Badlands, encompassing an area of more than 2000 acres, is by far the largest natural area registered so far. The primary rock unit exposed in the eastern part of the Little Badlands is the extremely fossiliferous, Oligocene age (about 32 million years old) Brule Formation. The low-lying clay hills in this region, consist of the Chadron Formation (slightly older, but still Oligocene age). Farther west, in the Little Badlands, the Brule Formation has been removed by erosion leaving the Chadron Formation the uppermost unit exposed. The farthest western outcrops in the area consist of the Eocene (about 50 million years old) Golden Valley Formation overlain by the Chadron (fig. 1).

Earl Douglass was apparently the first person to recognize the paleontological significance of the Little Badlands. He took part in an expedition sponsored by the Carnegie Museum in Pittsburg in 1905. In a series of articles he wrote after that expedition, he described some of the fossils, primarily rhinoceros and horse bones, collected from the Brule Formation during his trip to North Dakota. The specimens are presumably still at the Carnegie Museum. A. G. Leonard, former State Geologist of North Dakota, studied the geology of the Little Badlands area in the 1920s. The vertebrate fossils he collected, including horse, rhinoceros, deer and camel remains, were listed in his 1922 publication. It has only been in the past few years, however, that fossils from the Little Badlands have drawn much scientific attention, in part as a result of a jointly sponsored study by the Manitoba Museum of Man and Nature and the North Dakota Geological Survey. The Golden Valley Formation, exposed in the western portion of the Little Badlands, has yielded crocodile, turtle, fish, and plant fossils. Most of these fossils were initially described by scientists from large eastern museums and colleges who collected from that area of the Little Badlands during the late 1950s and early 1960s. In fact, turtle fossils are so abundant in one portion of the western Little Badlands that the area is called Turtle Valley.

The Oligocene-age Brule Formation, as in the eastern portion of the Little Badlands, is the main rock unit exposed at the Fitterer Ranch Natural Area (fig. 2). The same kinds of fossils that occur in the eastern Little Badlands are also found at Fitterer Ranch. Morris Skinner, from the Frick Laboratory of the American Museum of Natural History in New York City, was the first scientist to determine the importance of this fossil site. Skinner made extensive collections of vertebrate fossils from the Brule Formation at Fitterer Ranch in the 1940s and 1950s. Most of the fossils collected by him are housed at the American Museum and have not been studied. Fitterer Ranch is one of the main fossil sites included in the study of Oligocene vertebrate fossils from western North Dakota by the North Dakota Geological Survey and Manitoba Museum of Man and Nature (see NDGS Newsletter, December 1984). Over 60 different species of vertebrates have been identified through this study of fossils from the Brule Formation including: fish, frogs, turtles (fig. 3), snakes, birds, shrew-like insect eaters (fig. 4), rabbits, mice, squirrels, saber-toothed cats (fig. 5), ancestral horses, rhinoceroses (fig. 6), sheep-like oreodonts, giant pigs, camels, and deer.

The Little Badlands and Fitterer Ranch Natural Areas are two of the most significant fossil localities in North Dakota because the abundant fossils found at the sites provide us with information about the kinds of animals that existed in North Dakota 32 million years ago and the type of environment and climate in which they lived (fig. 7). The Little Badlands and Fitterer Ranch sites are also important from a biological perspective because two rare plants, the Bent-flowered Milk-vetch and Desert Wirelettuce, grow in the clay-rich soils and the buttes provide a habitat for Golden Eagles and other rare birds of prey.

It is my pleasure to again thank: Robert and Jane Fitterer (Dickinson), Albert and Anne Privratsky (South Heart), Ben and Birdi Privratsky (South Heart), Dan

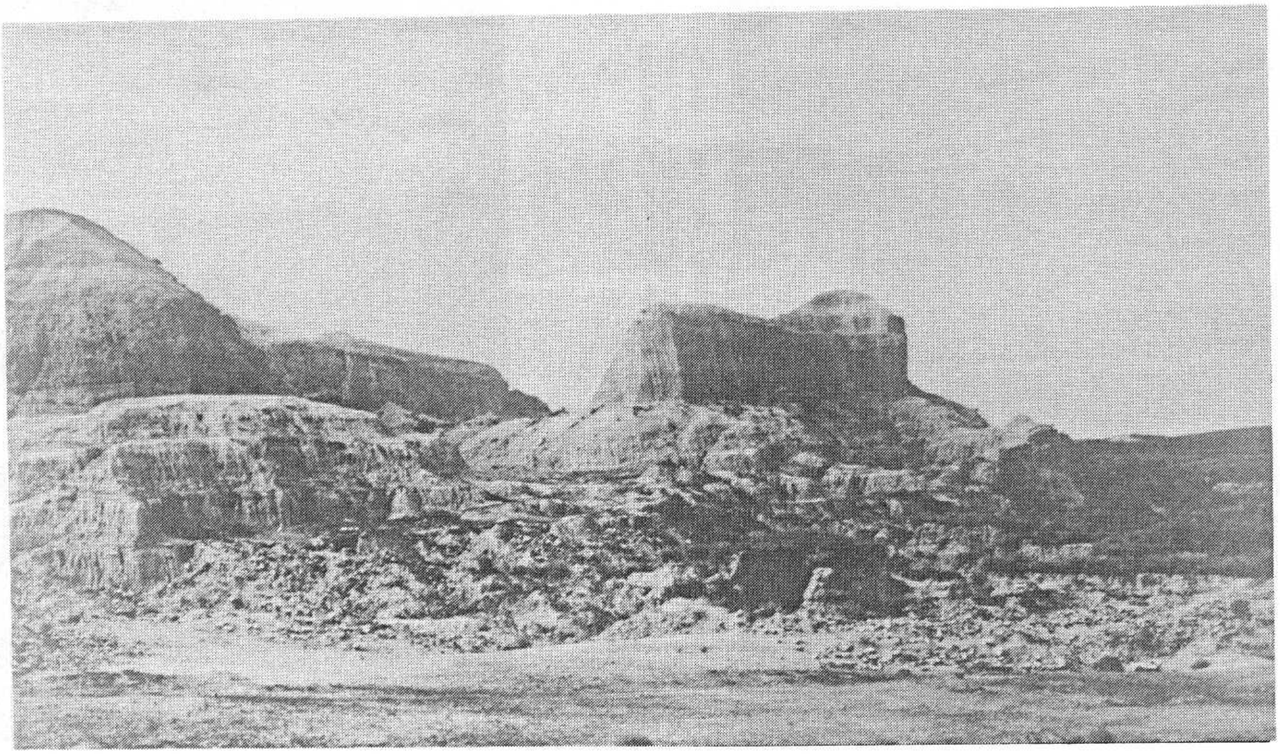


Figure 1. Badland terrain in the western part of the Little Badlands Natural Area where the Eocene Golden Valley and Oligocene Chadron formations are exposed.

