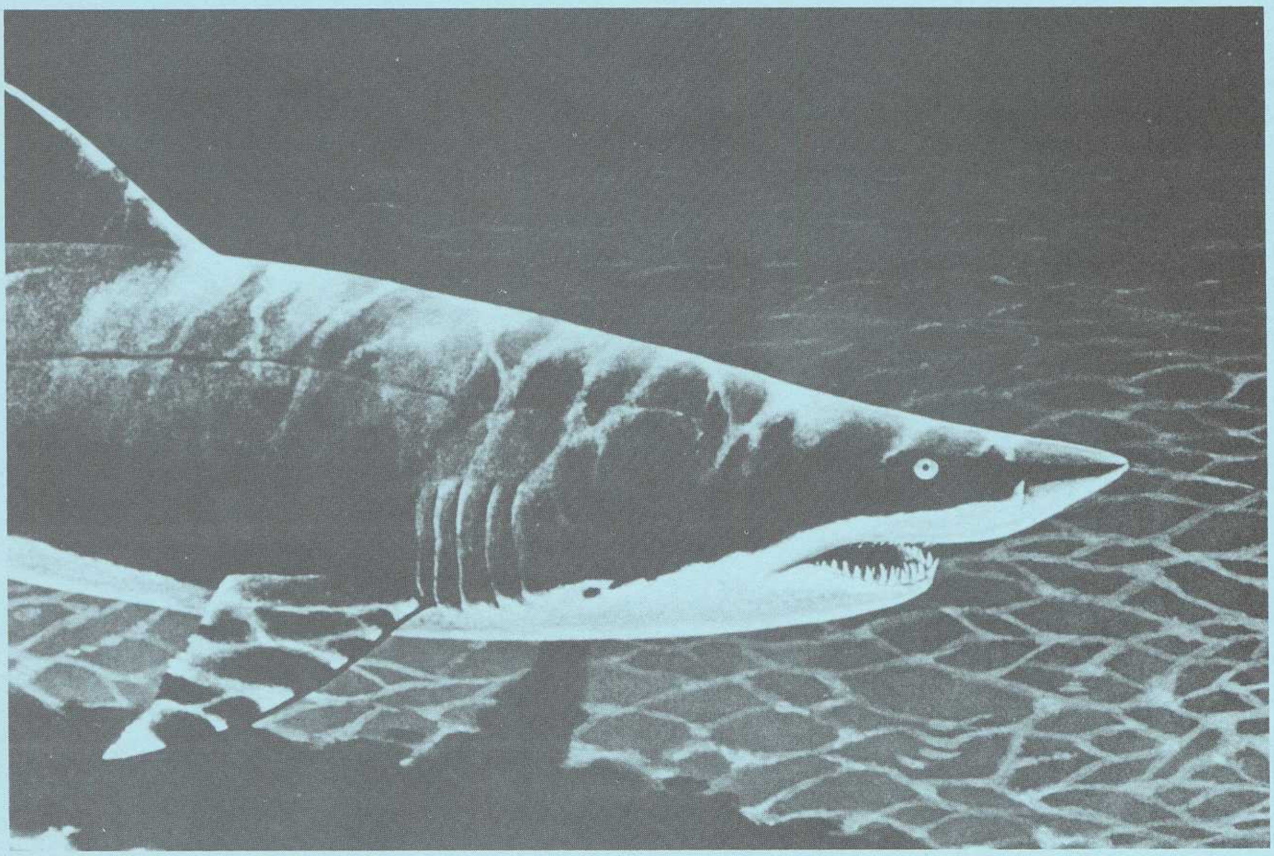
NEWSLETTER
NDGS

John P. Bluemle, Editor



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COVER PHOTO

Sand tiger sharks, similar to the one shown on the cover, thrived in the Cannonball Sea here in North Dakota about 60 million years ago. See the article on page 19 by John Hoganson about sharks in the Cannonball Formation in North Dakota. The picture on the cover is from an illustration that appeared in a 1976 book by R. Ellis, entitled Book of Sharks.

OIL AND GAS ACTIVITY DURING 1987

As in past June issues of the NDGS Newsletter, we are including an unofficial summary of oil and gas activity in North Dakota for the previous year. Oil production in North Dakota was 41.3 million barrels, down nearly 10% (4.3 million barrels) from 1986. A total of 3,577 wells were producing at the end of 1987. This compares to 3,698 wells producing at the end of 1986. Average daily production per well in 1987 was 31.68 BO, down from 33.53 BO in 1986.

During 1987, the Oil and Gas Division of the Industrial Commission issued 185 drilling permits, 24 more than during the previous reporting period. Of the wells drilled in North Dakota during 1987, 131 were developmental projects, 94 of which were successfully completed for a 71.7% success rate. The wildcat success rate during the year was 17.3%, with 8 successful completions of the 46 attempts. A total of 16 new oil or gas pools were discovered (table 1) in 1987.

TABLE 1. 1987 DISCOVERIES

Sun Exploration & Prod. Co.--O. M. Seel Federal #1 #8922 Sixmile-Red River	Case 4260	Order 4894 Producing	Comp. 3/19/87
True Oil Co.--Peterson #13-8 #12035 North Tioga-Bakken	Case 4261	Order 4917 Producing	Comp. 3/3/87
Sun Exploration & Prod. Co.--Strombeck #1 #12062 North Tioga-Silurian/Ordovician	Case 4343	Order 5026 Producing	Comp. 7/20/87
Meridian Oil Inc.--MOI #22-33 #12068 Hay Draw-Silurian	Case 4278	Order 4886 Producing-RC	Comp. 4/22/87
Meridian Oil Inc.--MOI #22-33 #12068 Hay Draw-Duperow	Case 4377	Order 5014 Producing-RC	Comp. 4/22/87
Jerry Chambers Expl. Co.--Sun #10-7 #12078 Rocky Hill-Madison	Case 4341	Order 4974 Producing	Comp. 5/2/87
Raymond T. Duncan--Rivers #1 #12085 Dolphin-Souris River	Case 4277	Order 4885 Producing	Comp. 4/6/87
Union Oil Co. of California--Machnicki #1-J32 #12117 Hungry Man Butte-Madison	Case 4384	Order 5044 Producing	Comp. 8/19/87

TABLE 1. 1987 DISCOVERIES--Continued

Columbia Gas Dev. Corp.--Rogers-Federal #15-1			
#12120	Case 4299	Order 4972	Comp. 7/14/87
Buford-Madison		Producing	
Wessely Expl. Co.--Johnson #4-24			
#12127	Case 4342	Order 4975	Comp. 7/28/87
Greenbush-Madison		Producing	
Amerada Hess Corp.--Koch Federal #7-21			
#12134	Case 4413	Order 5080	Comp. 9/10/87
Davis Creek-Madison		Producing	
TXP Operating Co.--TXPOC-State #23-36			
#12186	Case 4452	Order 5105	Comp. 12/17/87
Stony Creek-Madison		Producing	
Ladd Petr. Corp.--Fjerstad #14-11 A			
#12189	Case 4440	Order 5093	Comp. 11/17/87
Bonetrail-Stonewall		Producing	
ANR Prod. Co.--Iszley-USA #1			
#12216	Case 4446	Order 5099	Comp. 11/26/87
Cartwright-Duperow		Producing	
Berco Resources, Inc.--Gearey #1			
#12227	Case 4436	Order 5089	Comp. 12/10/87
Williams Creek-Birdbear		Producing	
CNG Producing Co.--Brandjord #1-20			
#12280	Case 4451	Order 5124	Comp. 12/19/87
Cimbel-Madison		Producing	

NONFUEL MINERAL INDUSTRY STATISTICS

--David Brekke

The U.S. Bureau of Mines recently released the 1986 Minerals Yearbook. It is a summary of nonfuel mineral activity both in the U.S. and internationally. The following, including Tables 1 and 4, is excerpted from the chapter on North Dakota. Copies of "The Mineral Industry of North Dakota" can be obtained free of charge from the Survey.

"The value of North Dakota's nonfuel mineral production decreased over $3 million in 1986 from that reported for 1985. Total value in 1986 was $20.8 million. The State ranked 48th nationally in nonfuel mineral production, accounting for less than 1% of the U.S. total. Construction sand and gravel contributed the greatest amount to the State's nonfuel mineral value and to its decline. Other commodities produced included clays, lime, peat, salt, industrial sand, and crushed stone. Of these, only clays and lime increased in production and value for the year. Elemental sulfur was recovered from natural gas processing."

Average annual employment in the nonfuel minerals industry for 1986 was 370, or about the same as that reported for 1985."

Table 1.—Nonfuel mineral production in North Dakota[1]

Mineral	1984		1985		1986	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Gem stones	NA	[e]$2	NA	[e]$2	NA	$2
Lime ---------- thousand short tons	60	5,912	56	5,562	74	7,359
Sand and gravel (construction) ---- do	6,426	11,351	[e]6,900	[e]13,800	5,135	10,741
Combined value of clays, peat, salt, sand and gravel (industrial, 1986), and stone (crushed miscellaneous, 1985-86)	XX	4,529	XX	4,820	XX	2,700
Total	XX	21,794	XX	24,184	XX	20,802

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

Table 4.—North Dakota: Noncoal surface mining activities

	1984	1985	1986
Number of mine operators	40	38	39
Number of active pits	153	107	123
Acres disturbed	462	370	287
Minerals mined:			
Clays ---- thousand cubic yards	133	44	56
Rock (cobbles) ---- do	--	11	16
Sand and gravel ---- do	3,330	2,974	2,502
Scoria ---- do	104	83	85

Source: North Dakota State Soil Conservation Committee. 1984, 1985, and 1986 issues of Surface Mining Report for Minerals Other Than Coal.

SURVEY IS NAMED NCIC AFFILIATE

--John Bluemle

The North Dakota Geological Survey recently signed an agreement with the National Cartographic Information Center (NCIC) providing that the Survey will be an Affiliate of the NCIC. The NCIC is a branch of the United States Geological Survey that provides information about maps and other cartographic information that can be obtained from many government and private sources. Virtually all topographic maps, aerial photographs, and space images can be obtained through the NCIC. Although the North Dakota Geological Survey is not yet able to supply North Dakota topographic and other maps directly, we can take orders for these maps and we have personnel trained to assist you in finding materials you may need.

We have a complete microfiche catalog of all Landsat photography for the USA and aerial photography (color, black and white, and color infrared) for North Dakota. Our NCIC materials also include a considerable amount of informational brochures, pamphlets, etc. If you have questions about the availability of maps and air photos for North Dakota, please contact us or stop by our office.

CORE LIBRARY HOSTS GENE SHINN OF THE USGS FOR TALKS AND CORE WORKSHOP

--Randy Burke

The Wilson Laird Core and Sample Library was the site for two talks on Saturday, April 9th, by Eugene "Gene" Shinn, senior scientist with Oil and Gas Conservation Division of the USGS. Gene presented one talk in the morning entitled "Rapid Sedimentation in the Persian Gulf" followed by a discussion and answer period. The afternoon presentation included a movie Gene had filmed entitled "Giant Stromatolites of the Bahama Banks," followed by a discussion and core workshop.

The core workshop centered around presentations and discussions of Mississippian cores by Mark Luther and Dr. Howard Fisher, Devonian cores by Randy Burke, and Pennsylvanian Tyler cores by Larry Quandt. The discussion focused on a comparison of the depositional textures and facies observed in the cores and those Gene presented earlier in his talk about the Persian Gulf. Lively discussion ensued over Mark Luther's model for hypersaline/anoxic water controls on the depositional character of their Mississippian rocks.

Gene was particularly curious about the high gamma ray marker beds because of their regional extent, and their textural and lithologic similarities in both the Mississippian and Devonian cores.

Congratulations are due to the core library staff, Rod Stoa and Mickey Rood, for their extra effort in assisting Wayne Freisatz and Kurt Eylands. Kurt and Wayne organized the event as part of Sigma Gamma Epsilon's Spring Banquet. In their usual style of excellence, Sigma Gamma Epsilon advisors Drs. "Bud" Holland and Alan Cvancara supervised and worked hard with the Sigma Gamma membership on the arrangements to bring Gene to North Dakota. The Survey thanks them for their efforts.

NORTH DAKOTA NATURAL SCIENCE SOCIETY MEETING IN KILLDEER MOUNTAINS

--John Bluemle

The North Dakota Natural Science Society is planning its summer field trip for August 20 and 21 in the Killdeer Mountains. Plans are not yet complete as I write this, but we expect to spend our time looking at a variety of biologic and geologic features in the Killdeer Mountains. We'll visit the Medicine Hole, a limestone cave on top of the Killdeers, and a variety of other interesting features.

Tentative plans are to gather at the city park in Killdeer (west side of Main Street) at 11:00 a.m., August 20. Travel will likely be by private vehicle. If you are interested in going on the field trip, you can pre-register or get further information by contacting John Schulz, 420 SW 2nd Street, Rugby, ND 58368. Or call me at 701/777-2231.

1987 NORTH DAKOTA NATURAL SCIENCE SOCIETY FIELDTRIP

--Tom Malterer

The North Dakota Natural Science Society conducted a two-day field trip on July 25 and 26, 1987. It included visits to two fens in eastern McHenry County. The Denbigh Peatland Area, along the Souris River and its tributaries, has a unique and interesting array of plant and animal life and unusual geologic conditions, which allowed considerable peat accumulation. Various individuals led parts of the field trip. Alexis Duxbury, Bonnie Heidel, and Carolyn Godfread (North Dakota Game and Fish Department) explained the plant ecology of the fens. John Bluemle (North Dakota Geological Survey) discussed surficial geology and hydrology of the area, and Tom Malterer (UND Energy and Mineral Research Center) discussed peat formation. An interesting newspaper article about the field trip is reproduced below. After visiting the fens, the group continued to the J. Clark Salyer Wildlife Refuge for a picnic and evening program that included a presentation of the geologic history of the area by Mark Lord, UND Geology Department.

(Mike Jacobs Grand Forks Herald article appears below):

Bog Preserves Past for Guests
Mike Jacobs, Grand Forks Herald,
Thursday, July 30, 1987
(reprinted by permission)

"IN THE DENBIGH BOG, McHENRY COUNTY, N.D. -- If you think nothing ever happens in McHenry County, you haven't been talking to geologists.

Or to the Cenex bulk truck driver.

There was a geological catastrophe here at the end of the Ice Age, according to Tom Malterer and John Bluemle, geologists at UND and the North Dakota Geological Survey.

Saturday, about 100 people visited the bog west of Towner, in north-central North Dakota, to see what's developed there in the last 10,000 years or so.

Glacial Lake Regina, located to the northwest, in what now is Saskatchewan, drained suddenly, scouring a wide, deep valley and exposing rocks that the glacier itself had left when it melted. Once the river had passed, a lake filled its valley, and sand and other lake sediments accumulated on the bottom.

As the climate got warmer and drier, the lake disappeared. But ground water still ran into the lake bed, creating a unique environment that supported plants that usually aren't found this far south.

