NEWSLETTER NDGS

1895
NORTH DAKOTA GEOLOGICAL SURVEY
1895 - 1995

Industrial Commission of North Dakota, North Dakota Geologial Survey Vol. 22, No. 1, Spring 1995

The North Dakota State Capitol. The administrative tower is flanked on the left by the legislative chambers and on the right by the judicial wing. Memorial Hall and plaza link the administrative and legislative branches of government and it is there where a new guidebook to the capitol grounds begins. See page 25 for a review of *A Visitor's Guide to the North Dakota Capitol Grounds: Buildings, Monuments, and Stones. Photo by Bob Biek.*

FEATURES

DEPARTMENTS

NDGS Newsletter (ISSN: 0889-3594) is published quarterly by the North Dakota Geological Survey, a division of the Industrial Commission of North Dakota. *NDGS Newsletter* is designed to reach a wide spectrum of readers interested in the geology and mineral resources of North Dakota. Single copies of *NDGS Newsletter* are distributed free upon request. Please share the *NDGS Newsletter*; we encourage its reproduction with recognition of source.

Your comments — and contributed articles, photographs, meeting announcements, and news items — are welcome. Correspondence, subscription requests, and address changes should be addressed to Editor, *NDGS Newsletter*, North Dakota Geological Survey, 600 E. Boulevard Ave., Bismarck, ND 58505-0840; (Tel. 701-328-4109).

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NEWSLETTER

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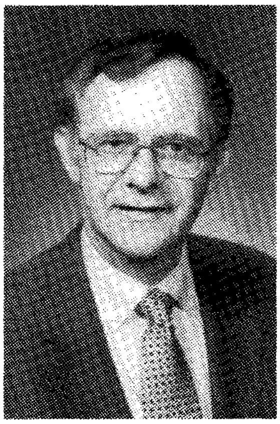
FROM THE STATE GEOLOGIST

by John P. Bluemle

NDGS Celebrates Centennial



The North Dakota Geological Survey is observing its one hundredth anniversary in 1995. We have a number of important activities planned during this, our Centennial year.

The Survey is hosting the 87th Annual Meeting of the North Dakota Academy of Science on April 20th and 21st. This will be only the third Academy of Science meeting to be held in Bismarck in recent years; earlier meetings were held here in 1982 and 1988. The Academy meetings will be held at the North Dakota Heritage Center, a particularly appropriate setting, especially in view of the fact that 1995 is also the State Historical Society's Centennial year and we have cooperated with the Historical Society in developing geological exhibits in the Heritage Center.

A major part of the Academy of Science meeting this year will be a day-and-a-half symposium on North Dakota geology organized by NDGS paleontologist, Dr. John Hoganson (see symposium schedule on following pages). Twenty presentations from geologists around the state and elsewhere will detail the results of research on topics ranging from surface mapping, petroleum geology, paleontology, and environmental geology. John Hoganson is also giving the banquet presentation talk, titled "Sea lilies, dinosaurs, and woolly mammoths: the fossil record of prehistoric life in North Dakota" on the evening of April 20. The presentation will be in the Heritage Center auditorium and will be open to the public.

The geology symposium will include a walking fieldtrip to look at the building stones used on the State Capitol grounds. The trip, which will also be open to the public, will be led by NDGS geologist Bob Biek, who wrote a guidebook to the monuments and building stones of the capitol grounds. The guidebook was recently published by the State Historical Society.

As part of our observance of our Centennial, we expect to issue several special publications to commemorate the event, including a new Bibliography of North Dakota Geology and a Centennial Volume consisting of a collection of essays on North Dakota geology.

We hope to release a CD ROM providing a variety of information, including a variety of digital map data created at the NDGS. This will include a statewide surficial geology map, a shaded relief map, physiographic province map, an endangered species distribution map, and some county-based maps showing coal exploration borehole locations. Space permitting, we will include other digital maps or data that might be ready when the CD ROM is created. With the exception of the surficial geology map, digital maps will be provided in two formats: ARC/INFO graphics files, and Postcript files. In addition to these two formats, the surficial geology map will also be provided as an ARC/INFO Export file.

As one of the first agencies in North Dakota to provide and distribute information via the Internet, the NDGS will continue to expand the variety of useful earth-science related information that can be accessed using this increasingly popular medium.

Finally, we intend to "officially" observe our 100th birthday, along with the 100th birthday of the Historical Society, at a party on June 23rd at the Heritage Center. Please come!

A Symposium on
NORTH DAKOTA GEOLOGY:
IN RECOGNITION OF THE NORTH DAKOTA GEOLOGICAL SURVEY CENTENNIAL

North Dakota Academy of Science 1995 Annual Meeting
North Dakota Heritage Center, Bismarck

Symposium Coordinator and Editor
John W. Hoganson
North Dakota Geological Survey

Symposium Agenda
April 20, 1995

INTRODUCTION

1:20 John W. Hoganson, North Dakota Geological Survey

HISTORY OF NORTH DAKOTA GEOLOGY

1:30 **Opening Remarks — 1895-1995 — North Dakota Geological Survey's First Century:**
John P. Bluemle, North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

2:00 **Paleocene Paleontology and Stratigraphy in North Dakota: Early Contributions by A. G. Leonard:**
Joseph H. Hartman, Energy and Environmental Research Center, University of North Dakota, Grand Forks, ND 58202

2:20 **History of Coal Mining and Utilization in North Dakota:**
Dean A. Moos* and David Bickel, Reclamation Division, North Dakota Public Service Commission, Bismarck, ND 58505

2:40 **History of Glacial Research in North Dakota:**
John R. Reid*[1] and John P. Bluemle[2], [1]Department of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58202-8358; [2]North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

3:00 **Coffee and Discussion Break**

SUBSURFACE GEOLOGY

3:20 **The Newporte Structure: The First Petroliferous Basement Impact Crater:**
Nels F. Forsman*[1] and Timothy R. Gerlach[2], [1]Department of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58202-8358; [2]Energy and Environmental Research Center, University of North Dakota, Box 9018, Grand Forks, ND 58202