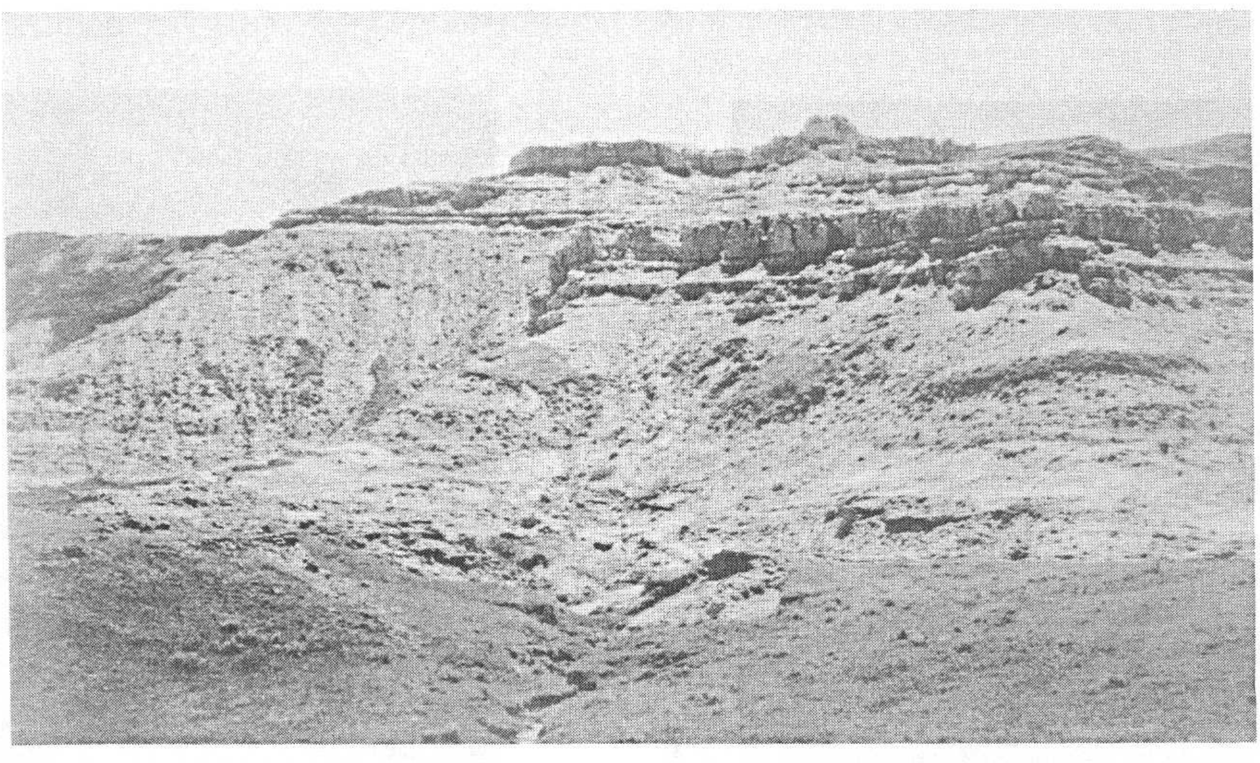


Figure 2. Outcrop of the fossiliferous Oligocene age Brule Formation at the Fitterer Ranch Natural Area.

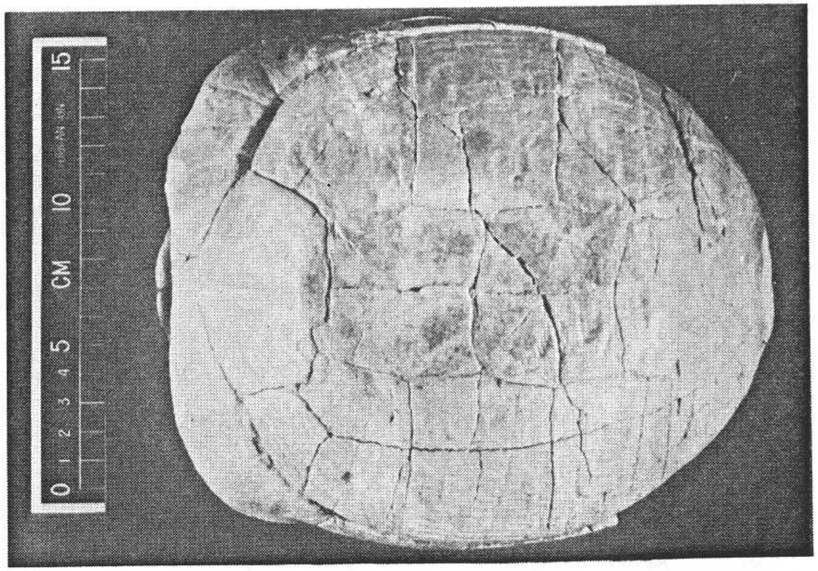



Figure 3. Shell (top view) of the dryland tortoise, <u>Stylemys.</u>

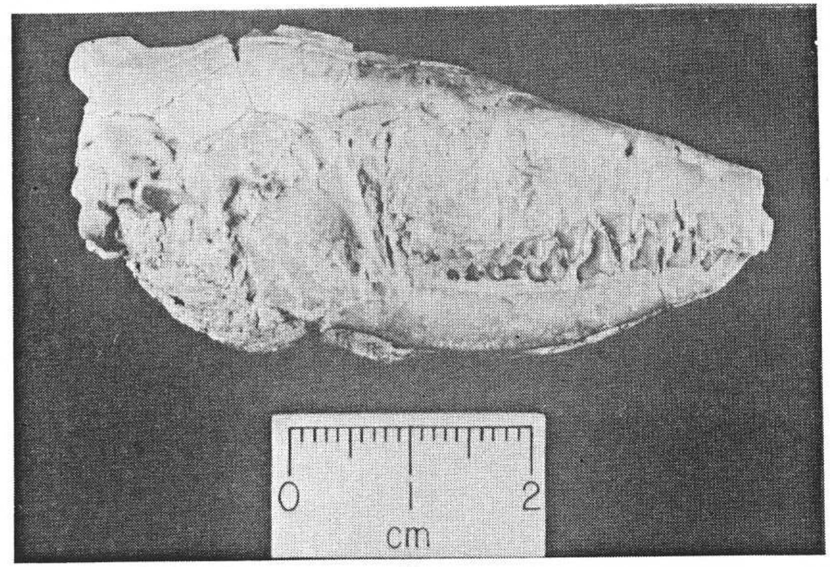



Figure 4. Skull (right side) of the insect-eating, shrew-like animal, <u>Leptictis</u>. On loan from the North Dakota State University geology department.