Botanists refer to this as a "relict area," left over after the environment changed, permitting the development of the prairie ecosystem that is typical of North Dakota.

These plants grew and died, but their remains did not decay in the usual way, because there is a constant supply of cold water flowing into the former lake bed. This water is high in calcium, leached from the surrounding prairie.

The result is a natural area known as a fen.

The stuff that's accumulated in the fen is called peat. It has accumulated here at the rate of perhaps two inches a century. By Saturday, the layer was almost 18 feet thick. The surface is spongy, and visitors bounced on it as if it were a bed mattress.

Malterer knows what's below the surface because he has probed into the peat layer. At 20 feet, 6 inches below the surface, he struck a layer of coarse sand, with boulders as much as 2 feet across strewn about on it. On top of that, he found 18 inches of lake sediment, and on top of that, a foot-thick layer of something called "gyttja," a peatlike substance formed of material carried into the site. Then he found 18 feet of peat that has formed in this location.

The peat is extremely uniform, indicating that there has been little change in the plant life in this bog since the end of the Ice Age.

(Malterer is uncertain exactly how old the bog is. He'll be able to tell after he conducts radio carbon dating tests on sediments he's brought up from the bottom.)

Today, plants that are rare in North Dakota grow in this bog--and several similar bogs in various parts of the state.

Alexis Duxbury, a botanist with the North Dakota Game and Fish Department, said the plant life here is richly diversified for a bog area. On Saturday, she pointed out such rare plants as lady's tresses (a kind of orchid), little bladderwort and northern grass of parnassus.

This fen area is a part of the North Dakota Natural Areas Registry, an effort to find unique natural areas in the state and tell landowners and others about their natural values.

The Denbigh Bog is an example of the program's success, according to Pam Dryer, the natural resources and trails coordinator for the North Dakota Park Service.

"Landowners have been educated about what's there," she said. "They knew about it before, but they might not have realized its significance."

That's right, according to Delores Kongslie, whose family owns part of the bog. "It's nice to know there are rare plants down there," she said. "I'm glad to know that people can see it and we can preserve it."

Her neighbor, Jean Nelson, agreed. "If we were thinking about something we'd do, we wouldn't do it now," she said. Her family realized that trying to drain the area would be a waste of time, she said.

The natural registry program tries to recognize landowners like the Kongslies and the Nelsons. Others who own parts of the Denbigh bog, besides Lawrence and Jean Nelson and Vernon and Delores Kongslie, are Raymond and Helen Anderson, John and Willetta Bruesch, Kenneth and Doris Nelson and Lynn Kongslie.

So far, 33 bog sections -- six of them fens -- have been registered. A total of 56 landowners are involved in the registry program.

Last week's, organized by the North Dakota Natural Sciences Society, was a happening. "We were tickled to see people sloppy around up to their ankles in mush," Jean Nelson said, "You could say it was the biggest thing that's happened around here in quite a while."

That's for sure, Bob Keller said. He drives the bulk delivery truck for the Towner Cenex station, and he's on the road in McHenry County almost daily. He drove by the bog at midafternoon Saturday, just as field trip participants were leaving the bog.

"I thought, 'That's something you don't see every day.'"

NDGS HELPS OUT ON SCIENCE-FAIR PROJECT

--Julie LeFever

We recently had the opportunity to offer suggestions and help to a young scientist from Grand Forks County. Joshua Paur of Gilby, North Dakota, decided to do a geologic study for his science-fair project (abstract is reproduced below). Joshua came to the NDGS before his local competition at Midway School. He decided to do a project that would determine the direction glaciers moved over North Dakota by examining and identifying the rocks found in several areas around the state. His underlying hypothesis was that, as glaciers moved into North Dakota, they carried debris from surrounding areas and within that debris there may be rocks unique to a particular region. Careful identification of the collected rocks and comparison of those rocks to the rocks of surrounding regions would then suggest the area from which the glacier may have come. Joshua then collected and identified 100 rocks from four different locations in the state. His findings and conclusions were then presented at the Midway Science Fair.

Joshua won a 1st-Place trophy in the Junior Division at the local science fair at Midway. He moved on to the Northeast Regional Science Fair, where he won the chance to participate in the State Science Fair at Jamestown this past April.

Joshua's Abstract:

MIGRATING ROCKS?

I collected 400 stones from four different sites across North Dakota. After identifying all the stones as accurately as possible I calculated and recorded percentages of rock types at each site. By comparing rocks indigenous to Canada and North Dakota, certain rocks show that they may have been transported by glaciation. My hypothesis is that glacier migration into North Dakota from Canada can be tracked from rock types.

Site one, my home town of Gilby, showed a large percentage of limestone rocks. This indicates the direction of glaciation was from the north where limestone prevails in the bedrock.

Site two, Valley City, had a high percentage of granite which indicates the glacier transporting these rocks came from an area east or northeast of Valley City where granite is the prevailing bedrock.

At Bismarck, my third site, the highest percentage of rocks was sandstone which is too soft to withstand transporting by a glacier. These rocks are indigenous to the Bismarck area so are not conclusive evidence to track glacier migration.

At Hettinger, my fourth site, the high rhyolite and concretions percentage showed that the rocks migrated from the west or northwest. Presently, the accepted theory is that glaciers did not travel this area, and that the rock migration occurred because of the flooding activities during prehistoric times.

Through this experiment I not only learned how to identify rocks and where they came from, but also how they were involved with glaciation.

Joshua Paur and his Science Fair project.

FUEL-STORAGE TANKS REMOVED ON UND CAMPUS --John Bluemle

The University of North Dakota Plant Services recently removed several oil storage tanks from their premises. The Survey was asked to take soil samples to see whether the tanks might have leaked over the years and contaminated the soil and groundwater. The photo below shows a 10,000-gallon fuel tank being removed after the ground around it had been excavated. Often, old buried fuel tanks are badly corroded and the potential for leakage and groundwater contamination is great. The tanks removed on the UND campus appeared to be in good condition and, although chemical analyses are not yet complete, the ground does not appear to be seriously contaminated.

Figure 1. Oil tank being lifted from excavation near Plant Services complex, UND campus.

AGREEMENT SIGNED WITH BLM TO MANAGE FOSSIL RESOURCES

--John Hoganson

In February, 1988, an agreement was signed between the Federal Bureau of Land Management and the NDGS to cooperatively manage paleontological resources on BLM lands in North Dakota. This agreement, similar to one established between the NDGS and U.S. Forest Service in 1986, allows the NDGS to take an active role in granting permits for fossil collecting activities on BLM-controlled lands in North Dakota. It also provides for information exchange between the NDGS and BLM about fossil sites located on or near lands in North Dakota under BLM jurisdiction. In addition, the BLM will recommend to out-of-state collectors that all or a representative sample of fossil specimens recovered from BLM lands in North Dakota be deposited with the NDGS for permanent curation.

NEW PUBLICATIONS

Atlas Series Map 4--"Surface Geology of the Souris River Map Area, North Dakota," was drawn by Mark L. Lord. The map covers a part of north-central North Dakota, north of 48° North Latitude and between 100° and 101° West Longitude; most of the area is in McHenry and Bottineau Counties. Each map in this series covers an area of one degree of longitude by one degree of latitude. The total area covered by Atlas Series Map 4 is about 3,250 square miles.

The colored Atlas map shows the composition of the surface materials and their origin. Four elements of the surface geology of the Souris River Map Area are shown on the map: (l) the lithologies and textures of the surface materials; (2) an interpretation of the age of the sediment; (3) a description of the topography of the area; and (4) a description of the origin of the sediment. Lithologies are shown by the use of color. The age and origin of the sediment are shown by the use of map-unit numbers. A detailed description of the map unit and line symbols are also included.

The Souris River Map Area can be divided into three areas based on the occurrence of similar or genetically related landforms. These areas include the Glacial Lake Souris plain, the Turtle Mountains, and the Glaciated Plains. Each of these areas contains a unique set of landforms determined by the geological processes responsible for depositing or modifying the sediment in the area.

The map is the result of a compilation of previous work, an interpretation of the geology based on aerial photographs, and field studies. The base used in making the map was prepared by the U.S. Geological Survey. It includes roads, towns, drainage, and topography. The Souris River Atlas Map 4 is drawn at a scale of 1:250,000 (1 inch to 4 miles).

The map is provided in a 9 1/2" x 12" envelope, which includes title and other information. As work on our Atlas Mapping Project continues, we will provide additional maps and other information from time to time. These will be added to the Atlas Series as they become available.

Souris River Atlas Map 4 can be obtained for $3.00 from the Survey.

Miscellaneous Series 70--"An Overview of Dolphin Field, Divide County, North Dakota," was written by Thomas

J. Heck. This is a short summary of a relatively new oil field, discovered in 1986, that has produced more than 500,000 barrels of oil from the Dawson Bay Formation, a relatively new producing horizon in North Dakota. Wells in the field have both high initial potentials and good cumulative production, and rapid payouts can be expected. The field produces from a stratigraphic trap located along a structural nose. Similar traps may be found by drilling the updip edges of structurally high porosity thicks. The report will be of interest to explorationists operating in North Dakota. The 14-page report can be obtained for $1.00 from the Survey.

Miscellaneous Series 71--"Leachate Generated by an Oil-and-Gas Brine Pond Site in North Dakota," was written by Edward C. Murphy and others. The information included in this publication first appeared in the journal Groundwater in January 1988. The eight-page report describes two unlined ponds that were used for holding and evaporation of brines produced with oil and gas at a well site in north-central North Dakota. The brine-evaporation ponds were in use from 1959 until the late 1970s when they were backfilled and leveled. Continued salt-water migration at the site since closure has decreased crop yields in surrounding fields and has killed trees in a shelterbelt within an area of approximately 10 acres.

The authors of the brine-pond report estimate that brine leachate will continue to migrate at slow rates for tens and possibly hundreds of years if no remedial action is taken. They recommend specific actions in their report. The report is available from the Survey for $1.00.

Miscellaneous Map 28--"Generalized Bedrock Geologic Map of North Dakota," was compiled and drawn by John P. Bluemle. It is intended primarily for the use of students studying geology, but it should be useful for other non-geologists as well. The small (8 1/2" x 11") map is printed in color on a base that includes counties, major towns, and highways. The map shows the distribution pattern of the geologic formations that occur in North Dakota. The map is available without charge from the North Dakota Geological Survey.

Miscellaneous Map 30--"Precambrian Structure Map of North Dakota," was compiled and drawn by Thomas J. Heck. The buried Precambrian surface is the deepest horizon recognized in North Dakota; it is the ancient surface of the igneous and metamorphic rocks upon which the sedimentary deposits of the Williston Basin were deposited, beginning about 600 million years ago.

The map shows the locations of all the wells that have been drilled into the Precambrian rocks in North Dakota; all of these wells were used as data points in compiling the map. Structure contours are shown at a 200-foot interval. The Precambrian surface, which is not exposed anywhere in North Dakota, ranges from as high as 800 feet above sea level in the southeastern corner of the state, where it is buried beneath about 200 feet of Quaternary sediments, to as low as 14,200 feet below sea level, near the center of the Williston Basin in Williams and McKenzie Counties, where it is covered by over 16,000 feet of younger sedimentary rocks.

Miscellaneous Map 30 is drawn at a scale of 1:1,000,000 (approximately 16 miles to an inch), and measures 20" x 26". It can be obtained from the Survey for $1.00.

"Catalog of North Dakota Oil Analyses" was compiled by the North Dakota Geological Survey staff, and includes oil analysis data from oil wells on file with the Survey. Information in the compilation includes such things as the interval sampled in the well, gravity, pour point, viscosity, salt content, paraffin, sulfur, fraction of gasoline and kerosene, residual crude fraction, and other data. Wells included in the compilation are arranged by township and range. Field, operator, and formation are also listed. Information on approximately 800 analyses is listed in the 42-page publication.

The catalog is available for $3.00 from the Survey.

PRESENTATIONS BY NDGS GEOLOGISTS

Survey geologists have been kept quite busy lately speaking to groups on various aspects of North Dakota geology. These presentations range from formal papers delivered at professional meetings, to talks given at service clubs and informal groups.

Randy Burke recently gave two talks. He spoke to the North Dakota Geological Society in Bismarck on the geologic history of reefs and how the Devonian Winnipegosis reefs fit into this scheme. Randy's other talk was on the carbonates of Shark Bay, Western Australia, and their strong similarities with the Mississippian carbonates of the North Dakota Williston Basin. He may be giving another talk on his observations of the Lake Macleod, Western Australia evaporite basin and its importance as a modern analogue for many evaporite/carbonate deposits in the Williston Basin.

Dave Fischer recently spoke at the monthly meetings of the Grand Forks Lions and Kiwanis Clubs on the history of oil and gas economics in North Dakota.

Ed Murphy gave four talks during the month of March. He presented two papers at the North Dakota Groundwater Symposium in Bismarck. The first was on his long-term study of the interaction between waste drilling fluid and groundwater; and the second was co-authored with Steve Tillotson and dealt with groundwater quality around selected landfills in the state. He also spoke to the North Dakota Paleontological Society and the Lake Agassiz Gem and Mineral Society on the Cretaceous-Tertiary stratigraphy of western North Dakota.

Dave Brekke participated in the North Dakota Groundwater Symposium in Bismarck in March by presenting a poster session on Trace Elements in Cretaceous Shales in North Dakota. John Bluemle also had a poster display at the Groundwater Symposium, his on the reasons and effects of saline seepage in the Red River Valley.

Ken Harris gave a paper at the North-Central meeting of the Geological Society of America in Akron, Ohio, in April, titled "Computer-Assisted Stratigraphy of Glacial Sediment in Eastern North Dakota and Northwestern Minnesota."

Marv Rygh spoke to the Conference on Oil and Gas Information and Data-Base Management in Norman, Oklahoma. The purpose of that meeting late last year was to examine the current status of activities and future plans of state organizations with respect to the collection, management, and utilization of state-level oil and gas information.

John Bluemle gave a paper at the annual meeting of the North Dakota Academy of Science in Bismarck in April, titled "Excavations in Hogback Ridge, North Dakota." That paper was co-authored by Nate Hunke and Mark Lord, UND geology graduate students. John also led a field trip in conjunction with the Academy meetings for the North Dakota Natural Science Society. Participants on the trip examined the geology between Harvey and Bismarck, North Dakota. John gave a talk in January on the geology of Scotland (the Georoots route) to the North Dakota Geological Society in Bismarck.

During June, John Bluemle spoke (1) to the Water Resources Committee of the Legislative Council in Devils Lake (on the geology and water resources of that area); (2) to a group of teachers in Devils Lake (as part of the ND Game and Fish Department's Project WILD); (3) to a group of teachers at the Leonard 4-H Camp (as part of the ND Water Commission's Project WET); (4) to a group of people attending the Muscular Dystrophy Association summer camp at Turtle River State Park; (5) to people attending the North Dakota Chapter of the Nature Conservancy annual meeting in Turtle Lake; and (6) to a group of teachers attending a workshop in Bismarck in conjunction with the Rocky Mountain Gem and Mineral Show. In July John is scheduled to speak to the Lion's Club in Grand Forks and to another Project WET workshop for teachers in the Washburn area.