3:40 **Depositional Environments and History of the Winnipeg Group (Ordovician), Williston Basin, North Dakota:**
Jonathan B. Ellingson* and Richard D. LeFever, Department of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58202-8358

4:00 **Diversity and Distribution of Lodgepole Buildups in the Williston Basin and Central Montana:**
Randolph B. Burke* and Paul E. Diehl, North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

April 21, 1995

STRATIGRAPHY/PALEONTOLOGY

8:00 **A Specimen of *Plioplatecarpus* from the Upper Cretaceous Pierre Shale, Cedar Creek Anticline, southwestern North Dakota:**
Nancy Overland Schaefer*[1], Terry Schaefer[1], G. L. Bell[2], and Bruce A. Schumacher[2], [1]Pioneer Trails Regional Museum, Bowman, ND 58623; [2]Museum of Geology, Rapid City, SD 57701

8:20 Cartilaginous Fishes from the Fox Hills Formation (Cretaceous: Maastrichtian), North Dakota:
John W. Hoganson*[1], J. Mark Erickson[2], and F. D. Holland, Jr.[3], [1]North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840; [2]Geology Department, St. Lawrence University, Canton, NY 13617; [3]Department of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58202-8358

8:40 Hell Creek Formation (Cretaceous: Maastrichtian) Microsite Faunas; Their Potential as Paleoenvironmental Change and Extinction Indicators:
Dean A. Pearson, Department of Paleontology, Pioneer Trails Regional Museum, Bowman, ND 58623

9:00 A *Tyrannosaurus rex* from the Hell Creek Formation (Cretaceous: Maastrichtian), Bowman County, North Dakota and Observations on its Depositional Setting:
Laura Oakland* and Dean A. Pearson, Department of Paleontology, Pioneer Trails Regional Museum, Bowman, ND 58623

9:20 Bird Tracks from the late Paleocene of North Dakota:
Allen J. Kihm*[1] and Joseph H. Hartman[2], [1]Department of Earth Science, Minot State University, Minot, ND 58707; [2]Energy and Environmental Research Center, University of North Dakota, Grand Forks, ND 58202

9:40 Coffee and Discussion Break

10:00 *Champsosaurus gigas* Erickson: A Restored and Mounted Skeleton (ND94-225.1) in the North Dakota State Fossil Collection:
Johnathan M. Campbell* and John W. Hoganson, North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

10:20 The Medicine Pole Hills Local Fauna: Chadron Formation (Eocene: Chadronian), Bowman County, North Dakota:
Dean A. Pearson*[1] and John W. Hoganson[2], [1]Department of Paleontology, Pioneer Trails Museum, Bowman, ND 58623; [2]North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

10:40 Urban Outcrops: Building Stones of the North Dakota Capitol Grounds:
Robert F. Biek, North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

11:00 WALKING FIELD TRIP — BUILDING STONES OF THE STATE CAPITOL
Robert F. Biek, North Dakota Geological Survey

12:30 LUNCH

ENVIRONMENTAL GEOLOGY/GEOARCHEOLOGY

2:00 Use of Electric Pulse Disaggregation to Liberate Fossils from North and South Dakota Sediments:
Bernhardt Saini-Eidukat*[1], Brenda Pederson[1], and Paul W. Weiblen[2], [1]Department of Geosciences, North Dakota State University, Fargo, ND 58105-5517; [2]Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455

2:20 Ground Water Flow System Response to Opening and Closure of the J. K. Ranch Lignite Mine, Dickinson, North Dakota:
David Bickel, Reclamation Division, North Dakota Public Service Commission, Bismarck, ND 58505

2:40 Slope Stability in the Bismarck-Mandan Area:
Edward C. Murphy, North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840

3:00 Going with the Flow?: Geotechnical Implications of Land Use Decision-Making, Red River Corridor, Fargo, North Dakota, and Moorhead, Minnesota:
Donald P. Schwert, Geosciences Department, North Dakota State University, Fargo, ND 58105-5517

3:20 Flakable Lithic Resources in North Dakota:
Mark R. Luther*[1] and Robert C. Christensen[2], [1]North Dakota Geological Survey, 600 East Boulevard Ave., Bismarck, ND 58505-0840; [2]North Dakota Department of Transportation, 608 East Boulevard Ave., Bismarck, ND 58505

CLOSING REMARKS

3:40 John P. Bluemle, State Geologist, North Dakota Geological Survey

Third Williston Basin Horizontal-Drilling Workshop
April 30 - May 2, 1995
Regina, Saskatchewan

Once again the North Dakota Geological Survey and Saskatchewan Energy and Mines are cosponsoring a workshop on horizontal drilling in the Williston Basin. This year it will be held in Regina, Saskatchewan from April 30 through May 2. Comments and suggestions received from many of the 300 people who attended last year have been incorporated into this year's meeting. The format will again be informal to allow better discussions and communication, with a chance to learn about the latest in ideas and activity in the Basin. The workshop will cover subjects on geology and engineering on both sides of the border, with talks and poster displays. In addition, there will be an informal open house at the Saskatchewan Research Council and the Energy and Mines Geological Laboratory. Scheduled and invited talks include updates on horizontal activity across the Basin, and the following topics.

Geology:
- Reservoir heterogenieity and potential candidates for horizontal drilling (keynote speaker);
- Mudlog gas responses;
- Moose Mountain Tilston, Wayne Field, and Lougheed Midale case studies;
- Montana horizontal possibilities (invited);
- Production performance and economics.

Engineering:
- Geosteering case histories (keynote);
- Coiled tubing;
- Case histories from Canada and the North Sea;
- Arcola Frobisher-Alida analysis;
- Underbalanced drilling;
- Re-entry options;
- Drilling with articulated motors;
- Reservoirs and fracture systems (invited);
- Porosity research results (invited).