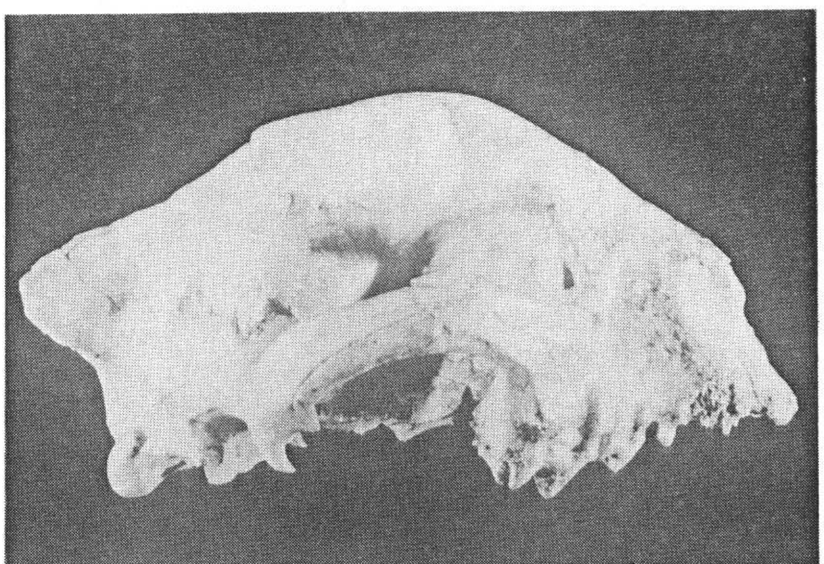


Figure 5. Skull (right side) of the early saber-toothed cat, <u>Dinictis.</u>

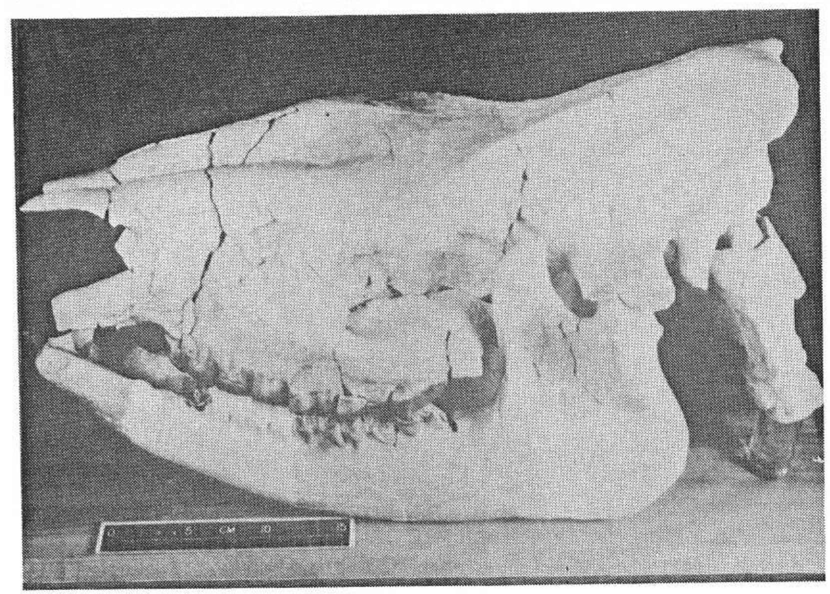


Figure 6. Skull (left side) of the hornless, running rhinoceros, <u>Caenopus.</u>

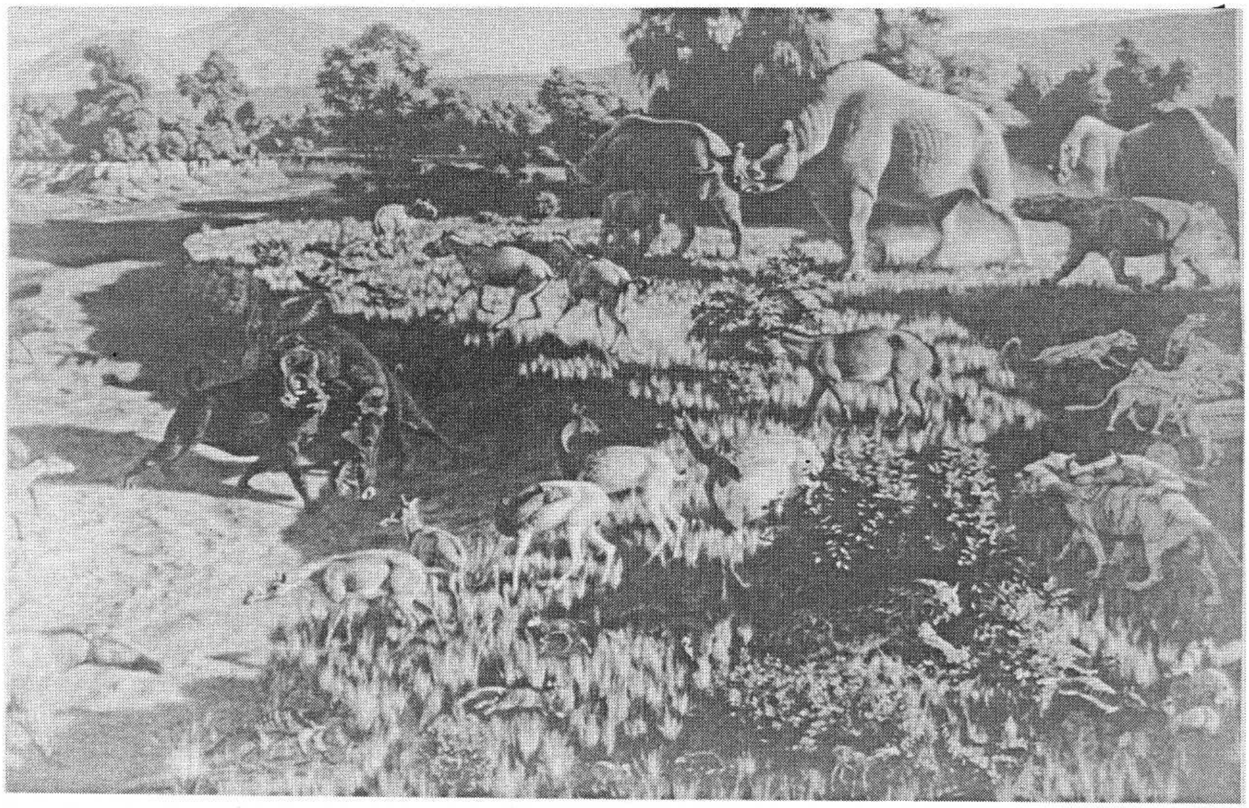
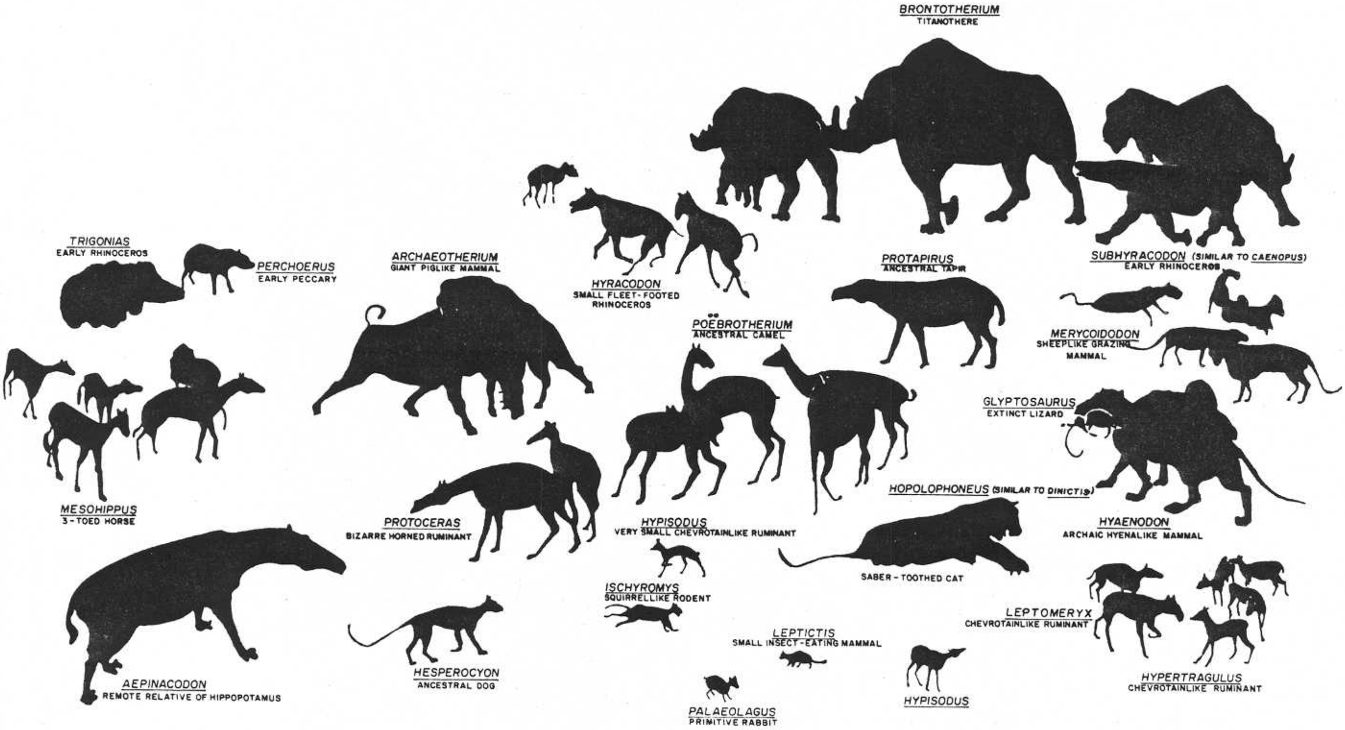