CLARA LAUGHLIN RETIRES FROM NDGS

On March 31, 1988, Clara Laughlin retired from her position of Administrative Officer with the Geological Survey after 23 years of service. During this time she served under State Geologists Laird, Noble, Gerhard, and Halvorson, and current Acting State Geologist Sid Anderson. She was instrumental in working up the Survey budgets and keeping track of all the goings on of the Survey. She was in fact kind enough to come in on a part-time basis to help with the budget for the upcoming biennium.

Clara had a good working relationship with the staffs of the Board of Higher Education and Office of Management and Budget. She also had a very good relationship with the members of the Survey and was liked and respected by the support staff she supervised. All of this assisted in the smooth operation of the Survey. She was a very key member of the Survey and will be greatly missed.

PERSONNEL CHANGES

As a result of Clara Laughlin leaving the Survey, several of our employees changed their positions. Clara has been replaced by Connie Borboa, who is our new Administrative Officer. Connie has been with the Survey since 1972, for the past 3 years as Administrative Secretary.

Debra Kroese has been promoted from Information Processor to Administrative Secretary. She continues to type manuscripts and letters for our geologists. Linda Carlson is now an Information Processor. She had been our Receptionist for the last year.

JANNA MOLSTAD, NDGS RECEPTIONIST

Janna Molstad is the new Receptionist at the North Dakota Geological Survey. Janna is a 1983 graduate of Red River High School in Grand Forks, and she attended the East Grand Forks Technical Institute, from which she received a Secretarial Degree. She previously worked at Miller's Town & Country as a bookkeeper. Her duties as a receptionist will include answering the telephone, typing, and working on special projects for the Survey.

SUPPORT STAFF TAKES FIELD TRIP

Most of the NDGS support staff went on a field trip to see the geology of the Devils Lake area in early June. The trip, which was led by John Bluemle, included stops at the Devils Lake lagoon area to discuss the geologic problems associated with potential groundwater pollution and to Sully's Hill, to view the large ice-thrust/Devils Lake thrust-source complex. We also visited Fort Totten Cavalry Square Historic Site and the Sully's Hill National Game Preserve. The trip was successful--both educational and enjoyable. The picture on the next page, taken on Sully's Hill, shows the Survey employees who went on the field trip. From left to right are Clara Laughlin, Marilyn Rood, Connie Borboa, Kent Hollands, Debbie Kroese, Linda Carlson, Marvelyn Bohach, Eula Mailloux, and Palmer Roos.

Figure 1. NDGS staff who went on field trip.

TESTING NEW AND INNOVATIVE PEAT SAMPLING TECHNIQUES --Tom Malterer

Peat sampling is definitely a unique experience. Under "normal conditions," a person sampling peat is between ankle and knee deep in water, juggling sampling equipment, sample bags, trying to keep a backpack and notes dry, fighting (mostly ignoring) mosquitoes and deer flies, and enjoying the idea of working outdoors on exciting and relevant research. Along with this introduction are two photos (next page). They could carry a variety of captions: Diving Into the Job - Getting Away from the Mosquitoes - Necessity is the Mother of Invention - Innovative Peat-Sampling Technique - Scuba Diving for Peat - A Typical Peat Sampling Day - Bobbing for Peat-UFFDA - (Add your own version).

The circumstances that led to this scuba diving for peat venture revolved around retrieval of a peat-sampler head, which became detached and unretrievable by conventional methods, at some depth. The particulars of the event are better left for another time, although Tom Malterer, UND Energy and Minerals Research Center, is noticeably silent about the matter.

Figures 1 and 2. Innovative peat-sampling techniques (see text for explanation).

QUATERNARY SCIENTISTS FORM SUPPORT GROUP

--Ken Harris

THE FRIENDS OF THE NEW DES MOINES LOBE QUATERNARY FIELD CONFERENCE was held on June 17, 18, and 19 at Hartford Beach State Park near Wilmot, South Dakota, on the western shore of Big Stone Lake. The purpose of the conference was to stimulate communication among geologists and soil scientists interested in all aspects of the Quaternary geology and paleoecology of the Upper Midwest. Forty geologists and soil scientists from Iowa, Michigan, Minnesota, North and South Dakota, and Wisconsin attended the meeting. The North Dakota Geological Survey, North Dakota State University--Geology Department, and the South Dakota Geological Survey co-hosted the three-day meeting.

The conference consisted of technical talks and discussion during the day with a field trip each evening and on the morning of the 19th. Fourteen speakers presented talks on their current work and representatives of the participating state geological surveys summarized the Quaternary programs of their respective organizations. Jay Gilbertson, South Dakota Geological Survey, led short field trips on Friday and Saturday evenings, and a half-day field trip on Sunday. The field trips highlighted the glacial geology of the Prairie Coteau and the glacial stratigraphy exposed in outcrops along the Minnesota River Valley.

The name used for the field conference, FRIENDS OF THE NEW DES MOINES LOBE (FONDL), was borrowed from a similar field conference that was orchestrated by Charles Matsch, John Brophy, Lee Clayton, and Steve Moran in the early 1970s. The original conference (FONDL I) focused on the same general area and topics. This, then, was the second FRIENDS OF THE NEW DES MOINES LOBE FIELD CONFERENCE (FONDL II).

This conference was structured so that it was informal in nature and low in cost. The participants camped in a group-camping area and the setting seemed to promote an atmosphere conducive to discussion and informal field trips. We had a productive meeting and despite soaring temperatures everyone seemed to have a good time.

Sally Fisk and Kevin Krogstad, NDSU--Geology Department, handled on-site registration and helped with logistics. The organizers of the FONDL II Field Conference were Don Schwert, NDSU--Geology Department; Jay Gilbertson, South Dakota Geological Survey; and Ken Harris, North Dakota Geological Survey.

LANDFILL STUDIES CONTINUE

As we reported in the last NDGS Newsletter, Ed Murphy, Environmental Geologist with the Survey, is continuing his studies of North Dakota landfills this summer. He has recently been drilling observation wells around the landfills at Williston, Devils Lake, Wishek, Napoleon, Linton, and Harvey, as well as at an industrial dump site at Williston. Ed's study, being conducted with the cooperation of the North Dakota State Department of Health, is intended to determine the extent of groundwater contamination and any associated health risks at each site. Ed also hopes to learn enough about conditions in various parts of the state so that we will be able to better assess the potential risk for groundwater pollution at proposed landfill sites.

DEVILS LAKE LAGOON STUDY

The Survey was asked this spring to investigate the possibility that the sewage lagoons on the southwest side of Devils Lake might be contaminating the local groundwater, especially that in the Spiritwood Aquifer, which is located to the immediate south of the lagoons. The lagoons cover about 270 acres of land and another 200 acres of holding ponds is periodically flooded by effluent from the lagoons. In June, the North Dakota Geological Survey, along with the North Dakota State Water Commission, drilled 38 test holes around the perimeter of the lagoons and ponded area to determine the composition and permeability of the near-surface materials and to better define the exact extent of the Spiritwood Aquifer. At the present time, results are inconclusive, but the wells will be monitored over the next several months to determine whether contaminants are migrating away from the lagoons.

Figure 1. Ed Murphy, left, is interviewed by channel 8 (Devils Lake/Grand Forks) news regarding our test drilling around the Devils Lake lagoon.

Figure 2. Test hole sample cores laid out for inspection. We obtained cores of the glacial sediment and lake sediment in the upper 25 feet in the area surrounding the lagoon. The undisturbed cores give us a better idea of the composition, consistency, texture, and permeability of the materials and help us determine whether the lagoon might be losing water through the ground.

FOSSIL SHARKS OF NORTH DAKOTA --John W. Hoganson and Alan M. Cvancara

Introduction

There is something fascinating about sharks. Maybe it is because their physical appearance leaves little doubt in our minds that after millions of years of evolution these beasts have become the ultimate predator in the marine environment. Consequently, the same type of mystique that surrounds the dinosaur Tyrannosaurus rex also surrounds the Great White shark. To some of us, sharks become even more interesting when we find their perfectly preserved teeth weathering out of a 60-million-year-old sandstone.

Man's fascination with fossil shark teeth dates back a long time. Fossil shark teeth with holes bored through them have been found in Upper Paleolithic sites suggesting that Cro-Magnon man wore them as ornaments. Early Egyptians also wore fossil shark teeth as charms, and during the Bronze Age they were used as tools to etch patterns on pottery. During the Middle Ages in Europe these fossils were called "Glossopetrae" or the petrified tongues of serpents (tongue-stones) and were used to ward off various ills such as rheumatism. In medieval Europe, tongue-stones were regarded as an effective antidote for snake bite, and in Italy were (and in some places still are) thought to be protection against the Evil Eye. According to Pliny, the Romans considered tongue-stones necessary for those courting women presumably serving to "loosen the tongue." It wasn't until the 1700s, however, that these fossils were recognized as being teeth of sharks. Only recently have fossil shark teeth started to attract much serious scientific interest.

Shark teeth are the most common vertebrate fossils found in Cretaceous and Tertiary marine rocks but, as we will discuss later, they are one of the most difficult fossil vertebrate groups to work with. Both of us had previously encountered fossil shark teeth during other projects, but neither of us had seriously studied them before now. In other words, we didn't know what we were getting into.

What Are Sharks?

Of the two categories of higher fishes, sharks are in the Chondrichthyes or cartilaginous fish group in contrast to the bony fishes or Osteichthyes. In Chondrichthyes bone is completely absent and the internal skeleton consists of cartilage. Cartilaginous fish include not only sharks, but also their close allies skates and rays and the less common chimaeras or ratfishes.

Even though sharks first appeared in the late Devonian (about 360 million years ago), they are not considered the most primitive fishes because they are actually the last major fish group to appear in the fossil record. Sharks similar to those existing today began to develop during the Jurassic and by the end of the Mesozoic most of the existing families of sharks had appeared. In fact, many of the shark teeth found in Cretaceous and early Tertiary rocks are so similar to those of living sharks that they can be placed in existing genera. There are 342 species (31 families) of sharks living today.

Sharks evolved in the marine environment and have subsequently invaded most of the world's oceans; a few have even adapted to freshwater conditions. Some normally marine species have been found living in rivers hundreds of miles from the nearest ocean and other marine forms have been taken in lakes great distances from the nearest marine habitat. Even though sharks are most commonly found in warm water, tropical or subtropical regions, they have been observed at all latitudes and one species even thrives in the Arctic Ocean at temperatures of 0° to 7°C. Sharks live in almost all habitats in the marine realm from shoreline to depths of greater than 2,000 metres.

All sharks are carnivores and most are active predators. Many sharks prey on small schooling fish and others eat invertebrates such as clams and crabs. But the large, active swimming sharks with streamlined bodies and fearsome looking teeth occupy the top of the marine food chain and will attack large prey such as whales. The Great White shark, immortalized in the JAWS movies, epitomizes this high degree of predatory adaptation. The Great White, up to 20 to 25 feet long, is, however, a diminutive cousin of the extinct "Great-Great" White shark that lived during the Miocene. That species was probably the most voracious predator that ever existed in the marine realm. It grew to lengths of 60 to 75 feet, possessed teeth 5 to 7 inches long, and had a mouth gape of 6 to 7 feet. The superpredator Miocene Great White would surely have made the 25-

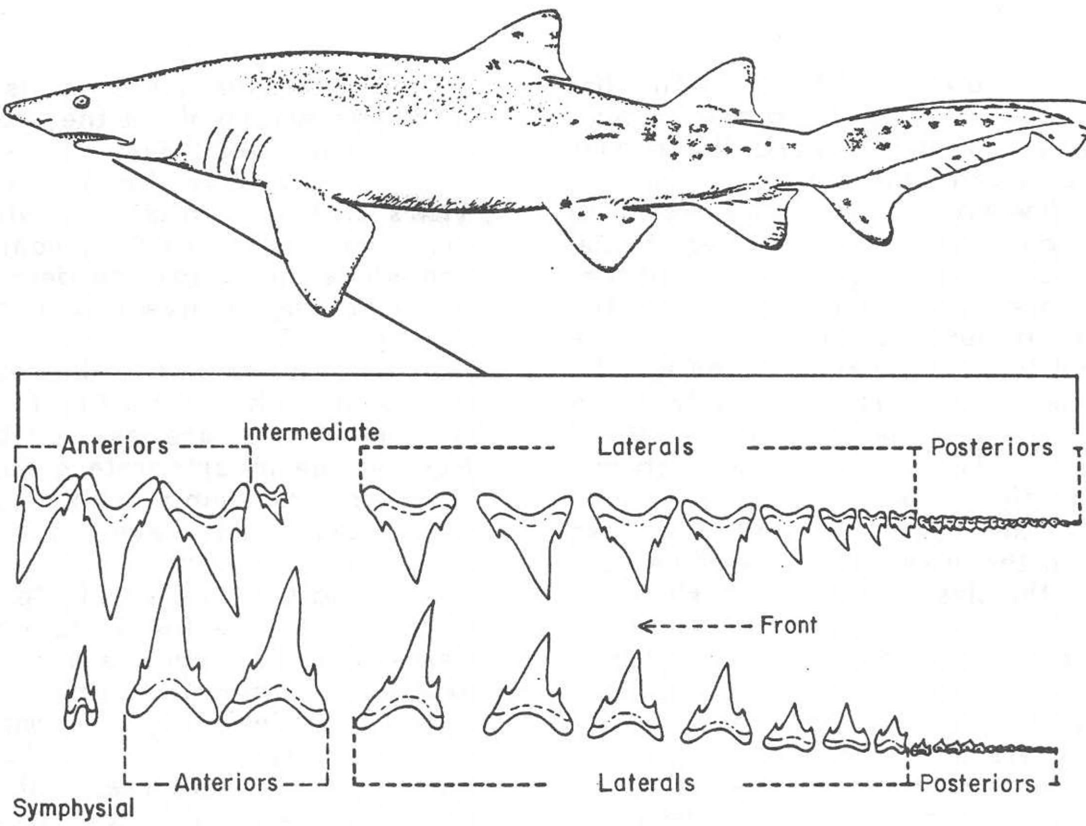

Figure 1. Tooth types of the sand tiger shark, Carcharias taurus. Upper and lower jaws (left side). From Compagno (1984) and Cappetta (1987).

foot-long mechanical shark in the JAWS movies look like a guppy.

Shark Teeth

Because cartilage disintegrates readily, entire shark skeletons are seldom found as fossils. Only teeth consisting of resistant orthodentine and enamaloid spines, dermal denticles, and sometimes vertebrae are preserved. Spines are rarely found and vertebrae and minute dermal denticles are of limited use for identification. Primarily we must work with isolated teeth.