Information and ideas gained from the horizontal-drilling workshop can translate very quickly into drilling and development activity. For example, a talk last year on the Spearfish pool at Manor Field in Saskatchewan sparked exploration and leasing on similar prospects in North Dakota. New data presented on the Lodgepole Waulsortian mounds has helped maintain activity on that play around Dickinson Field, where two operators have recently had considerable wildcat success. Another talk on the Red River potential in Bowman County encouraged a lease play and horizontal drilling, with a new field discovery (Cougar Field) and extension of another. In addition to these examples from last year's meeting, several other reservoirs are being drilled horizontally for the first time in North Dakota. Development at Haas Field has significantly increased production there and similar work ongoing at Rival and Kimberly has been encouraging as well. Deeper reservoirs are being considered also, with drilling permit applications for development wells in the Duperow and Interlake Formations. Much of this activity is a reflection of new horizontal-drilling technology and subsequent cost reductions.

For more information on the horizontal-drilling workshop contact Bill McClellan at 701-328-4109 or Ken Stalwick at 306-787-2571. — *Bill McClellan*

7th International Williston Basin Symposium

JULY 23–25, 1995

HOLIDAY INN
BILLINGS MONTANA U.S.A.
I-90 at City Center Exit

Sponsored by the
MONTANA, NORTH DAKOTA
& SASKATCHEWAN GEOLOGICAL SOCIETIES
and the
FORT PECK TRIBES

W. KIPP CARROLL, GENERAL CHAIRMAN
406-245-2367

The 7th International Williston Basin Symposium will be held June 23-25, 1995 in Billings, Montana. This two-day symposium will feature talks and poster presentations on tectonics and exploration methods; regional sedimentation and stratigraphy; field studies; and oil sources, reserves, and hydrodynamics. Two field trips are scheduled prior to the meeting, and a core workshop will be held on the afternoon of Sunday, July 23. Cores from the Ordovician Red River Formation, Mississippian Lodgepole Waulsortian mounds, and Mississippian Mission Canyon Formation will be studied. The Lodgepole portion of the core workshop will be led by Randy Burke, Paul Diehl, and Tom Heck of the NDGS. For further information, contact W. Kipp Carroll, General Chairman, at 406-245-2367.

Survey Receives Grant to Map the Geology of Theodore Roosevelt National Park

The NDGS was recently awarded a $9,000 federal grant for geologic mapping of the North and South Units of Theodore Roosevelt National Park. The grant comes from the State Geologic Mapping Element (STATEMAP) of the National Geologic Mapping Program. The grant will be used to match state funds on an equal basis.

The mapping will be done by NDGS geologist Bob Biek at a scale of 1:24,000 (1 inch on the map equals 24,000 inches or 2,000 feet on the ground). The maps will be accompanied by both technical and general interest reports on the geology of the park. The project is scheduled for completion by July, 1996.

About 480,000 people visit Theodore Roosevelt National Park every year. While it offers much more, the park is perhaps the single greatest geological attraction in North Dakota. Recently park naturalists and NDGS geologists collaborated to update a popular geological roadlog to the the park. NDGS paleontologist John Hoganson is in the middle of a three-year assessment of the park's fossil resources. Yet despite this and other research in the park, the park lacks basic, detailed geologic maps. The geologic maps will provide a useful educational and planning tool for park naturalists and are expected to provide a framework for more detailed geologic studies.

To learn more about the mapping project, please call Bob Biek at (701) 328-4109.

Research Proposals Requested From Small Independent Petroleum Operators

BDM-Oklahoma (BDM), Management and Operating Contractor for DOE's National Oil and Related Programs, is soliciting proposals to a requirement generally titled "Research and Development by Small, Independent Operators to Provide Solutions towards Production Problems."

Responses to this Research Opportunity Announcement (ROA) number OKL-5027-01 will be considered for a one-year period: February 1, 1995 through January 31, 1996. Proposals will be evaluated and award determinations will be made throughout the year-long response period. Responses must be sent to: BDM-Oklahoma, Inc., Todd Martinez, P.O. Box 2565, 220 N. Virginia Avenue, Bartlesville, OK 74005. Reference the ROA number OKL-5027-01 on the exterior of the shipping container.

This procurement is set aside for small independent petroleum operators operating onshore in the lower contiguous 48 states. Small independent operators are further defined as having (1) no affiliation with a major oil or gas producer (domestic or foreign) and (2) no more than 50 full-time company employees or contractors.

The selection of one or more applicants for contract award will be based on a scientific and engineering evaluation of the responses (technical and price/cost). New and innovative concepts, ideas, and approaches are of primary interest and will be ranked highest in the evaluation process. **Proposals aimed at applying proven concepts should not be submitted.** Price/cost is ranked as the second order of priority.

The estimated funding from MBD is not more than $50,000 per award. Cost sharing with BDM is required at an amount of not less than 50% of the total proposed amount and may consist of in-kind contributions. Questions on technical issues may be referred in writing to Herb Carroll, fax (918) 337-4558. Contractual issues and price/cost questions should be referred in writing to Todd Martinez, fax (918) 337-4504.

BDM seeks proposals for research and development that integrate solutions to production problems experienced by small independent petroleum operators. Proposed efforts must incorporate innovative field technologies for use by small independent operators to increase production, reduce operational costs, reduce environmental concerns, or any combination thereof. The types of technologies to be considered are not limited to, but may include, reservoir characterization, well drilling, completion or stimulation, environmental compliance, artificial lift, well remediation, secondary and tertiary oil recovery, and production management.

As an integral part of its proposal, the contractor will be required to demonstrate and implement an aggressive technology transfer plan primarily targeted for small independent petroleum operators. Proposal Submission Forms may be obtained by contacting Todd Martinez at the above Bartlesville, OK address or fax number. — *Paul Diehl*

NDGS Publications Clerk Retires

Eula Mailloux retired from the North Dakota Geological Survey on December 31, 1994. Eula had been the Survey's publication clerk for the past 6 years and prior to that she worked as a clerk in Grand Forks for the previous 9 years. As our publication clerk, Eula was an ideal person in the position — conscientious, pleasant and always courteous in dealing with the public.