Figure 7. This reproduction of a mural by J. H. Matterness in the U.S. National Museum is a reconstruction of an Oligocene age landscape. Although Matterness based his painting on fossils found in South Dakota and Nebraska, many of the same animals lived in North Dakota. The Little Badlands and Fitterer Ranch Natural Areas probably appeared similar to this (except for the close proximity of the volcanoes) about 32 million years ago.




KEY TO THE MATTERNES MURAL

**Little Badlands and Fitterer Ranch Natural Areas**
**Registry Ceremony of December 2, 1988**

Group Photo Caption

First row (l to r): Robert and Jane Fitterer, Marion Schmidt, Albert and Anne Privratsky, Gail Beverlin (Natur Conservancy), Darlene (Mrs. Donald) Lutz, Arlys (Mrs. Allen) Schmidt, Steve Beverlin (Nature Conservancy) John Hoganson (Geological Survey), Harvey Schmidt. Second row (l to r): Albert Schmidt, Don Adamski, Bird and Ben Privratsky, Dan Privratsky, Doug Eiken (Parks and Recreation Department), Governor George Sinner Allen Schmidt, Donald Lutz, Frank Karner (Geological Survey).

Privratsky (Dickinson), Donald and Darlene Lutz (New England), Harvey and Annaliese Schmidt (Dickinson), Albert and Georgeann Schmidt (New England), Allen and Arlys Schmidt (New England), Marion Schmidt (Dickinson), Don Adamski (South Heart), and Ray and Mary Obritsch Schmitt and family (Dickinson) for volunteering to preserve part of North Dakota's natural heritage.

## NORTH DAKOTA CLINKER

--John Bluemle

Everyone who lives in or has travelled through western North Dakota, eastern Montana, or northeastern Wyoming has noticed the colorful reddish layers and brick-like masses of baked and fused clay, shale, and sandstone that color and shape the landscape. These baked materials, known as clinker (or locally as "scoria"), formed in areas where seams of lignite coal burned, producing heat that baked the nearby sediments to a form of natural brick. Clinker is not a deposit, but rather it is a material produced during burning of the lignite beds. Clinker beds typically range from a few feet to 50 feet or so thick in western North Dakota; considerably thicker beds are found in Wyoming and Montana.

The first reference to clinker that I know of was by William Clark who, while he and Meriweather Lewis were mapping the Missouri River in 1805, made the following entry in his journal while they were wintering at Fort Mandan (March 21, 1805):

*Saw an emence quantity of Pumice Stone on the sides & feet of the hills and emence beds of Pumice Stone near the Tops of them, with evident marks of the hills having once been on fire. I Collecte Somne of the different sorts i.e. Stone Pumice & a hard earth, and put them into a funace, the hard earth melted and glazed the others two and the hard Clay became a pumice Stone glazed.*

On April 16, 1805, Meriweather Lewis wrote the following:

*I believe it to be the strata of coal seen in those hills which causes the fire and birnt appearances frequently met with in this quarter. where those birnt appearances are to be seen in the face of the river bluffs, the coal is seldom seen, and when you meet with it in the neaghbourhood of the stratas of birnt earth, the coal appears to be presisely at the same hight, and is nearly of the same thickness, togeter with the sand and a sulphurious substance which usually accompanys it.*

After Lewis and Clark, numerous explorers mentioned seeing clinker as they travelled through the region. I won't repeat their quotes here as they would get too long for this newsletter article. Explorers who recognized and understood the origin of clinker included Larocque (1805), Catlin (1832), Maximilian (1833), Nicollet and Fremont (1839), Audubon (1843), and Harris (1843, 1845).

Other early explorers reported abundant coal fires in the northern Great Plains region, but most of these fires were extinguished by the end of the 19th century. Over the years, range fires have ignited lignite beds many times. In two places in western North Dakota, lignite seams were recently burning for many years. One of these locations was in the South Unit of Theodore Roosevelt National Park near Medora, and the other was south of there, near Amidon. During early October 1976, prairie fires that burned over several areas of southwestern North Dakota ignited underground lignite seams in at least 30 locations over a 7000-acre area near Amidon. Although nearly all of the fires were extinguished before the following spring, some of them did burn for several months.

This past summer (July 1988), a number of lignite seams were ignited during widespread fires in the badlands. Most of these were put out by the U.S. Forest Service. According to Jack Norland of the U.S. Park Service, a total of nine coal veins were ignited by the Buck Hill fire in July. The Buck Hill fire was started by lightning. After the Buck Hill fire was put out, it was determined that two of the burning coal veins were in locations where there was a possibility they might start another wildfire, so these fires were put out by digging them out. The other seven locations didn't pose any threat of starting additional fires, so they were allowed to burn. As I write this article, in late December, at least one lignite fire is still burning in the South Unit of Theodore Roosevelt National Park. The Park Service hasn't yet decided whether to attempt to put the fire out or to allow it to burn, as an example of a natural geologic process.

Spontaneous combustion, lightning, and the actions of man have been responsible for igniting lignite seams. Some of the lignite fires started as a result of the Buck Hill fire in July appear to have been ignited due to the burning of juniper roots down from the surface. The fire can apparently follow the roots down into the coal and start it burning in that way.

Over the years, such a large number of lignite seams have burned, over such a broad area, and under such a variety of situations, that it seems likely spontaneous combustion has been responsible for many of the fires. Lignite that contains a high percentage of sulfur is especially prone to spontaneous combustion. The "ideal" situation, favoring such combustion, is a combination of a finely divided condition of the coal, a slight amount of heat from an outside source (sunlight), and several feet of overburden to retard heat losses by radiation.

Lignite exposed to air by the removal of the overlying sediment due to erosion loses moisture and tends to slack or crumble to fragments. The powdered coal absorbs oxygen in quantities at least two to three times its own volume. This absorption of oxygen takes place at ordinary temperatures and, because the process generates heat, it is self-accelerating.

Regardless of how it starts, burning is most likely to persist where coal beds are exposed on a fairly steep bank, making it possible for large quantities of fine coal dust to accumulate over the lower part of the outcrop. Thin lignite beds commonly do not burn long because piles of powdered coal extensive enough to retain self-generated heat cannot accumulate along their outcrop. An overburden thickness of 100 feet or more over the coal also prevents ignition unless the coal bed is exceptionally thick.

The presence of the minerals pyrite and marcasite (forms of iron sulfide) and moisture in the lignite results in the production of heat. As this chemical reaction takes place at ordinary temperatures, it is a means by which the coal may be heated to the point at which it can ignite spontaneously. Pyrite and marcasite are nearly always present in relatively large quantities in and near lignite seams that have ignited.