At some fossil localities, shark teeth are extremely abundant. One of the reasons for this is that sharks are polyphodont, that is, teeth are continuously replaced throughout the life of the fish. Individuals of some species may produce thousands of teeth. Replacement teeth form in rows inside the jaw and, as if on a conveyor belt, gradually but regularly swing forward into place. In that way, teeth that are lost during feeding or other ways, are renewed almost immediately.

Identification of sharks from isolated teeth is difficult because most sharks are also heterodont. As in mammals, each species usually posses-ses teeth of several very different types. The shape of an individual shark's teeth may not only differ from the front to the back of the jaw but also the teeth in the upper and lower jaws may be different. For example, in the common sand tiger shark living today (fig. 1) the lower jaw (actually ½ of the jaw) contains, from front to back, a small asymmetrical, symphysial tooth near the center of the jaw; 2 rows of high crowned, sharp anterior teeth; 7 rows of lateral teeth that have straight crowns and become progressively smaller toward the corner of the mouth and numerous rows of small, low-crowned posterior teeth. In the upper jaw there is no symphysial tooth, 3 rather than 2 rows of anteriors, an additional intermediate tooth, 8 rows of laterals whose crowns are slanted toward the rear of the mouth, and numerous rows of posteriors. To complicate the matter even further, there can also be differences between the teeth of adults and juveniles within the same species and also between the sexes. Because of heterodonty, the classification of fossil shark teeth became confused. Many fossil "species" that were created actually only correspond to teeth from different positions in the jaw. Early researchers apparently did not have an adequate knowledge of the variation that can exist in the dentition of modern shark species. Some of them even described new species based on a single fossil tooth. One of the reasons that there have not been many studies of fossil shark teeth is because of this confusion. Our approach has been to examine as many modern shark jaws as possible to become familiar with the types of dental variation that can exist and to take a conservative approach in classification of the fossil teeth that we are studying.

Shark Teeth from the Cannonball Formation

Our reasons for studying the vertebrate fossils of the Cannonball Formation in North Dakota were to:

(1) determine the kinds of vertebrate organisms that lived in or near the Cannonball Sea;

(2) gain more information about the marine environment and possibly the climate in which they lived;

(3) determine if any of the fossils would further define the age of the Cannonball Formation;

(4) determine if the fossils provide more information about the provenance of the Cannonball Sea.

The Paleocene (about 60 million years old) Cannonball Formation consists principally of poorly consolidated sandstone and mudstone deposited by the last sea to invade central North America. Fossils of invertebrates, especially clams and snails, are fairly abundant in the Cannonball Formation, but vertebrates are less conspicuous. Most of the invertebrate groups have been or are being studied but the vertebrate fossils have not been seriously studied until now.

In addition to shark teeth, the other vertebrate fossils found in the Cannonball Formation are teeth from skates and rays (3 species), ratfish jaws (2 species), shark dermal denticles, fish spines, fish otoliths (ear bones), fish vertebrae, fish scales, crocodile remains, and turtle fragments. By far, however, the most common vertebrate fossils are shark teeth represented by about 1000 specimens in our collection, most of which were collected weathering out of sandstone. We have recovered shark teeth from approximately 50 localities in western North Dakota and northwestern South Dakota (fig. 2).

At the North Dakota Academy of Science meeting in 1987, we presented the preliminary findings of this study and at that time reported the occurrence of three species of sharks in the Cannonball Formation. That total has now risen to eight, due to another season in the field and additional laboratory analyses. The list of sharks now includes:

Notorhynchus serratissimus [Hexanchidae: cow sharks]

Megasqualus orpiensis [Squalidae: dogfish sharks]

Squalus minor [Squalidae: dogfish sharks]

Carcharias macrota [Carcharinidae: sand tiger shark]

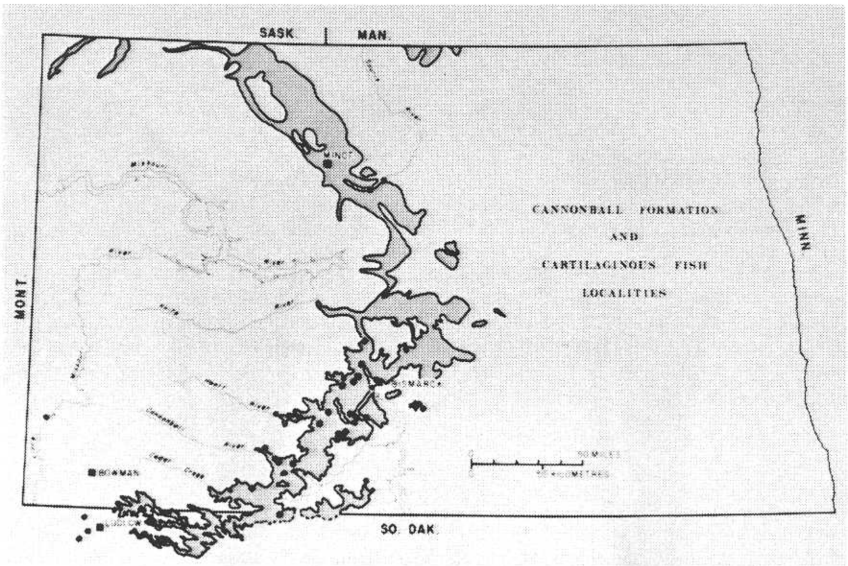

Figure 2. Map showing the outcrop area of the Cannonball Formation and localities (dots) where cartilaginous fish fossils have been found.

Paleohypotodus rutoti [Odontaspididae: sand tiger shark]

Otodus obliquus [Otodontidae: fossil family related to mackerel sharks]

Paraorthacodus eocaenus [Paleospinacidae: fossil family]

Unidentified [Triakidae: houndshark]

By far the most abundant shark teeth found in the Cannonball Formation are from Carcharias macrota (figure 3), a sand tiger shark similar to the ones illustrated in figure 1 and on the cover of this Newsletter. Most of the other species are comparatively rare. The very distinctive Paraorthacodus eocaenus was represented by only one specimen and Megasqualus orpiensis and Squalus minor, very small teeth, would not have been found at all if we had not screened the sand at one site. Notorhynchus, Squalus, and Carcharias are genera that still exist in today's oceans whereas the remainder of the Cannonball shark genera are extinct.

The following are some of our preliminary findings resulting from study of the Cannonball shark fossils.

(1) A diverse cartilagenous fish fauna existed in the Cannonball Sea.

(2) The cartilagenous fish fauna was similar to those living in oceans covering parts of Europe, North Africa, and the U.S. Gulf and Atlantic Coast during the same time that the Cannonball Sea occupied parts of North Dakota.

(3) Some of the shark species that lived in the Cannonball Sea appear to indicate that the sea was temperate (as some mollusks do) and probably invaded the mid-continent from the south.

(4) The shark fossils indicate a Paleocene age for the Cannonball Formation. We hope to be able to define the age of the Cannonball Formation even more precisely by the time this study is completed.

Future fossil shark studies

With the Cannonball shark study nearing completion, we are beginning to shift our attention to the cartilaginous fish fossils of the Cretaceous formations in North Dakota. We have begun some preliminary field work, but

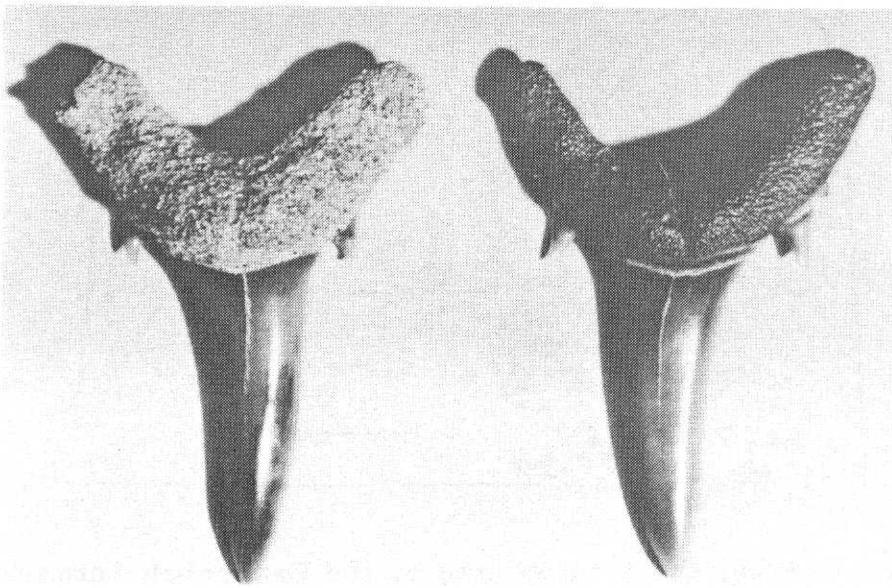

Figure 3. Anterior teeth of the sand tiger shark, Carcharias macrota from the Cannonball Formation. Largest tooth is just over 1 inch high.

will not concentrate our efforts on that project until next summer. Shark teeth are not common in the Cretaceous units exposed in North Dakota but have been found in the Carlile, Niobrara, Pierre, Fox Hills, and Hell Creek Formations. Our objectives will be to determine the species of fish that existed during the Cretaceous, to define any evolutionary trends in the fish faunas, and to determine if the sharks experienced major extinctions at the end of the Cretaceous by comparing the Cretaceous faunas to those from our Cannonball study.

NEW ENHANCED OIL RECOVERY PROJECTS

--Marv Rygh

During the past year, four new enhanced oil recovery (EOR) projects have either begun or are in final preparatory stages in North Dakota. This is encouraging news for the oil industry in the state. Two of the EOR projects are waterflood units in Billings County, both operated by Tenneco Oil Co. Another EOR project is a gas-injection unit in Divide County, operated by Raymond T. Duncan and Associates. The fourth project is an air-injection unit in the Medicine Pole Hills Field in Bowman County operated by Koch Industries.

The two new waterflood units in Billings County produce from the Mission Canyon Formation and have similar reservoir characteristics. The first unit to be approved by the North Dakota Industrial Commission was the North Elkhorn Ranch Unit. This unit, located in T144N, R101W, encompasses portions of the Devils Pass, Anderson Coulee, and Elkhorn Ranch-Madison Pools. The unit covers 7,360 acres with 42 wells completed and 35 wells currently producing from the Mission

Canyon. Tenneco's plan is to convert six of the producing wells into water-injection wells. Estimated oil recovery from the project is 4,806,100 bbls over the next 22 years. Incremental recovery (oil that would have not been recovered under primary production) is estimated to be 3,378,500 bbls. Total production from the pool, including primary production before the unit began, will amount to 11,940,600 bbls. Water injection began in January 1988.

The second waterflood approved by the ND Industrial Commission was the Big Stick-Madison unit. This unit, located in Tps141 and 142N and R101W in Billings County, encompasses all of the Big Stick-Madison Pool and portions of the Four Eyes and T.R.-Madison Pools. The unit covers 14,501 acres with 93 wells completed in the Mission Canyon. Of these, 61 are currently producing. Tenneco's plan is to convert 15 wells to water injection. Estimated oil recovery from the project is 20,180,950 bbls. Of that total, 13,362,385 bbls is incremental or additional production projected as a result of implementation of the waterflood. Total production from the pool including primary production before unit production began, is projected to total 58,562,400 bbls. Water injection is slated to begin in the latter part of the summer.

The two new Madison waterfloods just described are similar in a number of ways (a list of reservoir parameters is given as a basis of comparison (table 1). Both fields were discovered in 1979 and both produce from approximately the same depth. Both reservoirs are solution-gas drive with a combination structural/stratigraphic trap controlling oil accumulation. Other parameters, such as pay thickness, porosity, initial water saturation, original bottom-hole pressure, bubble-point pressure, gas/oil ratio, and oil gravity, are quite similar.

The density of injection wells is somewhat less in the North Elkhorn Ranch Unit although neither field is on a pattern spacing; locations of injection wells were chosen on a site by site basis according to reservoir simulation studies performed by Tenneco. The Big Stick Unit has 10 injection wells located near the perimeter of the reservoir and 5 injection wells located near the center. The six injection wells in the North Elkhorn Ranch Unit are distributed uniformly throughout the field. Planned injection rates are similar in both fields. Big Stick Unit injection rates range from 840 to 3,000 BWPD (barrels of water per day) with an average of 1,300 BWPD. North Elkhorn Ranch Unit injection rates range from 300 to 2,800 BWPD with an average of 1,500 BWPD.

The most significant difference between the two units is the size of the reservoirs and the number of wells. The Big Stick-Madison unit has approximately five times more total recoverable reserves than the North Elkhorn Ranch Unit.

The two units are very important to the future of secondary recovery in North Dakota. Madison reservoirs account for the majority of oil production in the state, and if these two Madison reservoirs respond well to the waterflood, more operators may consider implementing secondary recovery in other oil fields in North Dakota.

The third secondary recovery project approved by the ND Industrial Commission was the Dolphin-Dawson Bay Unit. This unit is located in T161N, R95W and T160N, R96W in Divide County and encompasses all of the Dolphin-Dawson Bay Pool. Six wells are situated in the unit. The Dolphin-Dawson Bay Pool, discovered in October 1986, is unique in North Dakota. The Dawson Bay Formation produces in only two other fields in the state, the Temple and the Marmon Fields, both in Williams County. The Temple-Dawson Bay Pool has two wells with substantial production, but the Marmon-Dawson Bay Pool produced a few thousand bbls out of one well, which has been plugged and abandoned.

The Dolphin-Dawson Bay Pool wells have been voluntarily shut-in since December 1987. During normal primary production, the reservoir pressure was declining rapidly and approaching the bubble-point pressure. The operators, particularly Raymond T. Duncan and Associates, were concerned about keeping the reservoir pressure above the bubble point in order to recover additional oil. The unitization plans call for gas injection into the reservoir to increase the reservoir pressure. One of the six producing wells will be converted into a gas injection well.

A substantial amount of natural gas will be needed to repressurize the reservoir. 5.2 Bcf (billion cubic feet) of natural gas will be purchased and injected into the reservoir to raise the pressure from 3500 psi to 4100 psi. This gas will be enriched with propane to increase the BTU content of the gas to 1200 BTU per cubic feet. The enriched gas has proven to have better miscibility characteristics in laboratory tests. The estimated time to repressurize the reservoir to 4100 psi is 90 days. Oil production will not commence until after that repressurization period.

The Dolphin-Dawson Bay Pool had already produced 409,000 bbls before it was shut in. Remaining primary reserves are estimated at 828,000 bbls and incremental recovery utilizing gas injection is estimated at 1,944,000 bbl. Gas injection is planned to start this summer and production will resume in November.

One of the few tertiary recovery projects in the state is the Medicine Pole Hills-Red River Pool. This unit is located in T130N and Rs103 and 104W in Bowman County and encompasses the central and eastern portions of the Medicine Pole Hills-Red River Pool. The operator in the field is Koch Industries.