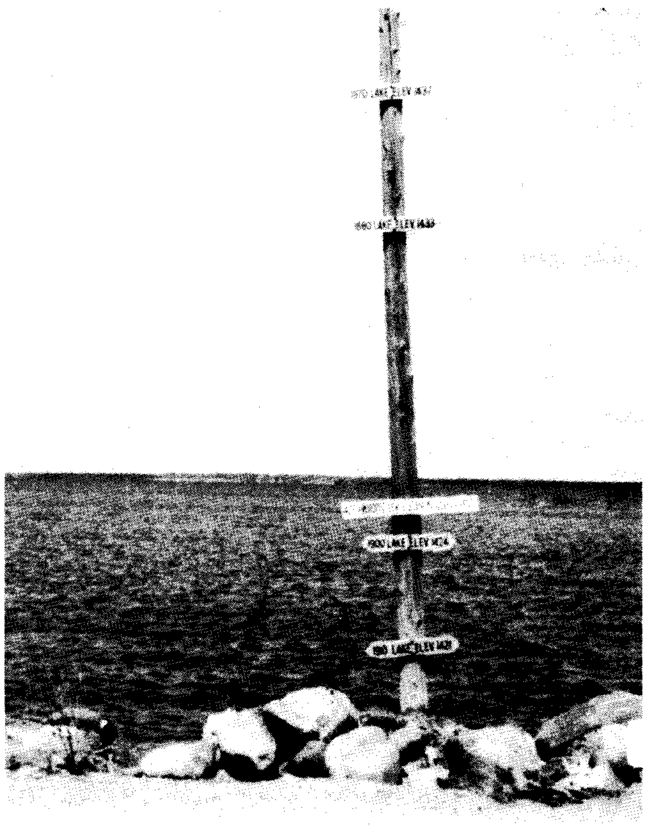
Eula joined the survey in 1979 when we were in Grand Forks and she came with the Survey when it was moved to Bismarck in 1989. She came to the Survey from Sturgis and Rapid City, South Dakota, where she grew up and attended school. She had taught in a rural school near Sturgis and also in the Whitewood Public School prior to moving to Grand Forks.

We recently awarded Eula a Certificate of Appreciation for her 15 years with the Survey. She and her husband Dale plan to stay in Bismarck for now.

THE FLUCTUATING LEVEL OF DEVILS LAKE

by John Bluemle

As I write this, in February, the level of Devils Lake stands at 1,431 feet. That's the highest it has been this century, and it's likely the level will rise still higher with the spring melt. A number of solutions are being debated to solve the immediate problem — the likelihood of severe flooding this spring. The long-term problem is, simply stated, that the lake seems to either have too much water or not enough (and it tends to saltiness when it is low). Certainly, the problem can be solved by building both an inlet and an outlet, delivering water to the lake during times it is low and removing the excess when it gets too high (and, in the process, freshening the water). My purpose here is to examine the geologic history of Devils Lake and suggest some reasons it rises and falls so dramatically.



Signpost showing historic levels of Devils Lake, circa 1940's. This marker was located near the junction of state highways 20 and 57 just south of the city of Devils Lake and served as a reminder of the lake's naturally fluctuating level.

Why does the level of Devils Lake fluctuate between such extreme limits? Are man's actions — draining wetlands, agricultural practices, road building, dike building, changing drainage routes, etc. — the reason for the recent rise in the level of Devils Lake? That was the contention of many people during the early 1980s, when the level of the lake was rising rapidly. Or is the problem simply one of climatic changes?

Nearly 30 years ago, Edward Callender, in a 1968 M.S. thesis at the University of North Dakota, documented five major and several minor fluctuations in the level of the Devils Lake beginning about 6,500 years ago (that's as far back as his study went; changes occurred before then too, of course). Callender recognized at least seven periods of low water level and brackish (salty) conditions and noted that the lake dried up completely for a time during the Altithermal Interval, a period of warm, dry climate that reached its greatest intensity sometime between 8,500 and 5,500 years ago. Generally, Callender verified that the Devils Lake environment has always been unstable (see Fig. 1 for a chart showing how the lake level has fluctuated through time). Relatively high lake levels (higher than the early 1995 elevation of 1,431 feet), occurred about 4,300, 3,500, 2,300, 1,250, 1,000, 750, and 250 years ago. These dates tend to coincide with periods of cooler, wetter climate in the northern plains. Relatively low lake levels occurred about 6,000, 4,000, 3,000, and 500 years ago, times coinciding with periods of warmer, drier climate. Historical records of fluctuations in the level of Devils Lake show that, in 1830, the lake was at an elevation of 1441 feet. It gradually declined between 1860 and 1940 when, at a level of 1,400 feet, it was only 3 feet deep (Fig. 2).

Changes in the lake level have been the rule rather than the exception over the years. The lake level rose to 1,440 feet several times in the past and it dropped to levels lower than 1,400 feet several times. Obviously, all of these past changes in the lake level occurred in response to natural climatic changes — no roads, drained wetlands, or other man-made features existed prior to settlement. It should also be noted that there was no City of Devils Lake existing on the lake shore and thus no harm done if the lake level rose.