When lignite beds burn, they harden, sinter (sintering is the process by which a material fuses to a hard mass, without melting), or sometimes the heat does melt the overlying and surrounding rocks. The baking process colors the nearby materials dominantly red, but also black, gray, purple, yellow, and other hues. The intensity of the colors depends on the mineral composition and grain size of the material that was baked and also on the intensity of the temperature reached during the baking process. The reddish color, which is most common, is due primarily to the presence of the mineral hematite (iron oxide, the same as common rust). The intensity of the colors of clinker also vary depending on whether the material is dry or wet. After a shower, the clinker is typically much brighter red than when it is dry.

The mineralogy of the clinker is diverse and unusual, a result of a combination of sedimentary rocks altered by temperatures as high as 1700°C, combined with low pressures. The clinker is typically depleted in silicon, aluminum, and potassium compared to the surrounding rock as well as being enriched in iron, magnesium, and calcium.

Clinker differentially resists erosion, both because it is harder than nearby unbaked rocks, and because heating and subsidence during burning produce high fracture permeability, which allows water to infiltrate, minimizing surface runoff. Thus, erosion leaves clinker as a cap on characteristically steep-sided, red-topped knobs, ridges, buttes, and mesas standing above more subdued topography on the less-resistant, unbaked rock nearby.

The heat produced during baking produces complex structures in clinker during subsidence. The lignite fires are systematically oriented in some places. Open fractures produced as the rock subsides by rotational slumping commonly serve as conduits for the release of combustion gases from the heated coal (fig. 1). As the combustible gas rises and mixes with air, the resulting fire can be hot enough to melt part of the adjacent rock. The resulting hard, resistant melted rock or "paralava," welds surrounding fragments and forms resistant "chimneys," which commonly stand above the general ground level after erosion has lowered the surrounding surface.

When the lignite burns, it is transformed to an ash that takes up only a fraction of the space as did the unburned lignite. Consequently, the overburden collapses into the burned-out space (fig. 2). By the time the overlying materials collapse, they have been baked to a hard material, and they are commonly partially fused as well. As they slump, the baked, melted, and sintered materials hold together, producing a rock that is as much as 75 percent air space (fig. 3). Oxygen can then be admitted through this porous, fractured rock and combustion gases are carried out so the coal can burn back even farther. After the clinker cools, the spaces that resulted from collapsing of the materials are convenient places in which rattlesnakes and other animals can live. Natural burning of the lignite beds throughout western North Dakota has, in some places, resulted in broad areas of hardened clinker-capped landforms and a characteristic irregular collapsed topography that might be referred to as "thermo-karst" or some such term.

In addition to its use for road metal and ornamental lawn and garden material, clinker is useful to geologists for several reasons. Clinker may contain excellently preserved leaf fossils. It can be used for dating episodes of topographic development in areas underlain by coal.

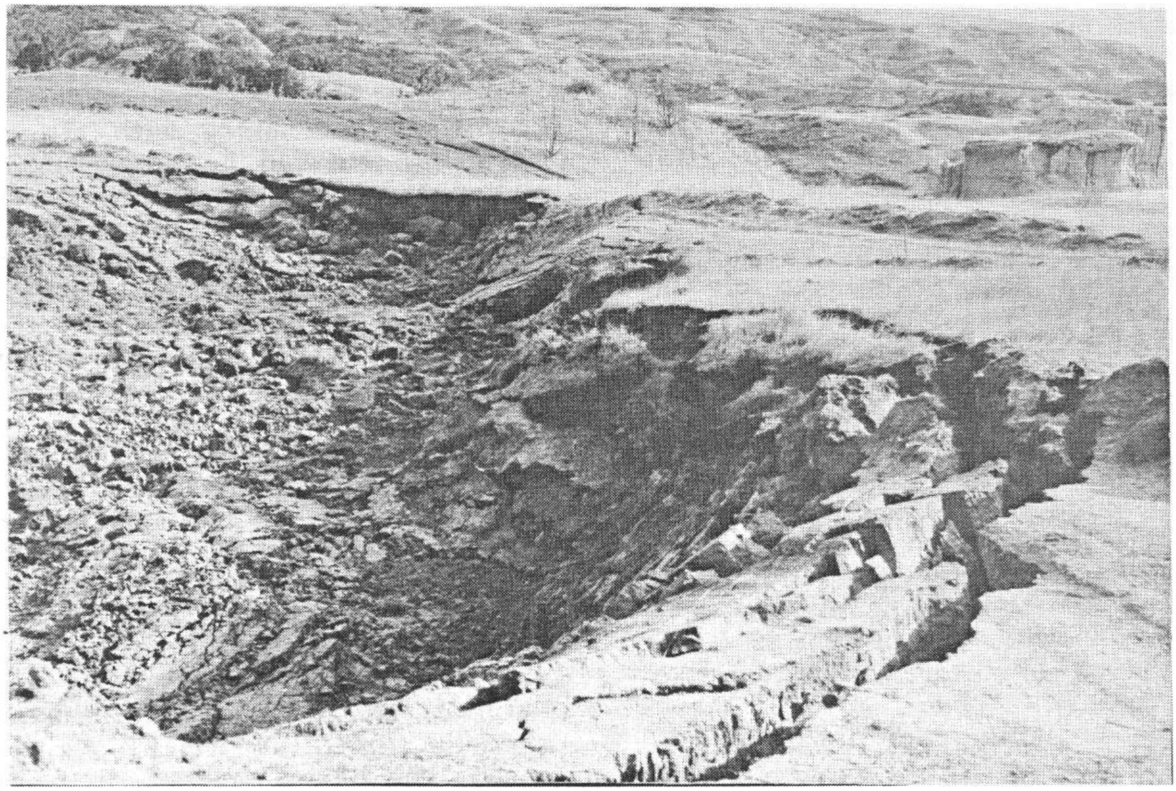


**Figure 1. Collapsed surface over burning lignite seam. When the material over the burned-out lignite collapses, it forms cracks that act as vents to allow oxygen to get to the burning seam, thereby causing it to burn further.**

Studies of the oldest in-place clinker in the Powder River Basin in Wyoming gave fission-track dates of 2.8±0.6 million years old (middle Pliocene time). The main time of burning in that area was between 1.4 and 0.5 million years ago (early Pleistocene). Periods of extensive burning occur at times when accelerated erosion exposes the coal beds; it is likely that an episode of erosion accompanied or immediately preceded extensive burning of coals. Although no radiometric dates have been obtained for North Dakota clinker, it seems likely that, since the erosion that is forming the Little Missouri River Badlands began about 700,000 years ago, the age of burning in North Dakota may also have been more recent than in Wyoming.

Actually there isn't any reason that clinker might not have been produced as soon as the lignite beds were exposed by erosion. Extensive erosion of the Paleocene-age, coal-bearing deposits began in Eocene time, so clinker may have formed that early. Fragments of clinker have been found in the basal conglomerate of the Oligocene-age, White River Formation, proving that clinker existed in the area prior to that time.