This Medicine Pole Unit is unique because it is the only active air injection project in North Dakota. Approval for the unit occurred back in April 1985, but startup of air injection did not begin until October 1987.

Currently, 3 injection wells and 13 producing wells operate in the Medicine Pole Hills Unit. This air-injection unit is similar to a number of other units in northwestern South Dakota. These units are also operated by Koch Industries. Since operations commenced last October, production from the unit has increased from 13,095 barrels per month in January 1988 to 16,882 barrels per month in April.

All of these enhanced oil recovery projects are important to the oil industry and the general economy of North Dakota. It is encouraging to see that new secondary and tertiary recovery projects have been initiated, particularly when the oil industry has been hard-hit by low oil prices.

Table 1. Field and reservoir data for North Elkhorn Ranch and Big Stick units (from ND Industrial Commission hearing).

FIELD DATA	NORTH ELKHORN RANCH	BIG STICK
Year of Discovery	1979	1979
Type of Trap	Stratigraphic/Structural	Stratigraphic/Structural
Producing Formation	Mission Canyon	Mission Canyon
Producing Mechanism	Solution Gas Drive	Solution Gas Drive
Proposed Unit Area	7,360 Acres	14,501 Acres
RESERVOIR CHARACTERISTICS		
Average Depth to Top of Pay	9,500 Feet	9,400 Feet
Average Productive Thickness	25 Feet	25 Feet
Average Porosity	15%	17%
Average Air Permeability	10 md	30 md
Average Initial Water Saturation	35%	35%
FLUID CHARACTERISTICS		
Gravity of Oil, Degrees API	39	40
Original BHP, psig	4,250	4,405
Reservoir Temperature, °F	250	255
Bubble-Point Pressure, psig	2,896	2,717
Original Solution GOR, SCF/STB	920	800
Formation Volume Factor at Bubble Point	1.64	1.56
Formation Volume Factor at Original Pressure	1.58	1.50
Viscosity of Crude at 250°F & 2,896 psig, cp	.32	.324
WELL STATUS		
Development Pattern Acres	160	160
No. of Producing Wells (5-1-87)	35	61
Maximum Producing Rate (1-1-83)	7,198 BOPD - 27 Wells	31,387 BOPD - 55 Wells
Present Producing Rate (5-1-87)	1,808 BOPD	3,506 BOPD

THE NAMING OF THE WILLISTON BASIN

--Bill Shemorry

(Editor's Note: I've extracted a part of a longer article that Bill Shemorry wrote about the geology of the Williston Basin and some of the early events that took place about the time the Basin was named. I certainly appreciate Bill's thoughtfulness in sending me these materials.)

In about 1910, oil prospectors and early geologists exploring the geology of the Great Plains first recognized the presence of the Williston Basin. These geologists, working for the U. S. and North Dakota Geological Surveys, mapped the surface expression of the Nesson Anticline in the Williston area. They found clear evidence that a great interior sea-way, covering the present-day Rocky Mountains and Great Plains area had existed and they theorized that this huge sea had extended from the present-day Gulf of Mexico to the Arctic Ocean.

Some of these geologists theorized that, eventually, this sea was greatly restricted by the upheaval which created the Rocky Mountains. It was also believed that, at about this same time, the Great Plains area was so uplifted as to raise it above sea level. This started a controversy among the geologists because this theory was not universally accepted. However, the upshot of it all was that it created enough interest to bring others to make critical studies.

Positive evidence for the existence of a Williston Basin was discovered in 1912 by geologist W. T. Thom, Jr., ('Taylor Thom') who at that time was working with two other eminent geologists, E. Russell Lloyd and L. Murray Newmann. They discovered fossil corals in beds of clay and sandstone exposed along the banks of the Cannonball River near the South Dakota border. This provided undisputable evidence that this area had at one time been at the bottom of a sea.

Thom spent much of the next decade defining the limits of what was first called the Cannonball sea basin. Some of this time was spent with various U. S. Geological Survey field parties working to the east of the Rocky Mountains.

Thom's associates at various times included Walter B. Wilson, Raymond F. Baker, J. D. Sears, E. T. Hancock, C. E. Dobbin, W. P. Woodring, H. S. Cave, Gail F. Moulton, N. W. Bass, and A. J. Collier. All at the time engaged in an energetic effort by the U. S. Geological Survey to map the geologic structures of North Dakota and eastern Montana.

Collier, in particular, was well known in North Dakota as being the author of a 1919 publication that described the Nesson Anticline. This was Bulletin 691-G of the U. S. Geological Survey. The Anticline was further described by another geologist, L. P. Dove, in Volume 12 of the Quarterly Journal of the University of North Dakota. The dissemination of this information, in turn, helped create the interest that resulted in some of the attempts to drill for oil, which took place in the 1920s.

During this period, prior to 1922 and after, the results of the various studies were published in a number of U.S. Geological Survey Press Notices. Dr. Thom identifies two of these as S. P. 14,846 and S. P. 30,113.

Almost in an offhand manner, Thom also takes credit for naming the Williston Basin. This information came to light in 1953 as the result of a letter written to him requesting information as to how the name had been chosen. The letter was signed by Bill Davidson, Jr., who at that time, two years following the oil discovery, was a hustling member of the Williston Chamber of Commerce Oil Committee.

Through the years, Thom had become one of the nation's leading

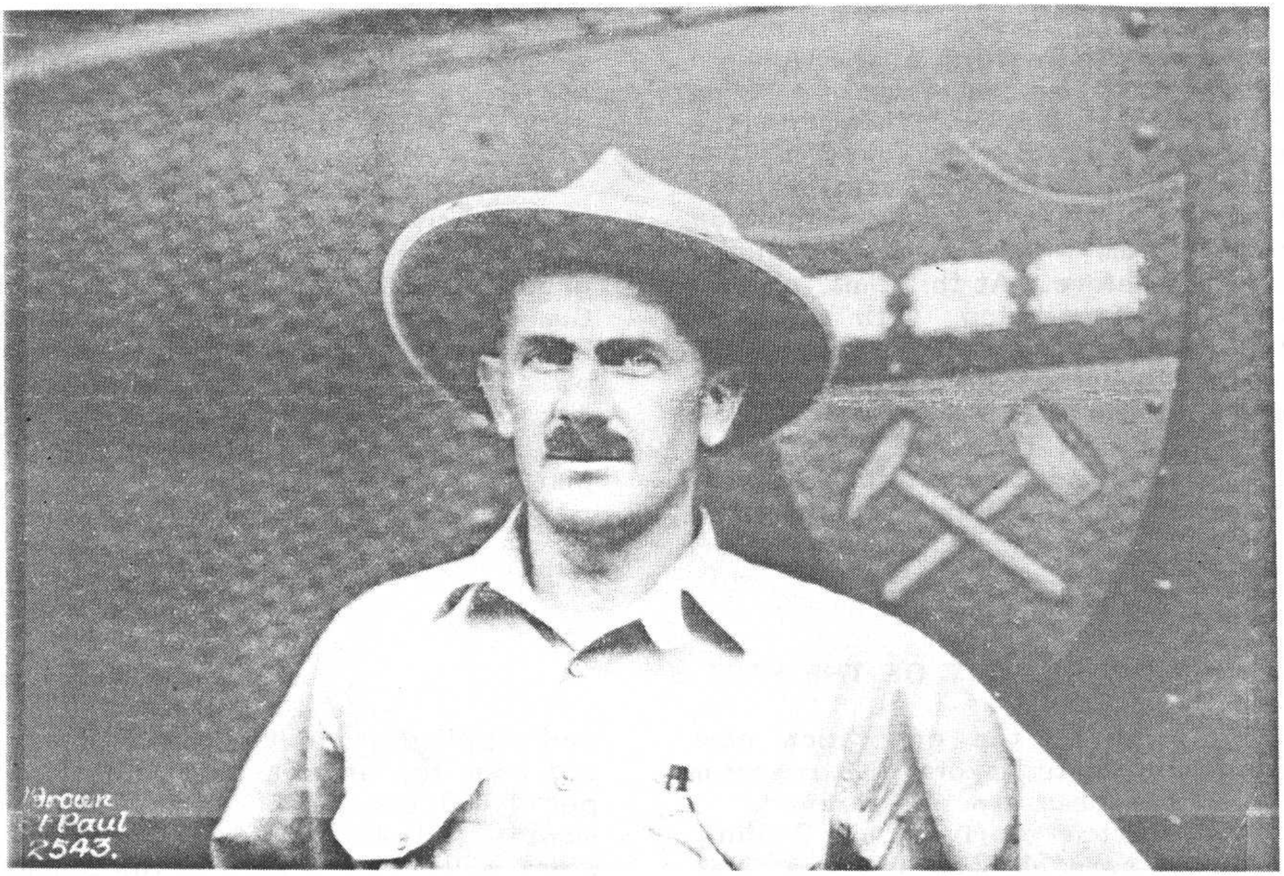

Figure 1. W. Taylor Thom, Jr. Dr. Thom was responsible for naming the Williston Basin. Photo taken in Billings, Montana in 1930.

geologists. In 1953, he was chairman of the Department of Geological Engineering and Blair Professor of Geology, Princeton University. He was also president of the Yellowstone-Bighorn Research Association. Previously during his work with the U.S. Geological Survey, he had advanced to Chief of Fuels Section (oil, gas, and coal).

In his response to Davidson, Thom enclosed a well-written article telling some of the history of early exploration and his role in naming the Williston Basin. The name "Williston Basin" was formally used in a scientific paper which Dr. C. E. Dobbin and Thom presented before the Geological Society of America on December 23, 1923. Publication in the GSA Bulletin followed on September 30, 1924.

Before that, Thom had used the name on a structural sketch map, which had been published in February 1923 by the American Association of Petroleum Geologists. This map, which accompanied his article on "The Relationship of Deep-Seated Faults to the Surface Features of Central Montana," was the one republished as figure 1 of the GSA article.

Semi-formal use of the name "Williston Basin" had also been made in a U.S. Geological Survey memorandum to the press which Thom prepared on the topic: "Possible Oil & Gas in North Dakota." This press notice No. 3761 bore the release date of June 13, 1923. The name "Williston Basin" was used three times in this memorandum.

Perhaps the writing of the Williston Basin article was the result of a surge of nostalgia, for Dr. Thom, on the previous June 23, 1952, had made a visit to the Williston Basin to see, first-hand, the drilling and production of petroleum which he had predicted 29 years before. At this time, oil man Jim Key of Williston, with whom he had been in contact, showed him around the oil installations and provided information.

In 1953, Dr. Thom wrote... "I wish to ...express my pleasure that the people of the Williston Basin region, after so many years of pioneering effort, are at last beginning to reap the benefits of these latest achievements of American daring and 'know-how'."

(Editor's Note: Wilson Laird told me recently that he recalls talking to Taylor Thom one day when he and a group of students passed through Grand Forks and he was very proud to have put the name, "Williston" on that particular piece of geography. According to Laird: "Taylor Thom was a great man and a wonderful geologist").

A DRILLING RIG OUT OF THE PAST

--Bill Shemorry

To much of the generation now populating North Dakota, it must seem like oil has been around "forever."

Well, that is nearly true. Drilling has been here almost since the first settlers came.

Although records are scanty and almost everyone who was living here in the early days of settlement is gone, a few tidbits of information remain to prove that as early as 1909 there was drilling for oil and gas in North Dakota.

One such item out of the past is the photograph which accompanies this story. This could be a picture of the very first attempt at drilling for oil in North Dakota. More likely it is the photo of a gas well drilled north of Minot at Westhope or Lansford, where briefly natural gas from a glacial deposit about 175-210 feet deep was used to heat homes and barns.

Eckman still exists and is a small town about 15 miles straight south of Westhope, and 18 miles east of Lansford.

Westhope received a certain amount of notoriety during the years preceding 1910 when the North Dakota Gas Company built a distributing system and supplied gas to its citizens, charging them the unbelievable rate of 30¢ per 1,000 cubic feet during summer months and 40¢ per M in the winter. Eight wells were drilled at the phenomenally low cost of 13.6¢ per foot.

Lansford also had gas service for a time during this same period. Here too it was transported through an underground system of pipes and used to heat and light 13 homes.

At any rate, things printed and written on the back of the post card identify it as the product of Golden's Big Studio of Westhope. It had been mailed at 5 p.m., April 15, 1909, from Eckman and bore the one cent postage stamp which the postal service charged in those days.

The card was addressed to a "Miss Groman" who either worked at or was a patient in the Mayville, N.D. hospital. A short message read, "Just to let you know that I am okay. Find farming kind of hard. Came here by team from Westhope. Your friend, Stenehjem."

Assuming "Stenehjem" was a surname, there was no first name for either the addressee or the sender. A phone call to Justin Stenehjem of

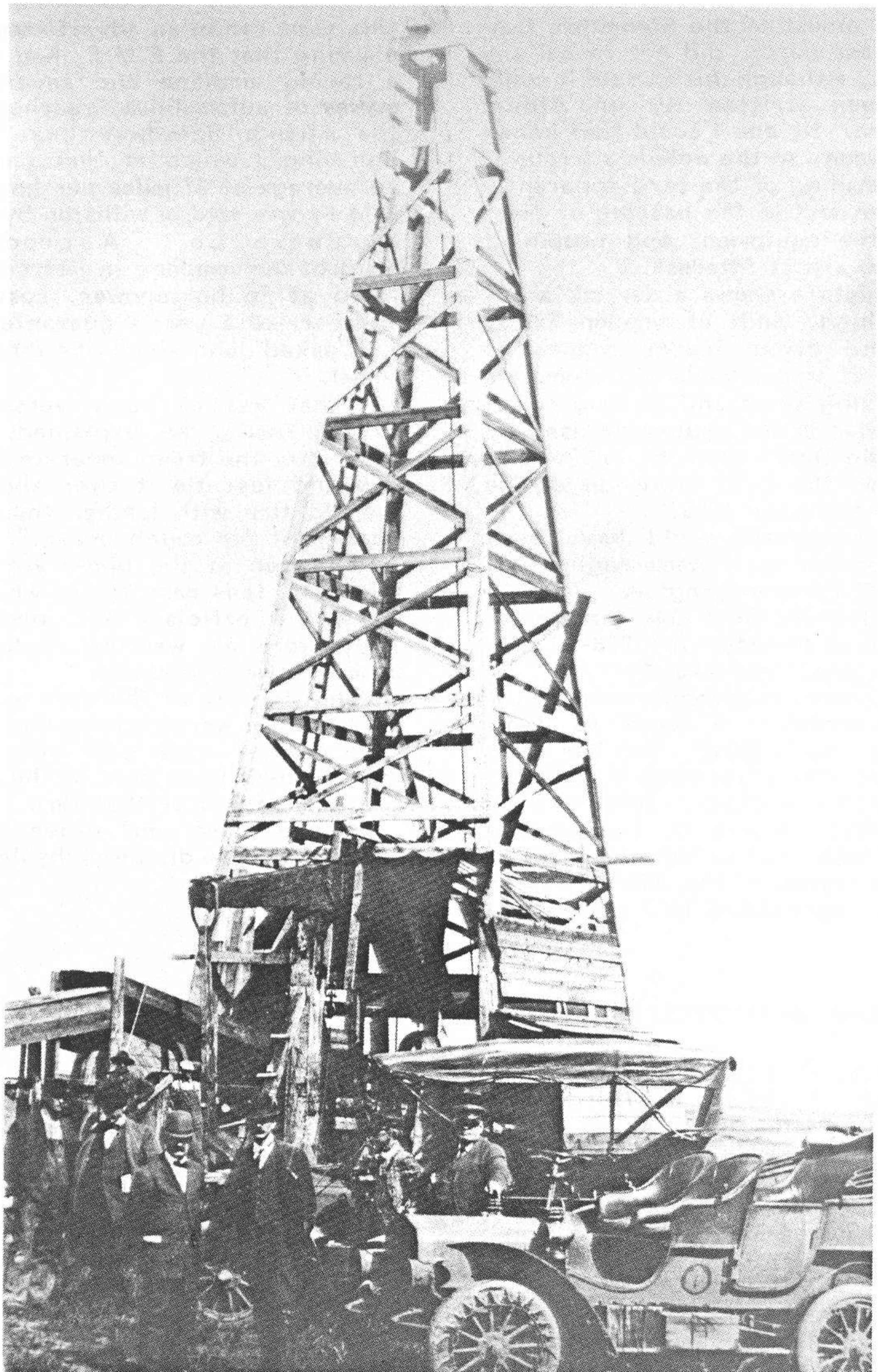

Figure 1. Early drilling rig.