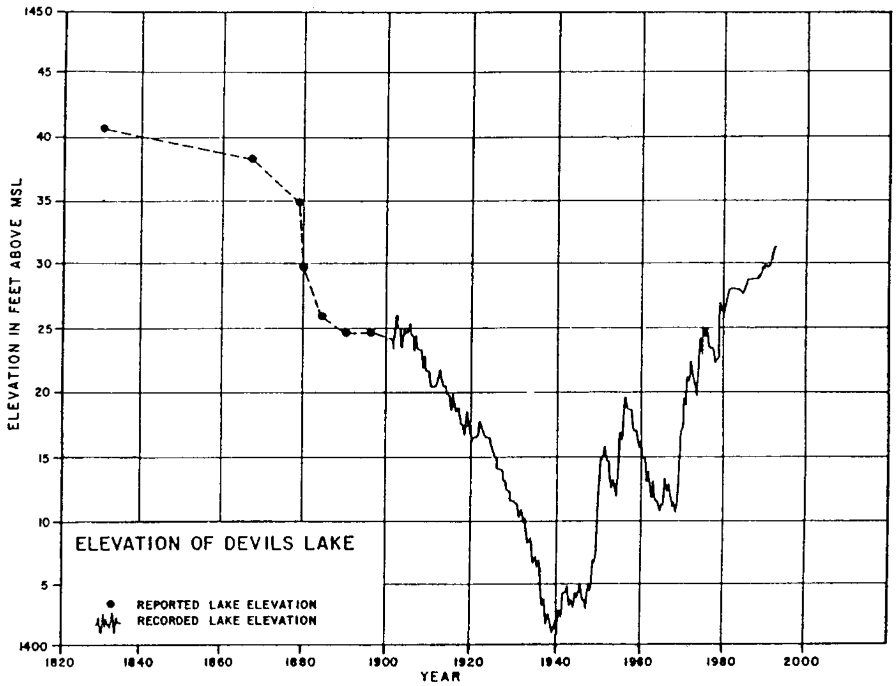


Figure 1. *Fluctuating level of Devils Lake since the early 1800s. Prior to about 1900, only a few accurate readings on the lake level are available.*

Even though draining of wetlands or current agricultural practices certainly affect the modern landscape, these and other cultural practices are insignificant with respect to overall changes in the level of Devils Lake.

In an effort to answer some of the questions about the fluctuating lake level, geologists with the North Dakota Geological Survey studied the geology and hydrology of the lake during the 1980s. These studies included sampling a buried soil horizon in several places during November of 1987. The buried soil zones we studied along the north shore of Devils Lake were overlain by beach gravels and underlain by offshore and nearshore lake sediments. We were able to identify what appeared to be the same buried soils in several other places over a five-mile distance along the lake shore.

Generally, the sequence of beds we examined along the lake shore indicates that, each time after Devils Lake rose to relatively high levels and deposited beach sediments, its level dropped sufficiently and for long enough periods of time to allow the extensive development of soils on the beach deposits. The lake then rose again, flooding the soils and depositing more beach deposits over them. This happened several times.

The radiocarbon dates we obtained on the soils we sampled are important because we were able to use them to show that Devils Lake has risen to levels higher than 1,447 feet in post-Altithermal time (more than once since 5,000 years ago, and at least once within the past 1,800 years). Whenever Devils Lake reached a level that high, it overflowed into Stump Lake. Until a few years ago, it was generally assumed that Devils Lake has not overflowed into Stump Lake since sometime prior to Altithermal time, more than 7,000 years ago.

Our soil dates further showed us that a complex series of relatively recent fluctuations have occurred in the level of Devils Lake. We now know that the lake has fluctuated more widely and more often than we had believed. From this we can infer that extreme 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 maintain a stable level or 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 don't appear to correlate well with obvious climatic trends. One reason for this may relate to the runoff pattern. Several smaller lakes are found immediately up-drainage from Devils Lake and these lakes serve to delay runoff to Devils Lake.

Another possible reason for the apparently anomalous fluctuating behavior of Devils Lake may relate to interaction with the groundwater system. I first suggested in the late 1970's that groundwater flows may account for much of the water entering or leaving Devils Lake. If the Spiritwood Aquifer, which directly underlies Devils Lake, is in contact with the floor of the lake, water can move freely from the aquifer to the lake or vice versa.

The Spiritwood Aquifer extends well beyond the limits of the lake, and beyond the limits of the Devils Lake drainage basin. In fact, it extends all the way from

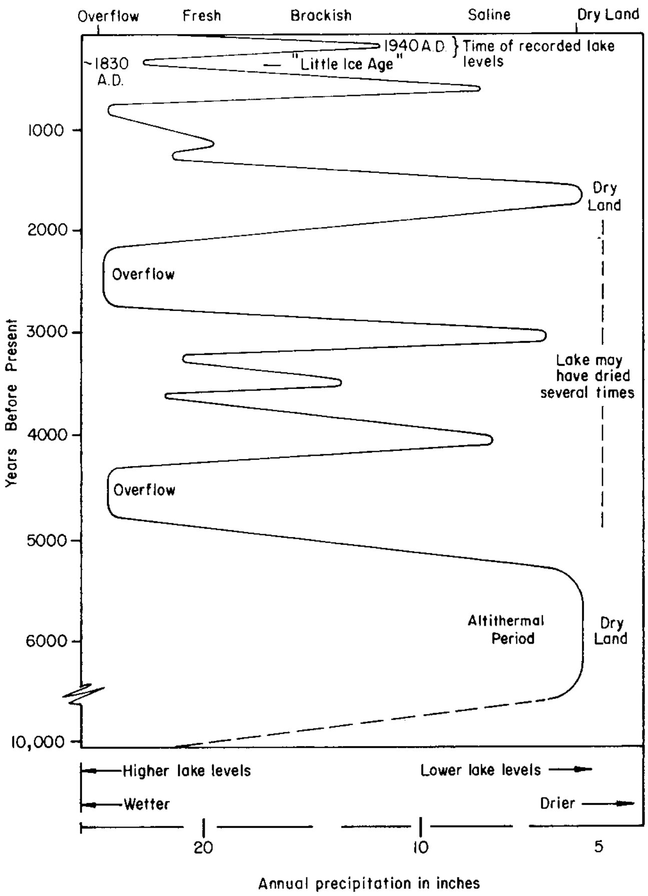


Figure 2. *Time/Event diagram showing how Devils Lake has fluctuated during the past 10,000 years. The lake overflowed to Stump Lake several times and it dried completely a number of times. The studies we did during the 1980's help us to better understand the last 3,000 years of the history of Devils Lake.*

north of the Canadian boundary to south of the South Dakota border, and it is interconnected by a system of buried preglacial valleys to aquifers several hundred miles to the southwest. In 1980 it was calculated that, in Ramsey County alone, the Spiritwood Aquifer had approximately 990,000 acre-feet of groundwater available from storage. The amount of water in the aquifer is far greater than is contained in Devils Lake itself (the amount of water in the lake changes greatly, of course, as the level of the lake, and its extent, increases or decreases).