Some of the clinker in western North Dakota is found today at elevations where the water table is too high for lignite to burn. This

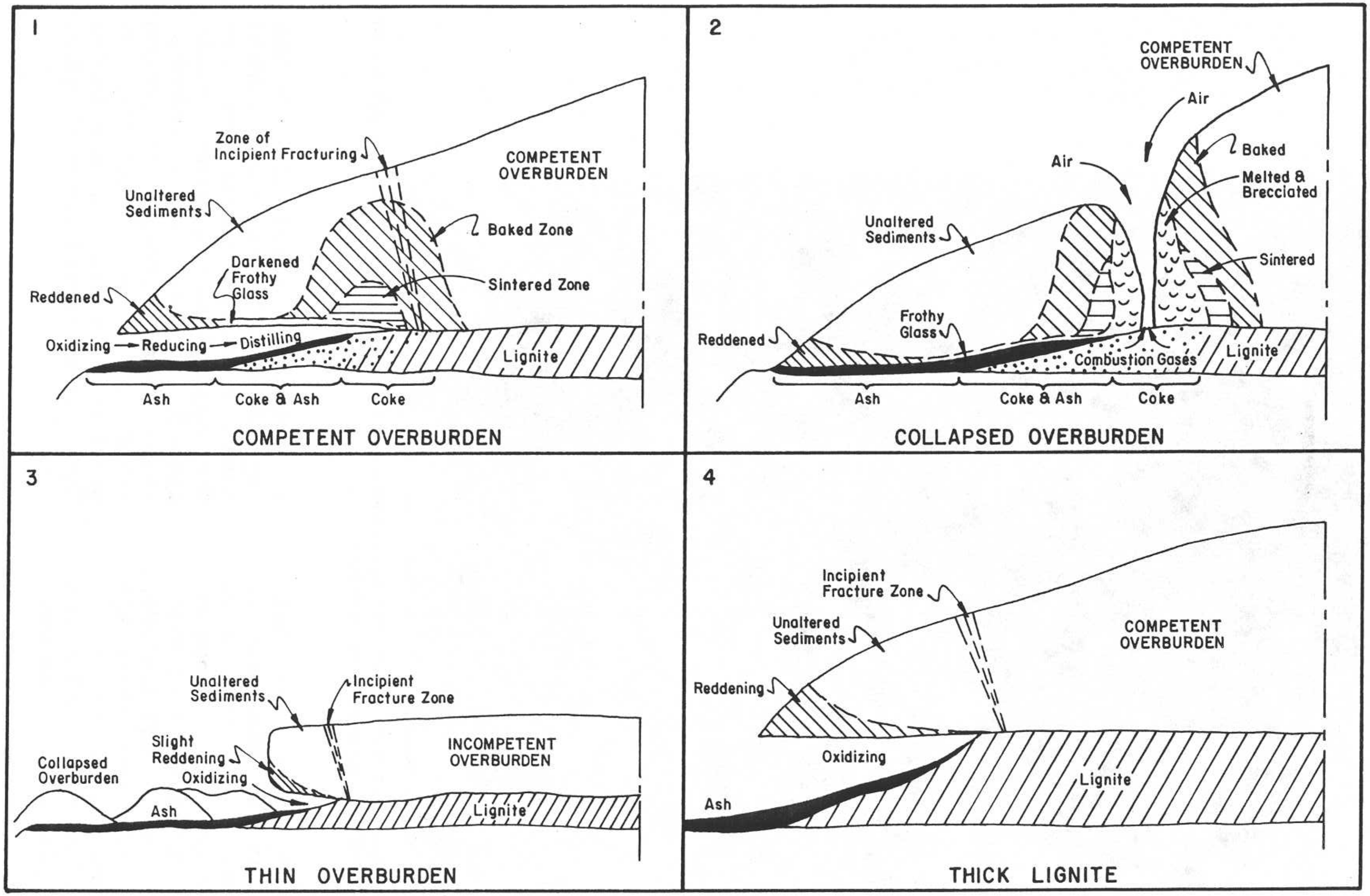



Figure 2. This four-part diagram illustrates some of the processes that occur as a lignite seam burns, baking the surrounding materials to clinker. As the lignite burns back from the outcrop, it bakes the overlying materials, producing a variety of products ranging from slightly reddened sediment to glass, depending on the temperatures reached. When the overburden collapses into the burned-out space, conduits are opened to the burning zone, allowing oxygen to enter, thereby perpetuating the fire.

**Figure 3. Clinker that has hardened into jointed columns as it cooled, somewhat like the columns at Devils Tower or the Giants Causeway, in miniature.**

clinker probably formed at times when the climate was drier and the water table was lower than it is today. This may have happened during warm, dry periods of time, such as the Hypsithermal Episode, which began about 8500 years ago and ended about 4500 years ago.

An interesting side effect of the burning of lignite beds is the way the combustion gases affect nearby vegetation. Air pollution resulting from the burning causes trees like the juniper, which is normally bush-shaped, to grow in a columnar shape. Near Amidon, an interesting stand of columnar junipers is growing in an area where a buried lignite seam burned for many years (fig. 4).

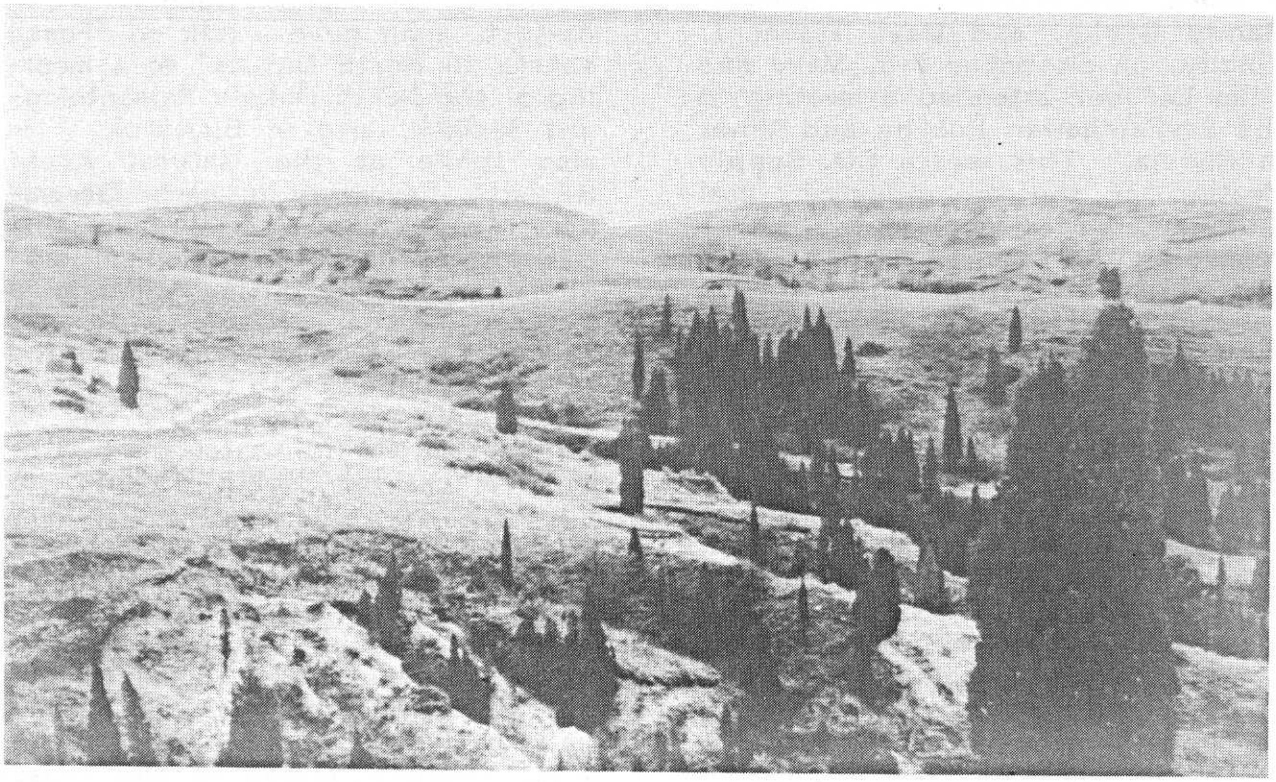


Figure 4. Juniper trees growing in the Amidon area near where a lignite seam recently burned for many years. The fumes from the burning lignite apparently altered the growth pattern of the trees, causing them to grow in this columnar shape. Seeds from these trees grow in the typical bushy shape of other junipers in the area.