Stanley, oldest of the Stenehjem family in these parts, did not reveal any specifics, although Justin said it could have been written by an Albert Stenehjem. No one I could find knows Miss Groman, so the details surrounding the mailing of the card apparently have been lost in the passing of time.

But the equipment and people of the photo are of interest...

The picture shows a derrick about 50 feet high, built of wooden 6x6's, 2x4's and other lesser pieces as braces. It was a cable rig, complete with walking beam and looking somewhat similar to the equipment used by Col. Edwin Drake when he drilled and discovered the first crude oil in the U. S. in the year 1859.

This equipment could have been powered either by a steam engine or a stationary kerosene engine. The rig used by Pioneer Oil & Gas three miles southeast of Williston in 1916-20 also looked a great deal like it.

The ancient automobiles are also of great interest. I went to John Shemorry, my brother, who has been in the automobile business in Williston longer than any other. John told me the vehicle closest to the camera probably was a car called an E.M.F. I looked in copies of the Williston Graphic newspaper dated 1910 and found this same car in an advertisement proclaiming that the E.M.F. had defeated a racing airplane and several other makes of automobiles, roaring around the Atlanta Speedway like "greased lightning", which at that time meant an average of 67 miles per hour. The E.M.F. was sold in Williston by Rawson Hardware Co. A product of Studebaker company in Detroit, it was rated at 35 horsepower, cost $1,000 and carried a year's guarantee.

I asked John about the fancy front wheel.

"That was an early version of a tire retread", he explained. "You could buy the tread separate from the tire and just tie it over the top of the old tire with leather thongs. It was meant for rough going."

The men in the photo are also of interest. It is easy to see which ones were the officials and promoters. They were all wearing derby hats, probably were bankers.

The drivers of the cars were distinct. They were wearing the military style leather caps with bills on the front, which were part of the garb of auto chauffeurs of that time.

The drillers and other oil field hands were also distinguishable. They wore bib overalls.

FIELD WORK IN MORTON COUNTY

--Wilson Laird

(Editor's Note: This article is another contribution by Wilson M. Laird, who served as State Geologist of North Dakota from 1941 until 1969. I greatly appreciate Dr. Laird's historical perspective and insights about North Dakota geology and the Geological Survey).

When I first came to UND in the fall of 1940, Frank Foley, who was at the time, State Geologist of North Dakota, took me to Bismarck to meet Cottie Seeger of the Carter Oil Co. and others with the oil industry who were working in the city at that time as a result of the small oil boom which had been generated with the drilling of the Kamp well on the Nesson Anticline in Williams County. This boom was short lived as the well was a dry hole and World War II was about to begin. As a matter of fact, the Kamp lease is now part of the Capa Field, I think, and production is only a half mile or less from the

Kamp location.

Carter was drilling a strat test west of St. Anthony in Morton County at the time of our visit, which was in November of 1940. We were taken out to see it and I was impressed with the barrenness of the country and the cold wind. Little did I know at the time that the major portion of my professional life would be spent in North Dakota. In any event, it stimulated my interest in the southern part of Morton County, and as it was the area that Foley had intended to map the following summer, that is where I started to do geologic work in North Dakota.

I did not expect to direct the work myself as I thought Foley would be in charge. However, Frank Foley took a position with the USGS in February of 1941 and I was left in charge of the North Dakota Geological Survey. So there I was mapping rocks of Cretaceous and Tertiary age; previous to that time I had worked in nothing but the Paleozoics of the eastern part of the United States. The lithology was different and the fossils were unfamiliar to me. In addition, the country and the people were different from anywhere I had ever worked previously.

I must say now that I got to love the country, particularly along the Cannonball River, and the people of the ranches were most courteous and helpful. Never before, and probably not since, have I been able to drive across pastures without objection of the owners. How different it is now where, especially in Texas, you can't get on some properties without permission.

The first summer, the field season of 1941, was one of financial austerity as were many following summers until the discovery of oil. The need for transportation was a necessity so I had to buy a used car as a new one was out of the question. Foley had left an old Ford panel truck parked near his home on the end of Princeton Street in Grand Forks. He had not drained the radiator so it froze and, in general, the truck was unusable. I traded it for a 1934 Plymouth two-door with a fabric top which cost the Survey $175. It wasn't much, but it ran for a number of years. The field group called it the Offenhauser Six after a famed racing car, which it definitely was not. At that time it was the best and only car the Survey had.

As Foley had left and there was no one to teach the mineralogy and hard rock courses, it was necessary to find a temporary replacement for that semester. Fortunately, Ernest Tisdale, who was a native of Grand Forks and a graduate of UND, was available. He had just received, a short time before, a Master's degree from Texas A&M. Ernie taught the "hard rock" courses while I taught the beginning course, paleontology, and geomorphology. As Ernie had nothing in sight for the summer, he signed on with the Survey for the mapping project in Morton County.

After school let out for the summer, I began to assemble the field party. Ernie was placed in charge and two students, Howard Garaas and Kenneth Peterson, were hired at $50.00 per month to assist him in the work. Their "board and room" were also provided as the Survey had the necessary camping equipment, which was needed as there were no accommodations handy in southern Morton County.

The next item was to find a suitable camping place with shade and water. Not knowing much about the country from personal observation, I sent Ernie to see John Sullivan, an attorney in Mandan. I had met John previously and he had been very courteous to me. John was an old-time lawyer and one of the best of the trial lawyers in the State at the time. He was the principal partner in the legal firm of Sullivan, Fleck, and

Sullivan of Mandan. I knew that Sullivan had a ranch on the Cannonball and that he would be able to tell us where to camp. He suggested that we camp in the front yard of his ranch house on the Cannonball and use the refrigerator on the porch as we wanted. He said that he was only there periodically and that no one else would use it so we felt free to do just that.

We set the tent up in the front yard. The tent was one that belonged to the geology department. It had, I believe, been used by Dr. Leonard when he was mapping the lignite in the western part of the state. As the porch was also screened, it made it handy to sit there, especially in the evening to keep away the flies.

John, when he was there, joined in the conversation and he especially liked talking to the young students. At that time, the government had a program of placing stallions out on ranches for breeding purposes with the idea that the government would have the first choice of any colts that they might want. One such was stationed at the Sullivan Ranch. Mrs. Sullivan, who was quite a horsewoman, would, from time to time, come out and ride the animal, much to the fear of the foreman and John, who thought that the stallion was probably too much for her. It never threw her to my knowledge.

The mapping went smoothly and several new formations not previously named were given names which have stuck, even after later geologic work in the area by others. One such was the Breien Member, which is about 17 feet above the base of the Hell Creek Formation. The credit for this name is given to me and Robert Mitchell, who worked for me on the second year of this study. While I get the credit for this formation, it was Bill Cobban, then of the Carter Oil Company, who pointed it out to me in the first place. Bill also pointed out to me the relationship of the upper banded member of the Fox Hills and the Colgate lithology, also in the same general area.

It is interesting to me that I found fossils only in the Breien while later work by Charles Frye for his doctoral dissertation found brackish water fossils almost to the top of the Hell Creek Formation. It is a case in point of more intensive work where the guidelines have been laid down by someone else. Also, Charlie had more persistence that I did, in all likelihood.

The most memorable event that sticks in my mind of the first summer of Morton County field work was a hailstorm, which hit during one of the weeks we were at the camp. The storm came up suddenly as such storms are wont to do and fortunately we were at the camp at the time, so it must have been near supper time. The rain and wind started and then came the hail. I ran out from the porch and pulled up the stakes of the tent so that it wouldn't be so taut and as vulnerable to the hail. However, there was nothing I could do about the fabric top of the old Plymouth. After a short time, it literally looked as if someone had been up there on the top of the car chopping it with a geologic pick. I was concerned, as our finances made such an event somewhat of a catastrophe until I remembered that I had taken out insurance on the car with W. J. Horner in Grand Forks. The repair bill came to $18.00 and was paid by the insurance company. What a change from such charges now, even with the deductible usually put on a policy!

The hail was something as to size. When the storm had stopped and I recognized how large the hailstones were, I measured a stone and found it was 2 inches in diameter. It was flat and about 1 inch thick. Like most large hailstones, it was formed of concentric layers of ice and the different layers were quite distinct.

At the end of the field season the party disbanded and Tisdale went to the Army while the other men went into different military services. Fortunately, all came back. Garaas and Peterson are now retired. Howard Garaas served for many years with Chevron and Peterson with National Geophysical (later Teledyne). Tisdale went to work for Cities Service and passed away a number of years ago.

As the work on Morton County was not completed in 1941, a second field season was needed to finish. That year (1942) I hired Robert Mitchell, professor at Muskingum College to work with me. He was one of my former professors when I was an undergraduate. This season we did not camp but stayed at Ulmers White Fence Motor Court in Mandan with our families. This motel is now gone, but it was an interesting and cheap place to stay.

I don't remember that much of importance occurred in the course of the field work that year except that the work got done. I spent much of my time taking elevations on the middle sandstone member of the Cannonball Formation to construct a structure map of the area. I used an altimeter, which was a pretty good instrument we had purchased the previous fall. This may not be a very good method as there can be mistakes made on the call of the member on which the elevations were based. In addition, some of the control points used are open to question. One, for example, that I used was the elevation of the Carter strat test. It seemed too to be consistently low so in some cases I didn't use it as it could make quite a difference in the map finally drawn.

As a result of all this work, the North Dakota Geological Survey published Bulletin 14, The Geology of the Southern Part of Morton County. My work in Morton County marked the beginning of my geologic career in North Dakota, and I don't regret a minute of it.

HISTORY OF NORTH DAKOTA GEOLOGICAL SURVEY

--David Brekke

Historical Development

The North Dakota State Constitution in 1889 directed that a University and School of Mines be situated in Grand Forks. The position of State Geologist, and with it the North Dakota Geological Survey (NDGS), was created by an act of the North Dakota Legislature in 1895, six years after statehood. This position was to be held by the Professor of Geology at the University. The Geological Survey was directed to make a "...complete account of the mineral kingdom... including the number, order, dip and magnitude of the several geological strata, their richness in ores, coals, clays, peats, salines and mineral waters, marls, cements, building stones and other useful materials, the value of said substance for economical purposes, and their accessibility." Other provisions called for the "...chemical analysis, curation and display, and preservation of materials collected by the survey in carrying out its duties...". A geologic map of the state was to be constructed..." as soon as practicable...". The School of Mines was formally opened in 1897 and the Survey received its first legislative appropriation in 1899 in the amount of $600 for the biennium.

Organizational Description

The NDGS is administratively under the North Dakota Board of Higher Education through the president of the

University of North Dakota. However, the NDGS has a legislative appropriation that is separate from that of the University. The Survey is organized into an Administrative Division and a Geology Division. The Geology Division is divided into a Subsurface Section and a Surface Section. Offices are located in Leonard Hall, the geology building on the University campus. The NDGS maintains the Wilson M. Laird Core and Sample Library, in which are housed rock samples from oil wells drilled in North Dakota. The Survey also maintains extensive files of basic data on both surface and subsurface geologic data, including well logs and cores from oil and gas exploration. The current staff of 23 includes ten geologists, eight full-time and two part-time, and one petroleum engineer.

HISTORICAL HIGHLIGHTS

E. J. Babcock, the first State Geologist, was appointed in 1895. Babcock was a chemistry instructor who was later named Director of the School of Mines. The new office of State Geologist provided for neither additional salary nor funds with which to operate. However, Babcock donated his time, expenses, and his chemistry laboratory to conduct new studies and continue earlier studies of lignite and clay deposits. The collapse of agricultural prices in 1893 pointed up the need for the diversification of North Dakota's economy. Babcock argued repeatedly for the need for practical development of mining and geology. He used the first Survey appropriation, granted in 1899, to publish the First Biennial Report in 1901, a summary of the previous ten years' work. This report contained information on the topography and geology of North Dakota, water resources, clay deposits, lignite deposits, and an optimistic discussion of future natural resource possibilities. At the time, it was considered one of the best public documents ever issued in the state and it created wide public interest. In 1902, the duties of State Geologist were assumed by Dr. Frank A. Wilder, the first professional geologist to hold the position. He published the Second Biennial Report, which was devoted almost entirely to lignite and enjoyed two printings for a total of 4,000 copies.

Dr. Arthur G. Leonard, who had been Assistant State Geologist of Iowa, was appointed State Geologist of North Dakota in 1903. Leonard is considered to be the father of geologic study in North Dakota. A scholar, he brought to the Survey a tireless and single-minded concentration on the problems of the state's geology. During his 30-year tenure as State Geologist, extensive studies and systematic mapping of lignite, clays, cement rock, and water resources were conducted with little or no appropriations. In 1904, a publication exchange was initiated with other agencies and societies. This became the basis for the present Geology Library at the University. The first NDGS geologic map of North Dakota was published in 1906 as part of the Fourth Biennial Report, an issue devoted to clay deposits and brick manufacturing. The NDGS involvement in oil and gas development dates to 1908 when investigations were made into reports of natural gas in Bottineau County. The gas was determined to be a form of marsh gas coming from the base of the glacial drift.