Cycles of increased and decreased precipitation affect the groundwater supply, but because the movement of groundwater through the aquifer system is relatively slow, rises and declines in the lake level that might result from such changes in the groundwater supply cannot be readily tied to obvious climatic cycles. Such rises and declines tend to lag behind climatic cycles by an unknown number of years.

If the Spiritwood Aquifer is filled to capacity, water from the aquifer may escape to Devils Lake, even during periods of short-term dry climate. Conversely, if the aquifer is depleted following a long period of drought, it would be possible, even during a wet year, for the lake to lose so much water to the aquifer that its level would continue to fall. Thus, the level of the lake may not be well synchronized with the immediate climatic conditions.

Landfill Investigations Nearing Completion

The NDGS and the North Dakota State Water Commission are nearing completion of a cooperative evaluation of the state's active landfills. The project originated with House Bill 1060, the comprehensive solid waste management bill passed by the Legislature in 1991. One of the provisions of that bill directed the state engineer and the state geologist to complete site suitability reviews of active municipal landfills by July 1, 1995.

A total of 47 landfills were evaluated during the past 3 1/2 years. Four to six monitoring wells were installed at each landfill. Groundwater samples from the wells were analyzed at laboratories operated by the State Water Commission and the State Health Department. Reports on each landfill have been provided to the landfill operators and the Health Department for use in site improvement, remediation, or landfill closure.

The reports were written by Phillip Greer of the NDGS and Jeff Olson of the NDSWC. Russ Prange of the NDGS and Gary Calheim and Albert Lachenmeier of the NDSWC provided drilling and technical support for the project. — *Phil Greer*

LODGEPOLE FORMATION PLAY UPDATE

by
Randy Burke and Paul Diehl

Discovery of another Lodgepole "mound" is stimulating the play with reports of an initial flowing potential of 2707 barrels of oil (BO) and 1.55 million cubic feet of gas (MMCFG) per day (Anonymous, 1995a). The Raymond T. Duncan Oil Co. completed this discovery in late December 1994 in the Knopik 1-11, which is located 3.4 miles southwest of Conoco Inc.'s mound discovery in the Lodgepole in Dickinson Field (Fig.1). Oil "runs and lease use" for the Knopik during January 1995 was 65,210 barrels.

Conoco Inc. initiated the play with their discovery of millions of barrels of oil in a Lodgepole Waulsortian-like mound in Dickinson Field on February 3, 1993. The development of the Lodgepole pool has been completed and the pool was unitized in June 1994.

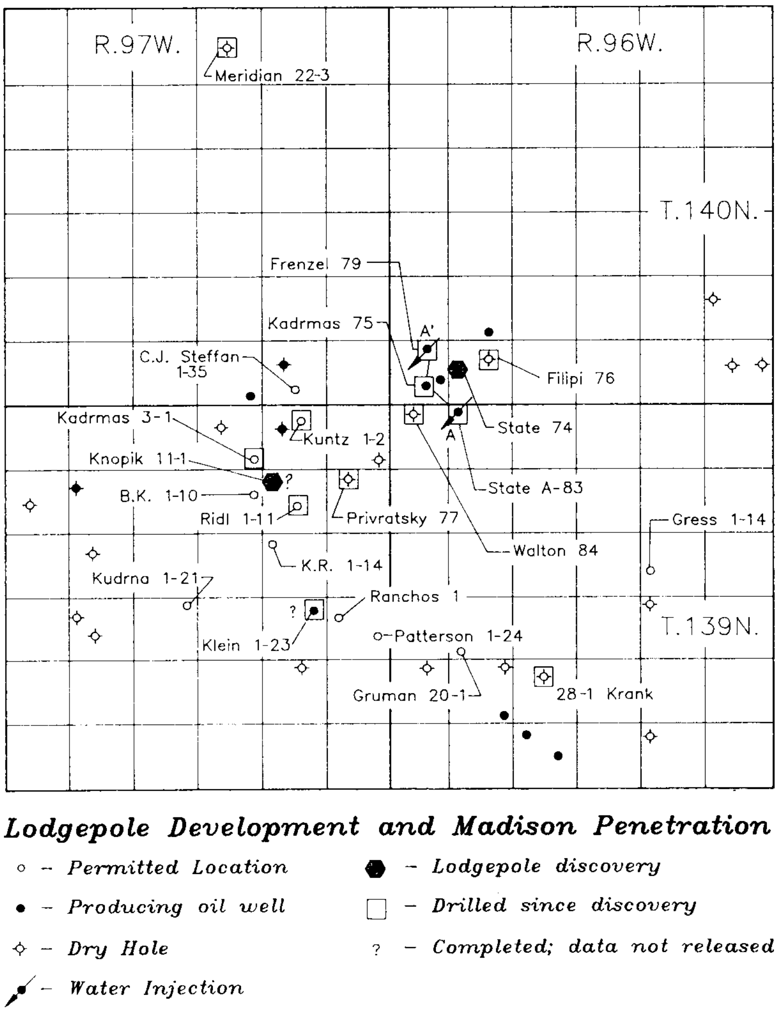


Figure 1. *Location map showing development of Lodgepole play, line of cross section A-A', and well status of all wells penetrating the Madison Group in the area surrounding the Conoco Dickinson Field Lodgepole discovery.*

Reservoir pressure maintenance by water injection has been initiated and the last of the confidential data from Conoco tests in the Dickinson unit were released in July 1994. Despite restricted production during one third of the time since discovery, this unit has produced over 1 million barrels of oil and more than half a billion cubic feet of gas, primarily from two wells. The following is an update about the Dickinson Lodgepole pool, the exploration activity, and the availability of new information from recent tests in the play (Table 1).