## RECENT MEETINGS, PAPERS, AND PRESENTATIONS BY SURVEY GEOLOGISTS

**Marv Rygh**, our petroleum engineer, attended the Midcontinent Regional Forum on Hydrocarbon Recovery in St. Louis in June. This was a Geoscience Research Institute meeting set up to review possible areas of study regarding enhancing oil recovery in existing oil fields. In August, in addition to attending the technical sessions, Marv coordinated the Survey's information booth at the Sectional meeting of the AAPG in Bismarck. In October, Marv attended the United States Geological Survey Undiscovered Conventional Oil & Gas Resources Assessment Workshop in Denver; this workshop was sponsored by the Association of American State Geologists. At that meeting, new USGS resource assessments of U.S. hydrocarbon reserves were reviewed. On November 21 and 22, Marv attended the Manitoba Energy & Mines Report of 1988 Field Operations meeting in Winnipeg. At that meeting, joint studies of the NDGS and Manitoba Mines Branch were discussed along with a variety of related problems. The meeting allowed people working in both the surface and subsurface geology on both sides of the U.S.-Canadian border to discuss their work and problems. [NOTE: The Manitoba Mines Branch meeting was also attended by several other NDGS geologists: **Sid Anderson, John**

**Bluemle, Ken Harris, Julie LeFever, Randy Burke, and Dave Fischer]**. Finally, on December 7-8, Marv and **Julie LeFever** attended a meeting at the Saskatchewan Energy and Mines in Regina. This was a $CO_2$ Supply Meeting of the oil industry, coal industry, and government agencies regarding the future source of supply and utilization of $CO_2$ in enhanced oil-recovery projects in the Williston Basin.

**David Brekke** represented the NDGS at the annual meeting of the North Dakota Lignite Council held in Bismarck in early October. He also represented the Survey at a meeting of the North Dakota Lignite Research Council. The Survey is a member of the Research Council, which recommends the distribution of grant monies relating to lignite research. The money is generated from a tax on lignite production. Also in October, Dave attended the national meeting of State Affiliates of the National Cartographic Information Center (NCIC) in Denver. This meeting was attended by national and regional federal NCIC representatives as well as other state affiliates. Discussions of mutual problems and federal-state relationships were held. Attendees also viewed the latest information-retrieval technology and saw presentations by federal agencies. In November, Dave spoke at a meeting of the North Dakota Environmental Health Association in Minot. His talk dealt with the geologic aspects of radon distribution in North Dakota. Dave explained the geologic and geochemical reasons why radon occurs in North Dakota.

George Lammers of the Manitoba Museum of Man and Nature in Winnipeg and **John Hoganson** of the Survey presented a paper at the North Dakota Academy of Science meeting in Bismarck last April titled "Oligocene fossil additions and new localities for North Dakota." In August, John gave a talk on "Fossil sharks in North Dakota" to a meeting of the North Dakota Paleontological Society, also in Bismarck. He also spoke at the Natural Areas Registry Ceremony in early December (see article elsewhere in this Newsletter) on "Paleontological significance of the Little Badlands & Fitterer Ranch Natural Areas;" **Frank Karner** also addressed the same gathering.

**Ed Murphy** presented a talk on Landfill Suitability Criteria for sites in northeastern North Dakota on November 17. The meeting was held in Park River and was sponsored by the Midwest Assistance Program (MAP, Inc.). This summer, Ed was appointed to the Governor's Task Force on Solid Waste Management. The sixteen-member task force consists of a mix of scientists, planners, representatives of the cities and counties, and haulers of solid waste. The group has been meeting since July and will be submitting a final report to Governor Sinner sometime in January. The report addresses the present practices and the future of solid waste disposal in North Dakota.

**Dave Fischer** and **John Bluemle** have just completed Miscellaneous Series 72, the "Update of Oil and Gas Activity in North Dakota in 1986-1987" (see article on new publications). Dave and John also had a poster display on the same topic at the August AAPG meeting in Bismarck. Dave recently co-authored a paper with Tom Heck and Lee Gerhard on the Medicine Pole Hills oil field in Bowman County. Their paper will be included in the AAPG Treatise of Petroleum Geology. Dave co-authored (along with Roger Borchert, Robert Johnson, and Lee Gerhard) an updated study of Glenburn Field in Bottineau County; this report will also be included in the AAPG Treatise. Another version of the Glenburn paper was invited to be included in a recent Rocky Mountain Association of Geologists publication dealing with carbonate reservoirs in the Rocky Mountain region.

During the past six months, **John Bluemle** helped with several workshops for science teachers. One of these, held in Grand Forks in early July, was sponsored by the Center for Teaching and Learning (CTL) at the University of North Dakota; Elmer Schmeiss of the CTL and **Frank Karner** and Nels Forsman of the survey and geology department were also involved in this workshop (figs. 1, 2, and 3). John helped with a workshop for science teachers held later in July in Washburn (Project WET, sponsored by the State Water Commission). In early November, John was involved in a field trip with teachers and students in northeastern North Dakota. John gave talks on various aspects of North Dakota geology to the Lions Club in Grand Forks and to the annual meeting of the Professional Soil Classifiers of North Dakota in Mandan. He and **Ed Murphy** helped lead a field trip to the Killdeer Mountains in August to examine several aspects of the natural science and history there. John published an article on the Killdeer Mountains in the August issue of North Dakota Outdoors. Over the past several months, John has also represented the Survey at several meetings of the Devils Lake Management Committee.

During the past six months, **Ken Harris** has been occupied almost entirely with field work and analysis of glacial stratigraphic data. Early this summer he co-hosted (with the South Dakota Geological Survey) a field conference of the Friends of the New Des Moines Lobe (FONDL) to northeastern South Dakota to study glacial stratigraphy. He also helped with the AAPG field trip to Manitoba in August. In October, Ken participated in a field trip of Quaternary stratigraphic sites on the Red River.

**Randy Burke**, along with Tom Heck, gave a paper: "Diagenesis and Structural Control on Production from Devonian Duperow Formation, Tree Top Field, Billings Anticline, North Dakota" at the August AAPG meeting. Randy and **Sid Anderson** were responsible for organizing the field trip to the Paleozoic Outcrop Belt of Manitoba for the AAPG meeting. The trip, which was well received by all who participated, focused on the Manitoba outcrops of the Red River, Stony Mountain, Stonewall, Silurian, Ashern, Winnipegosis, Dawson Bay, Souris River, and Duperow Formations. Randy published several other papers: "Bajocian Shallowing Upward Sequence and Reef Tract. In, Evolution of the Jurassic High Atlas Rift, Morocco: Transtension, Structural and Eustatic Controls on Carbonate Facies, Tectonic Inversion." This paper was published as Field Trip 9, AAPG Mediterranean Basins Conference and was co-authored by J. E. Warme. Randy co-authored an abstract titled "Rift Tectonics and Limestone Sedimentation: Jurassic of the Central and Eastern High Atlas, Morocco" with J. E. Warme, B. H. Hazlett, and D. K. Crevello; this abstract appears in the August issue of the AAPG Bulletin. In addition to these talks and papers, Randy provided materials for two core workshops: (1) the AAPG meeting in Bismarck (workshop was organized by Dave Fischer); and (2) the Rocky Mountain Association of Geologists meeting in Denver.