The first wildcat oil well in the state was drilled in 1915 in Ward County. After nearly a year, the well was abandoned at a depth of 244½ feet. During the early years of its history, the NDGS received numerous inquiries about oil in North Dakota and conducted several investigations. As a result, Dr. A. G. Leonard published Bulletin 1, "Possibilities of Oil and Gas in North Dakota", in 1920.

Dr. Leonard recognized that the

duty of the Survey was not only to promote the development of North Dakota's natural resources, but also to discourage the investment by citizens in proposals that had little chance of success. He also appreciated the educational value of the Survey and many of the early publications were written in such a way that they were understandable by the state's public school teachers. This goal was not always attainable, but Leonard was very patient with teachers who inquired about details. He also demonstrated an understanding of the concept of "land-use", which placed him well ahead of his time. He recognized the needs of practical men, such as water-well drillers, for good information on the geologic conditions anticipated in certain areas and he made an effort to accommodate their inquiries in detail. About 700 copies of each biennial report were earmarked for distribution to schools and additional copies were set aside for answering inquiries from people involved in the direct development of natural resources. Dr. Leonard died in late 1932.

Howard E. Simpson who had been hired in 1909 as the Survey's first groundwater geologist, was named State Geologist in 1933. In the same year, the Civil Works Administration, Federal Emergency Relief Administration, Emergency Administration of Public Works, and National Resources Board began their activities in North Dakota. They utilized the NDGS as the key to their programs and the Survey became more active than at any time in its prior history. Since the funds for these activities became available after the close of the field season, the first months were spent in repairing the ravages of the years without funding. Many articles were finally cleaned and catalogued; this included 16,000 library items, 5,900 museum items, 15,000 maps, and field notes. Simpson died in 1938.

Frank C. Foley, who was Assistant State Geologist at the time Simpson died, held the office of State Geologist from 1939 until 1941. The reason for Dr. Foley's short tenure as State Geologist is quite logical. The USGS offered him $2,600 per year in 1941, $600 per year more than he was getting at UND and the NDGS. When he was contacted at his home in Lawrence, Kansas several years ago, Dr. Foley recalled that he did not get any salary for the first five months of his employment as Assistant State Geologist in 1933. Although he started work on February 1 of that year, the State was unable to meet its payroll until July. Even so, Frank Foley did work for the North Dakota Geological Survey for eight years.

Dr. Wilson M. Laird came to North Dakota in 1941 and was named State Geologist at the age of 26. At the time, he was the only permanent Survey employee, although there was a long tradition of hiring University students on a part-time basis, especially for summer field work. An increase in political stature occurred when the 1941 State Legislature enacted an oil and gas conservation law and designated the North Dakota Industrial Commission as the regulatory authority and named the State Geologist as advisor and enforcer of the regulations. Dr. Laird was instrumental in seeking the passage of this legislation. At the time the statutes were enacted, the only oil and gas activity was a small gas field in the southwestern part of the state, but ten years later, oil was discovered in Amerada Petroleum Corporation's #1 Clarence Iverson well in Williams County. Most of the Survey's work during the war years and postwar years was carried out as cooperative ventures in water resource studies with the U.S. Geological Survey (USGS), which published any resulting reports. In 1944, Laird began detached service with the USGS in Montana on studies of oil and gas possibilities and he worked in Manitoba in 1949 on a study of the geologic formations present there. This work had given him an unusual opportunity to become acquainted with the strata of the Williston Basin before oil was discovered in North Dakota. Laird became president of the Association of American State Geologists in 1950.

The discovery of oil in North Dakota brought about an increase in funding and personnel for the Survey. The first petroleum engineer was hired, the first core library was authorized, and a sizeable increase in funding allowed the hiring of 15 additional staff. Branch offices to handle oil-well inspections were established in Bismarck and Williston. The discovery of oil sparked an increase in student interest in the geological sciences. It became apparent to the University that both organizations needed expanded facilities and a new building dedicated to the geological sciences was constructed in 1964. Laird and a committee of NDGS staff and geology department faculty put a lot of effort into designing a true geology building that would respond to the needs of geologists. The resulting building was named Leonard Hall, in honor of Dr. A. G. Leonard. The NDGS occupies most of the top floor of Leonard Hall. Laird resigned in 1969 to eventually become Director of the Exploration Committee of the American Petroleum Institute. He was later given the rank of Professor Emeritus of geology by the University of North Dakota.

Dr. E. A. Noble became State Geologist the year the 1969 State Legislature enacted laws concerning the reclamation of lignite mined lands. The NDGS at that time became an advisor to the state on reclamation issues. This led the Survey to conduct many studies throughout the 1970s of problems associated with the reclamation of lignite mines. The studies continue today with emphasis on abandoned mine lands. Coincident with the reclamation studies was a cooperative drilling project with the USGS begun in 1975 to evaluate the lignite resources of western North Dakota. This drilling program provided public information in many areas of 16 counties during four drilling seasons. In 1975, the Survey was designated an advisor and enforcer of regulations pertaining to non-fuel subsurface minerals and coal exploration. Noble left the Survey in 1978 to work for the USGS.

Dr. Lee C. Gerhard was appointed State Geologist in 1978 and presided over the oil boom of the latter part of the decade. It soon became apparent that the existing core library facilities were being overtaxed due to the large influx of new oil-well cores. A new and much larger core and sample library was designated and built in 1980. In addition to its storage capacity, this facility, the Wilson M. Laird Core and Sample Library, includes laboratory space for the preparation and analysis of cores. As a result of a tremendous increase in oil drilling activity, and greatly increased production, the State Legislature in 1981 decided to relocate the oil and gas regulatory function of the Survey in Bismarck as a separate agency of the North Dakota Industrial Commission. NDGS continues to maintain for its own use, and for public use, a set of updated well records and well logs of every well drilled in the state.

Dr. Don L. Halvorson was appointed State Geologist in 1982. During his tenure, NDGS obtained use of and eventually acquired its own computer system for the purpose of well-record management and geologic research. The Survey was designated the enforcer of solution-mining injection wells. A new one-degree atlas series mapping program began in 1984.

The Survey was designated a National Cartographic Information Center affiliate in 1988. The NDGS continues to advance knowledge of the geology of North Dakota through programs in surface and subsurface geology of the Williston Basin, petroleum geology, environmental geology, paleontology, and geochemistry.

Sidney B. Anderson was appointed Acting State Geologist in 1985 and continues in that capacity today. The Survey currently employs nine geologists, one engineer, one draftsperson, and twelve people who are involved in administration, maintaining the Core Library, bookkeeping, publications, and secretarial work.

RADIOCARBON DATES ON DEVILS LAKE BEACHES

--**John Bluemle**

In two past issues of the NDGS Newsletter, we included articles on the geology of Devils Lake (The Origin of Devils Lake, December, 1981 issue, and Fluctuating Levels of Devils Lake, June, 1983 issue). Since those articles appeared, we have continued our work on Devils Lake and the surrounding area, and last year we published a report on the geology of Ramsey County (NDGS Bulletin 71, Part 1, 1987). This report included new data on the geologic history of Devils Lake.

Devils Lake has been generally rising since 1940 and is currently at a level of 1,428 feet. We would like to better understand the frequency with which the lake has risen and fallen in the past, and it would be especially useful to know how recently the lake has risen higher than the 1,445-foot level. At that level, Devils Lake would overflow to the east into Stump Lake. Then, if the water were to reach a level of 1,457 feet, Stump Lake would overflow into the Sheyenne River through Tolna Coulee. Until a few years ago, it was generally assumed that Devils Lake has not overflowed into Stump Lake since sometime prior to Hypsithermal time, more than 7,000 years ago. In our 1987 report on Ramsey County, we suggested that overflow to Stump Lake occurred more recently than that, perhaps as recently as two or three thousand years ago, but until now we have had no firm evidence to prove this assertion.

Last November, at the request of Representative Gordon Berg of Devils Lake, the North Dakota Geological Survey sampled a buried soil horizon in several places (fig. 1). We submitted the samples to the United States Geological Survey for radiocarbon dating, and in March 1988 we received the results of these tests from the USGS. This article is a summary of the results we obtained along with an initial analysis of the implications of the dates.

We obtained all of our samples by using a backhoe to dig trenches across old beaches of Devils Lake. We studied the high beaches, which range from 20 to 30 feet above the modern lake level. Some of our samples could not be dated because they were contaminated by modern plant roots, but we did obtain four datable samples in three localities about two miles southeast of the city of Devils Lake, on and near the Mertens Lakeview Farm.

The buried soil zones we studied along the north shore of Devils Lake at the Lakeview Farm are overlain by beach gravels and underlain by offshore and nearshore lake sediments. Although we were able to identify what appeared to be the same buried soils in several other places as far as four or five miles to the west, the soils were especially well developed at the Lakeview Farm. Descriptions of the geologic sequences encountered in our excavations follow.

West Cut, Mertens Lakeview Farm. The top of the excavation at this cut

Figure 1. Representative Gordon Berg operating a backhoe, digging a trench across an old Devils Lake beach. This trench was dug in the Lakewood area.

is in a lake strandline at an elevation of about 1,447 to 1,448 feet, approximately 20 feet above the modern lake level. Samples 1 and 2 were taken from separate buried soil zones buried beneath and separated by beach deposits. The stratigraphic sequence exposed in this excavation was as follows:

Unit 7. Three feet of medium-grained, well-sorted, cross-bedded sand. A beach deposit. Elevation at top: 1,448 feet.

Unit 6. One foot of fine- to medium-grained, well-sorted sand with alternating light and dark layers. Elevation: 1,445 feet.

Unit 5. Eight inches of gravelly, gray sand; no apparent structure. Elevation: 1,444 feet +.

Unit 4. Four inches of dark brown, organic, sandy material. A paleosol. **Sample 2 taken here.** Elevation: 1,444 feet.

Unit 3. Four inches of clean sand containing no organic matter; cross-bedded, coarse, quartz-rich sand. Elevation: 1,443 feet +.

Unit 2. Four inches of dark brown, richly organic sand that appears to contain more organic material than Unit 4, above. A paleosol. **Sample 1 taken here.** Elevation: 1,443 feet.

Unit 1. Sticky, dark gray sandy clay with vague bedding visible. Offshore lake sediments. Elevation: below 1,443 feet.

<u>Grainbin Cut, Mertens Lakeview Farm</u>. The top of the excavation at this location was in a lake strandline at an elevation of about 1,458 feet, or approximately 30 feet above the modern lake level. Sample 3 was taken

from a black to very dark brown buried organic soil zone. The stratigraphic sequence exposed in this backhoe cut was as follows:

Unit 5. Two feet of alternating, one- to two-inch-thick bands of clean sand and thin organic-rich beds. All of this unit appears to be alluvial, washed-in material. Elevation at top: 1,458 feet.

Unit 4. One foot of black to very dark brown, organic-rich material. This is an in-place buried soil zone. **Sample 3 taken here.** Elevation of sample: 1,455.5 feet.

Unit 3. Six feet of coarse, cross-bedded sand with scattered streaks of organic material. Probably beach sediments. Elevation at top of unit: 1,455 feet.

Unit 2. Three inches of "pea gravel," mostly 1/4" to 1/2" size. Contains abundant shale pebbles. Elevation: 1,449 feet.

Unit 1. (Same as unit 3). One foot thick to bottom of cut. Elevation at bottom of cut: 1,448 feet.

Silo Cut, Mertens Lakeview Farm. The sample taken here was from a nine-foot-deep excavation, just west of a large silo. The surface elevation at this location is 1,457 feet. The geologic sequence exposed by the excavation was as follows:

Unit 5. Two feet of clean, well-sorted, cross-bedded sand. A beach deposit. Elevation at top: 1,457 feet.

Unit 4. One foot of sandy, black, organic-rich material. A buried soil profile. **Sample 4 taken here.** Elevation: 1,454 feet.

Unit 3. One foot of very clean, well-sorted, cross-bedded sand, essentially similar to unit 5. A beach deposit. Elevation: 1,453 feet.

Unit 2. Highly fossiliferous shell zone, four to five inches thick. A mash of soft and disintegrating shells, enclosed in soft, wet lake clay. Elevation: 1,452 feet.

Unit 1. Five feet of hard, pebbly glacial sediment (till). Elevation at bottom of excavation: 1,447 feet.

We excavated additional trenches, but we were unable to obtain samples suitable for dating from them.

PRELIMINARY CONCLUSIONS

Generally, the sequence of beds exposed by our backhoe cuts suggests that, after Devils Lake had risen to relatively high levels that resulted in the deposition of beach sediments, its level dropped sufficiently and for long enough periods of time to allow extensive soil development on the beach deposits. The lake then rose again, flooding the soils and depositing more beach deposits over them.

The radiocarbon dates we obtained on the soils we sampled are important because they indicate that Devils Lake has risen to levels higher than 1,447 feet in post-Hypsithermal time (since 5,000 years ago). Whenever Devils Lake reached a level that high, it had to overflow into Stump Lake. Our soil dates further show us that a complex series of relatively recent fluctuations have occurred in the level of the lake.

Sample 1 (the lower sample at the

first excavation) was dated at 2,760 ± 200 years B.P. (before present) and sample 2 (the upper sample at the same excavation) was dated at 2,150 ± 200 years B.P. Both of these dates are post-Hypsithermal. The two horizons dated are separated by sand that appears to be a beach deposit, and the upper horizon that we dated (sample 2) is covered by multiple beach deposits.

The dates on samples 1 and 2 tell us that, at least twice, in the time interval between 2,760 and 2,150 years ago, the lake level dropped below about 1,443 feet. It rose above that level (although I don't know how high) at least once in that time interval. It then rose above 1,443 feet, to at least 1,447 to 1,448 feet, sometime since 2,150 years ago (perhaps several times).

Sample 3, which was dated at 720 ± 200 years B.P., is inconclusive insofar as defining the geologic situation of the changing levels of Devils Lake. The date may, however, be useful in our further interpretations of the geologic history.

Sample 4, dated at 1,800 ± 200 years B.P., is especially interesting. It seems to prove that Devils Lake rose above a level of 1,455 feet sometime since 1,800 years ago. This is important new information in view of the fact that, until now, we had no real evidence that Devils Lake had risen above 1,448 feet at any time since the Hypsithermal.

DISCUSSION

Dates on soils are usually imprecise. Soils may be multiple and they may span a long period of time. A date on a soil may be a combination of an accretionary age (when the soil accumulated), the age of the decomposed rootlets (which may include modern contamination), and humic acid additions. All of these contribute to a large potential error for radiocarbon dating of soils. Even so, the dates we obtained for the buried Lakeview Farm soils are definitely post-Hypsithermal in age. The dates on the soils show that the lake has risen high enough within the past 1,800 years to overflow to Stump Lake.

The radiocarbon dates on the soils show us that the level of Devils Lake has fluctuated more widely and more often than we had traditionally believed. We can infer from what we have learned that wide and frequent natural lake-level fluctuations, on the order of several tens of feet at least every few hundred years (or maybe more frequently), are to be expected. The "natural" condition for Devils Lake is either rising or falling, either toward overflow or dry lake bed. The lake should not be expected to remain long at any given level.