Lodgepole Fm. Pool, Dickinson Field

Field Development

Seven tests have been drilled to define the Lodgepole reservoir in Dickinson Field, Stark County, North Dakota. The Conoco Inc. Dickinson State 74 was completed on February 3, 1993 following production tests of over 2000 BOPD. The last development test was the Conoco Inc. Walton 84 dry hole, which was plugged on January 29, 1994. Nine unsuccessful wildcat tests have been drilled in search of productive Lodgepole buildups since the Conoco discovery and prior to the Duncan Knopik 1-11 discovery.

The Dickinson State 74 was completed uphole after the primary objective Silurian Interlake, and the secondary objective Ordovician Red River were nonproductive — after perforating and testing the Interlake, the top 129 feet of the 296-foot-thick Lodgepole buildup were perforated (Table 2) on the morning of February 3, 1993. Fluid reached the surface ten minutes after dropping the firing bar down hole to initiate perforation. Later that day, a 16-hour test flowed 279 BO and flared an average of 130 MCFGD on

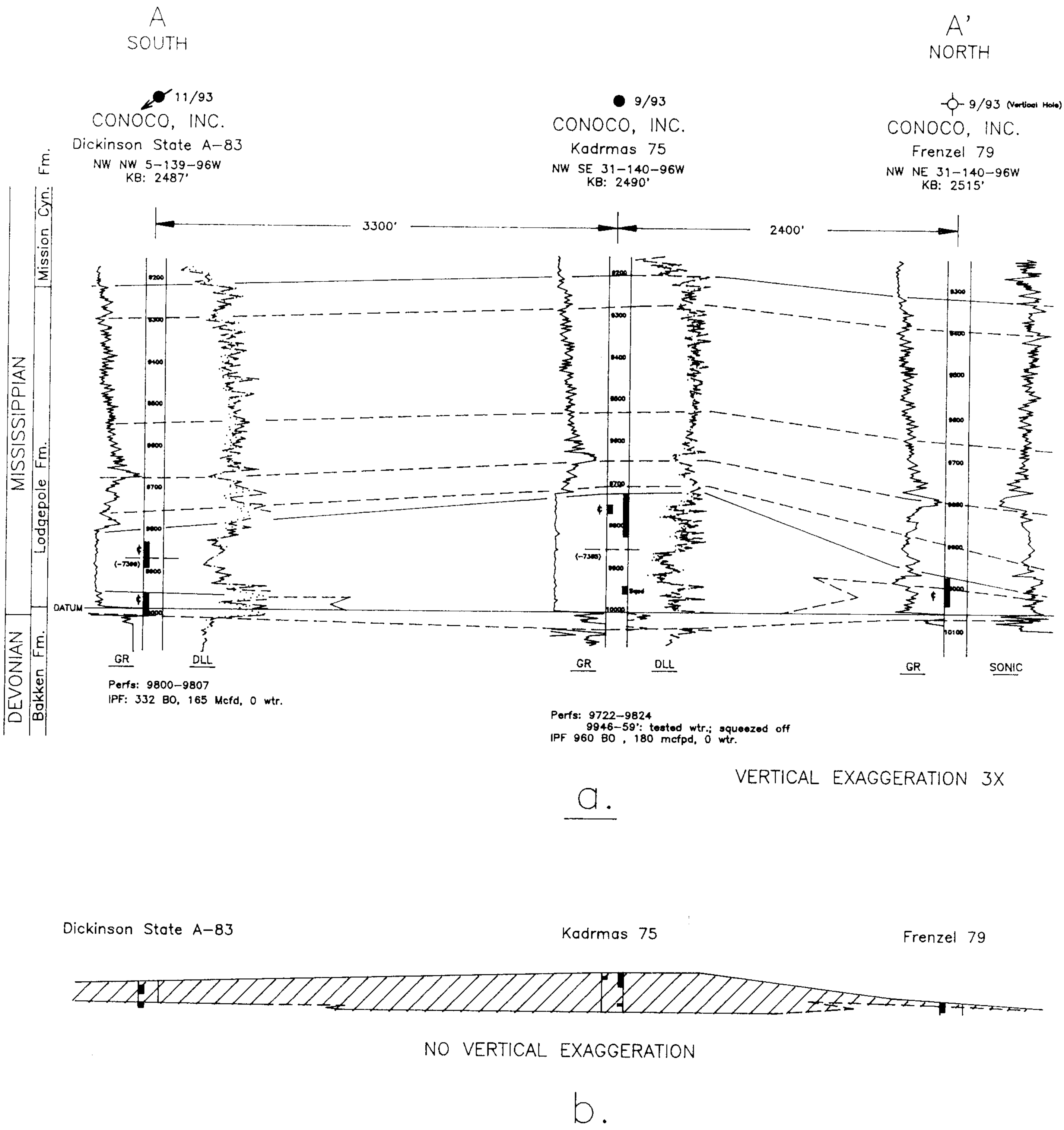


Figure 2. *Cross section A-A' at different vertical exaggerations.* **a.** *Vertical exaggeration at 3x, showing log correlations, cored intervals, oil water contact and perforated zones.* **b.** *No vertical exaggeration, illustrating the broad, relatively low relief of the Dickinson mound complex.*

a 12/64 inch choke with a flowing tubing pressure of 1500 psi with intermittent plugging of the choke.