**Sid Anderson**, Associate State Geologist, helped plan and organize the Rocky Mountain sectional AAPG meeting field trip to Manitoba to look at the Paleozoic outcrops there (see above). He also assisted the Program Chairman, Cooper Land, in recruiting papers and poster sessions for the meeting. In October, Sid and **Frank Karner** attended the United States Geological Survey Central Cluster Meeting in Austin, Texas. In December, Sid attended the annual meeting of the Interstate Oil Compact Commission in Overland Park, Kansas. Following the IOCC meeting, Sid and **Dave Fischer** attended a meeting in Overland Park of people from states involved in the Geoscience Institute, and a meeting of the Potential Gas Commission in Denver.

Figure 1. Dr. Nels Forsman, UND geology department, explains to a group of teachers attending a workshop how the geology affects the operation of the Grand Forks sewage lagoon.

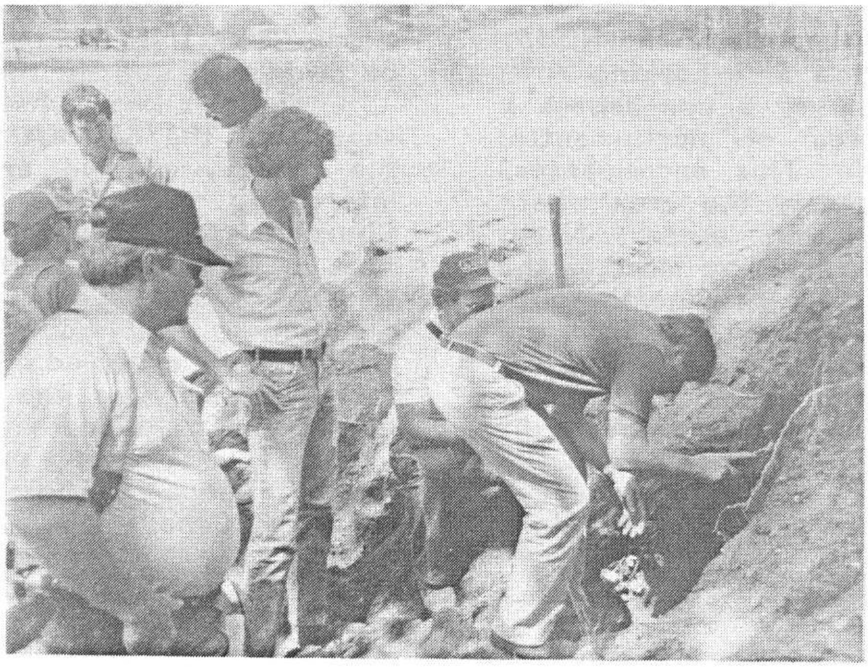


Figure 2. Dr. Frank Karner, State Geologist and UND geology department, digs in river sediment along the Red River in Grand Forks to illustrate how river deposits accumulate.

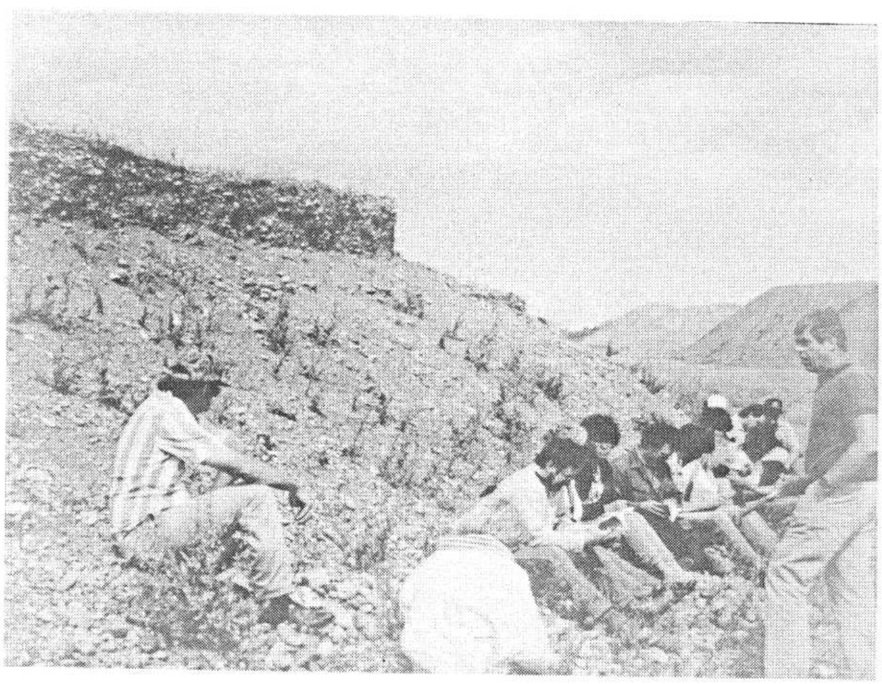


Figure 3. Dr. Frank Karner (standing, right) and Dr. Elmer Schmeiss (striped shirt, left) explain to a group of teachers how rivers deposited gravel in the Fordville area.

## SIDE-LOOK RADAR FLOWN

--Sid Anderson

At the suggestion of the NDGS, the USGS flew a Side-Looking Area Radar project over a one-degree x two-degree area of north-central North Dakota. This encompasses, from west to east, the area where the Souris River enters North Dakota to and including most of the Turtle Mountains. In a north-south direction, the area extends from the U.S.-Canadian border to south of Minot.

We have not yet seen the flight strip imagery, but we should be getting a look at it in January. The flight strips will be made into a mosaic later this spring when it will be made available by the USGS.

We don't know what all this will show, but the potential is great as the geology of the area is very interesting. The Precambrian Churchill and Superior Provinces meet in this area. Multi-stage dissolution of the Devonian Prairie Salt occurred in the area. Glacial Lake Souris also occupied part of the area. This is also the area where the Souris River enters North Dakota from Canada, makes a loop through Minot, swings north, and re-enters Canada.

## COMMENTS

Do you have questions, comments, or suggestions regarding the Newsletter or North Dakota Geological Survey services? For additional information on any of the items mentioned in this Newsletter, please contact John Bluemle, NDGS Newsletter Editor, North Dakota Geological Survey, University Station, Grand Forks, ND 58202-8156.

## CHECKLIST FOR NEW PUBLICATIONS

See pages 2 and 3 of this Newsletter for descriptions of publications.

| | |
|---|---|
| ____MS-72 ($3.00) | Oil Exploration and Development in the North Dakota Williston Basin: 1986-1987 Update |
| ____MM-29 ($1.00) | Geologic Highway Map of North Dakota |
| ____ED-17 (free) | Guide to the Geology of Northeastern North Dakota |
| ____ED-18 (free) | Guide to the Geology of Southeastern North Dakota |
| ____ED-19 (free) | Guide to the Geology of North-Central North Dakota |
| ____ED-20 (free) | Guide to the Geology of South-Central North Dakota |
| ____(DNAG) (free) | Williston Basin Stratigraphic Nomenclature Chart (published by the Geological Society of America) |

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