Even though long-term variations in the climate are ultimately the reason Devils Lake rises or falls, the short-term fluctuations we have observed for Devils Lake recently don't appear to correlate well with obvious climatic trends. A possible, partial reason for this may relate to the runoff pattern--several smaller holding lakes are found immediately up-drainage from Devils Lake; much of the drainage to Devils Lake passes through these lakes before it reaches Devils Lake. Another possible reason for the apparently anomalous fluctuating behavior of Devils Lake may relate to interaction with the groundwater system. If the Spiritwood Aquifer is filled to capacity, water from the aquifer may escape to Devils Lake, even during a period of short-term dry climate.

Further study will be necessary before it can be determined why the level of Devils Lake fluctuates the way it does.

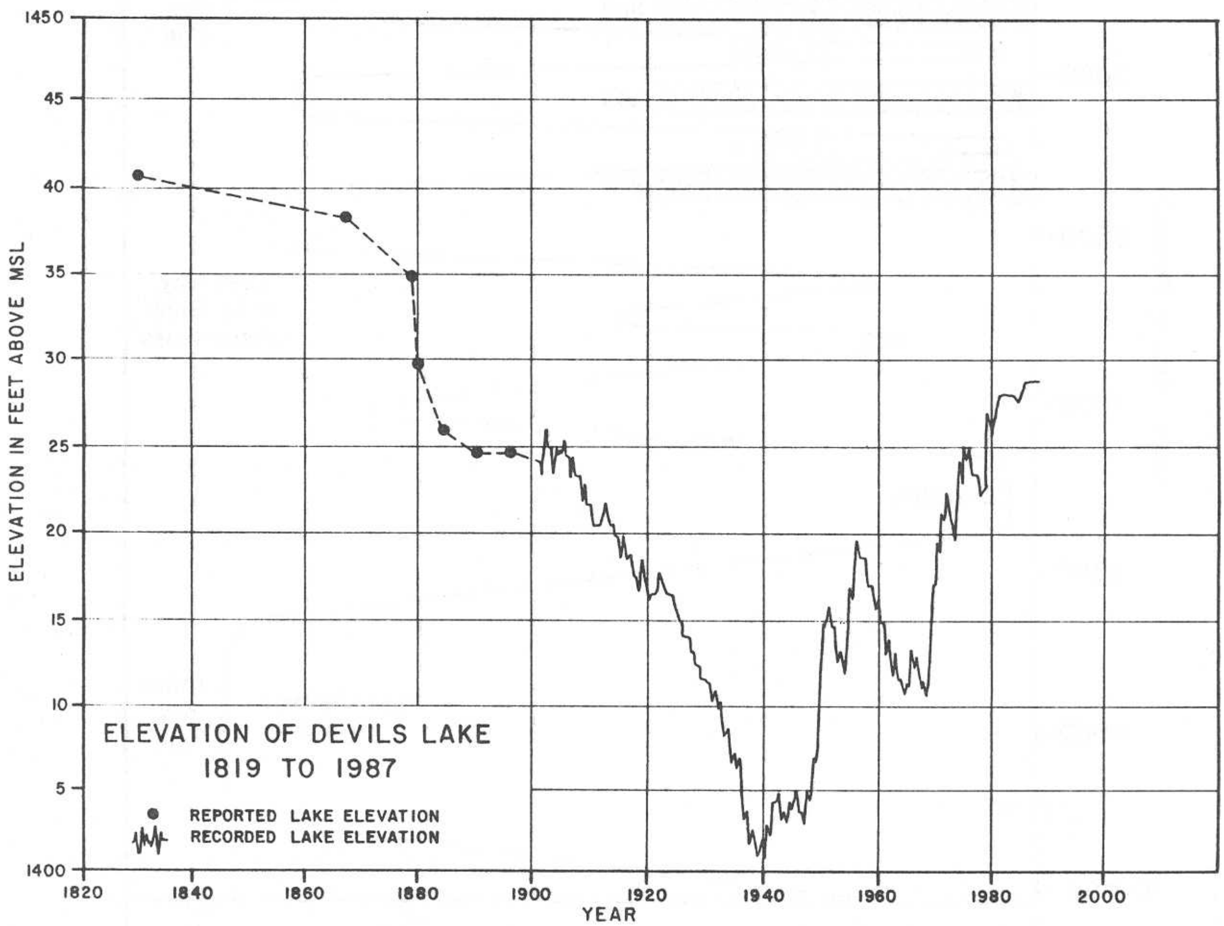

Figure 2. Fluctuating level of Devils Lake since the early 1800s. Prior to about 1900, only a few accurate readings on the lake level are available.

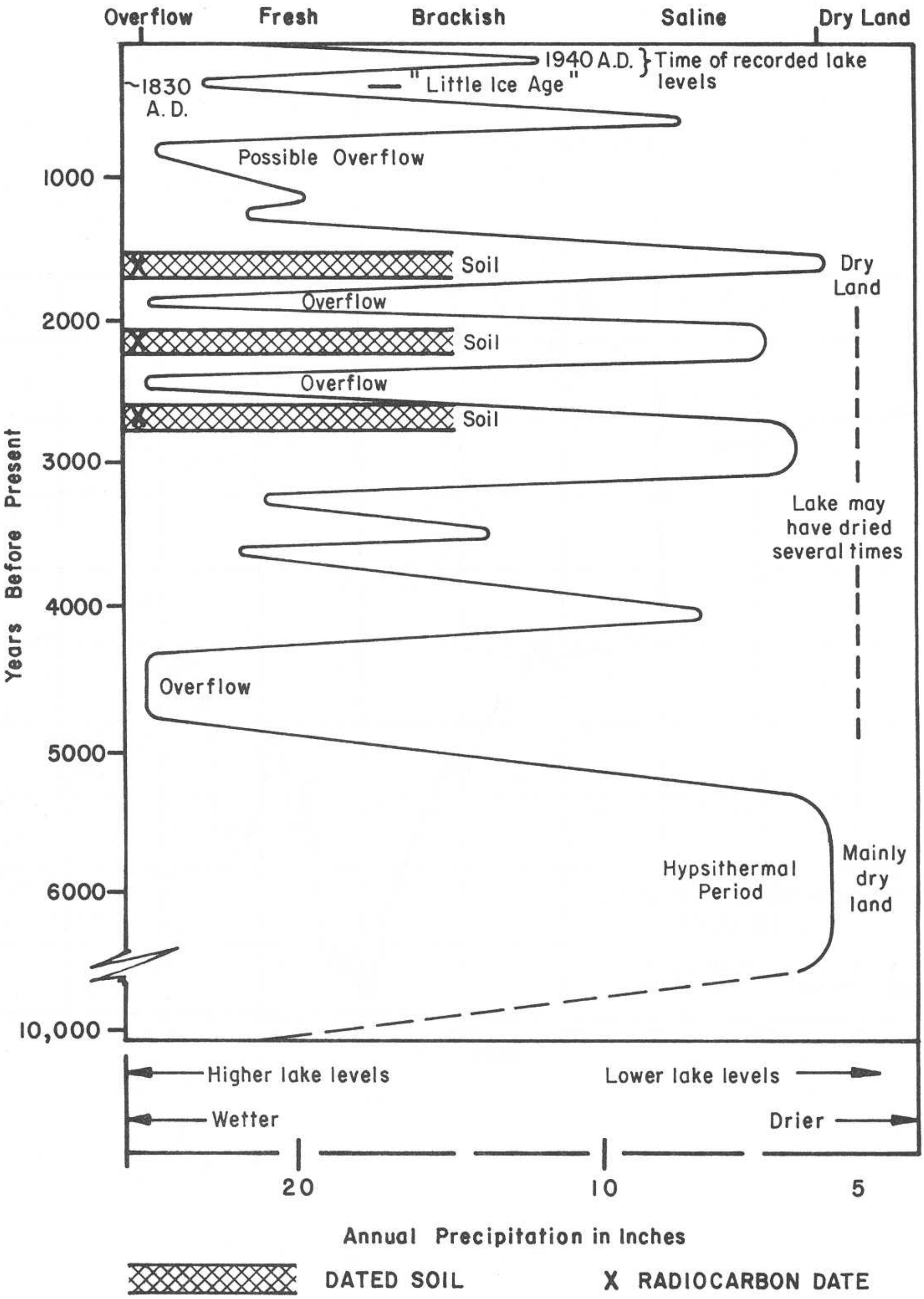

Figure 3. Time/Event diagram showing how Devils Lake has fluctuated during the past 10,000 years. The lake overflowed to Stump Lake several times and it dried completely a number of times. Our radiocarbon dates help us to better understand the last 3,000 years of the history of Devils Lake.

FORMER LEVELS OF DEVILS LAKE
(elevations adjusted to the modern datum)

1819	Between 1441 and 1448
1830	1441 (also reported at 1446)
1867	1437.95
1879	1434.1
1880	1429
1883	1434.1
1887	1426
1890	1424.2
1896	1424.6
1901	1424
1902	1425.8
1903	1424.8
1904	1425.0
1905	1425.2
1906	1424.6
1907	1424.2
1908	1423.4
1909	1422.6
1910	1421.4
1911	1420.4
1912	1421.4
1913	1421.8
1914	1420.6
1915	1419.2
1916	1419.6
1917	1418.8
1918	1417.4
1919	1418.0
1920	1417.6
1921	1416.7
1922	1417.2
1923	1416.3
1924	1416.2
1925	1414.8
1926	1413.7
1927	1413.6
1928	1412.8
1929	1412.2
1930	1411.4
1931	1411.4
1932	1410.9
1933	1410.2
1934	1408.2
1935	1406.9
1936	1406.7
1937	1404.3
1938	1403.7
1939	1402.7
1940	1402.3 (Reached a minimum of 1400.9)
1941	1402.3
1942	1404.5
1943	1404.7
1944	1404.0
1945	1404.7
1946	1405.0
1947	1403.6
1948	1405.2
1949	1407.2
1950	1415.5
1951	1414.5
1952	1414.5
1953	1413.0
1954	1414.4
1955	1416.8
1956	1419.4
1957	1418.7
1958	1418.3
1959	1417.1
1960	1416.2
1961	1414.9
1962	1414.3
1963	1413.2
1964	1411.8
1965	1411.6
1966	1412.9
1967	1412.8
1968	1411.7
1969	1410.5
1970	1419.5
1971	1421.0
1972	1422.3
1973	1420.6
1974	1424.1
1975	1424.8
1976	1425.1
1977	1423.0
1978	1423.2
1979	1427.0
1980	1426.1
1981	1425.9
1982	1426.9
1983	1428.1

Stump Lake (Corrected elevations) -- Inferred lake-level history

1300 A dry period began about 1300 A.D. Stump Lake fell below 1400 feet.

1535 Increased moisture; lake began to rise.

1541 Stump Lake rose above 1405 feet (continued moist conditions until about 1850).

1830 Lake level about 1443 feet

1887 1417 feet

1889 1415 feet

1910 1410 feet

SURVEY ACTIVITIES

--Sidney B. Anderson

The Survey is involved in a variety of projects, some of which are in press or in various stages of completion. The following is only a partial list of activities of the Survey.

John Bluemle has recently finished a new geologic highway map, which is now in press. This map promises to be a "best seller". John has also finished a report on Renville and Ward Counties, which should be published by the end of the year. He is finishing a publication on the geology of North Dakota to replace the Face of North Dakota.

John has recently participated in meetings on Devils Lake and helped with several field trips and workshops for teachers.

Ken Harris is working on two more "Atlas Series" studies, the Goose River and Pembina areas. In addition, he organized a field conference in June- "Friends of the New Des Moines Lobe". That conference was attended by members of the Geological Surveys of North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Nebraska, and Manitoba.

Marv Rygh has collected and submitted for analysis the first set of crude oil samples to the Canadian Geological Survey. These samples will be used in our joint project with the Canadian Geological Survey--a crude oil typing and source rock study.

Marv is also working on a study of the Pennsylvanian Broom Creek Formation.

Julie LeFever is working on a paper with Sid Anderson and Rich LeFever for AAPG Rocky Mountain Meeting which is a continuation of work on Nesson Anticline "Salts as Tectonic Indicators of Activity Along the Nesson Anticline," examining all of salts present.

Final changes are being made to the Study of Newburg/South Westhope Oil Fields for AAPG Atlas of Oil Fields.

Julie also has a Mississippian log cross section in final preparation stages. The section runs from the Glenburn Field in north-central North Dakota to the Billings Anticline in southwestern North Dakota.

In addition to working on the 1986-87 Oil & Gas Update, Dave Fischer has co-authored a paper with Lee Gerhard and Sid Anderson, "Petroleum Geology of the Williston Basin". This is an invited paper and is part of the AAPG Petroleum Basin Series, Cratonic Sag Volume. The paper is in review. Also with Lee Gerhard and Sid Anderson, Dave has in preparation- "Williston Basin Overview," for inclusion in Carbonate Reservoirs in the Rocky Mountains: to be published by the Rocky Mountain Association of Geologists.

Dave is in charge of the Core Workshop for the Rocky Mountain Section of the AAPG meeting in Bismarck in August.

Dave Brekke is continuing work on the trace elements in Cretaceous shales in cooperation with the U.S.G.S. Dave is also involved in a continuing cooperative study on radon with the N.D. State Department of Health. Dave will incorporate data from winter 87-88 into a revised geologic radon potential map.

Dave is also starting a computer mapping project using U.S.G.S. mapping programs and utilizing our new 2' x 3' digitizer.

John Hoganson is working with Alan Cvancara on a study of sharks' teeth in the Fox Hills Formation. John recently negotiated an agreement with the Bureau of Land Management and NDGS on permitting paleontologic work on BLM lands.

Randy Burke is continuing his study of Devonian Duperow reservoirs on the Billings Anticline, and is organizing the Paleozoic field trip into Manitoba for the Rocky Mountain Section of the AAPG. The trip will be run in conjunction with the Rocky Mountain Section AAPG meeting in Bismarck in August.

Ed Murphy has been busy installing observation wells around the landfills at several North Dakota locations. Ed was married on June 18 to Becky Dugan in Bismarck. Congratulations Ed.

I reiterate that this is just a partial list of studies and activities of the North Dakota Geological Survey.

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 10 and 11 of this Newsletter for descriptions of publications.

____Atlas Series Map 4 ($3.00)	Surface Geology of the Souris River Map Area, North Dakota
____MS-70 ($1.00)	An Overview of Dolphin Field, Divide County, North Dakota
____MS-71 ($1.00)	Leachate Generated by an Oil-and-Gas Brine Pond Site in North Dakota
____MM-28 (free)	Generalized Bedrock Geologic Map of North Dakota
____MM-30 ($1.00)	Precambrian Structure Map of North Dakota
____Catalog ($3.00)	Catalog of North Dakota Oil Analyses

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NORTH DAKOTA GEOLOGICAL SURVEY STAFF
(June, 1988)

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