The first stepout, the Conoco Privratsky 77, was a dry hole about 2.3 miles southwest of the discovery well. The next five tests that Conoco drilled were to define and develop the Lodgepole reservoir. Of the five, three penetrated and perforated various thicknesses of a gamma ray "clean" carbonate buildup: the Kadrmas 75, the Frenzel 79 (sidetrack), and State A-83 (Fig.2; Table 2). The Kadrmas 75 encountered a mound thickness of 284 feet, similar in thickness to the 296 feet in the State 74, whereas the State A-83 encountered only 151 feet of the buildup. The Conoco Frenzel 79 vertical hole encountered about 26 feet of distal flank beds before being plugged back and sidetracked into the mound. The successful Frenzel 79 sidetrack deviated as much as 48° from vertical penetrating 226 feet (drilling thickness) of reservoir rock in the hole but did not penetrate the Bakken. There was no indication of the mound in the Filipi 76 or the Walton 84. Northeast dips from a dipmeter log run in the Kadrmas suggest there may be more than one center of mound growth and that the reservoir may actually be in a cluster of mounds or a composite structure.

Cores were cut in three of the wells but none cored the entire mound interval (Fig. 2; Table 2). In the Kadrmas 75, 21 feet of core were recovered from the upper part of a mound. Textures in the core are

TABLE 1. LODGEPOLE PLAY: POST-CONOCO DICKINSON FIELD WELL STATUS, PERMITS AND RELEASE DATES OF CONFIDENTIAL DATA

Test Name	File No.	Location (Sec.,T.,R.)	Release Date	Status
DRILLED				
Conoco, Fichter 1	13615	NWNW 24-142-94		dry
True Oil, Meridian 22-3	13626	SENW 3-140-97		dry
Kearns, Miller 33-1 (re-entry)	10570	SWSE 1-138-96		dry
R.T. Duncan, Jilek 1	13677	NESW 29-140-95		
True, Schmidt 34-3	13676	SWSE 3-140-94		dry
Armstrong, Sabo 25-1	13678	NENW 25-140-95		dry
West Bay, Dvorak 1	13687	SWNW 21-143-94		dry
Columbia, Krank 28-1	13693	SWNE 28-139-96	3/15/95	dry
R.T. Duncan, Knopik 1-11	13715	NWNW 11-139-97	5/5/95	**producing**
Armstrong, Wolf 28-1	13733	SENW 28-139-95	6/1/95	completed
Conoco, Kadrmas 3-1	13744	SESE 3-139-97	7/23/95	**completing**
R.T. Duncan, Klein 1-23	13745	NENE 23-139-97	7/28/95	**completing**
Conoco, Kuntz 1-2	13754	NWNE 2-139-97	8/16/95	@ total depth
R.T. Duncan, Ridl 1-11	13724	NWSE 11-139-97	8/14/95	@ total depth
Conoco, C.J. Steffan 1-35	13764	SESW 35-140-97	≅ 9/10/95	drilling
Conoco, Ranchos 1	13755	SWNW 24-139-97	≅ 9/10/95	drilling
R.T. Duncan, Kudrna 1-21	13762	NENE 21-139-97		drilling
PERMITTED LODGEPOLE TESTS				
R.T. Duncan, Patterson Federal 1-24	13751	NESE 24-139-97		permitted
Armstrong, Gruman 20-1	13757	SWSW 20-139-96		permitted
R.T. Duncan, K.R. 1-14	13758	NWNW 14-139-97		permitted
R.T. Duncan, Gress 1-14	13761	W/2SW 14-139-96		permitted
R.T. Duncan, B.K. 1-10	13731	SENE 10-139-97		permitted

NORTH DAKOTA GEOLOGICAL SURVEY

600 E. Boulevard Avenue * Bismarck, North Dakota 58505-0840
Phone (701) 328-4109 FAX (701) 328-3682

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INDUSTRIAL COMMISSION
Edward T. Schafer - Governor, Chairman
Heidi Heitkamp - Attorney General
Sarah Vogel - Commissioner of Agriculture

Dear Fellow Geoscientists:

In an effort to keep one another apprised of current geologic projects, and to stimulate interaction among geologic researchers in North Dakota, the North Dakota Geological Survey is requesting your cooperation in completing the form on the following page. The form requests information about areas in North Dakota — and nearby areas of adjoining States and Provinces — being studied by geoscientists in your university or agency during 1995.

All geoscientists should complete the form — industry, academic, and government professionals, as well as students. **Please photocopy and circulate this form among your staff and/or colleagues for the required information and return by May 19, 1995.**

Responses will be published in the Summer, 1995 *NDGS Newsletter*; special searches of the data base can be made by type of study, county, and researcher at no charge. The NDGS will solicit and publish this information on an annual basis as a summary of "Geologic Projects in North Dakota."

Please detach and return the completed form to:

North Dakota Geological Survey
600 E. Boulevard Avenue
Bismarck, ND 58505-0840

Attn: Robert F. Biek

Thanks for your cooperation,

John P. Bluemle
State Geologist

Please detach and return completed form

Investigator(s): ______________________________

Organization(s): ______________________________

Address: ______________________________

City State Zip

County(ies) (refer to county codes): ______________________________

Location of Study: ______________________________

Type of Study (refer to study codes): ______________________________

Title/Subject: ______________________________

Scale of Geologic Mapping, if applicable: ______________________________

Date of Inception: ____________ Date of Completion: ____________

Location of Information (i.e., University thesis; state or technical agency open-file report or publication; other publication; company, confidential - where, release date and provisions):

____

May the NDGS have a copy of the completed report and/or map for our library: ______ Yes ______ No

County Codes

Adams	AD
Barnes	BA
Benson	BE
Billings	BI
Bottineau	BO
Bowman	BW
Burke	BU
Burleigh	BL
Cass	CA
Cavalier	CV
Dickey	DI
Divide	DV
Dunn	DU
Eddy	ED
Emmons	EM
Foster	FO
Golden Valley	GV
Grand Forks	GF
Grant	GR
Griggs	GG
Hettinger	HE
Kidder	KI
LaMoure	LM
Logan	LO
McHenry	MH
McIntosh	MI
McKenzie	MK
McLean	ML
Mercer	ME
Morton	MO
Mountrail	MR
Nelson	NE
Oliver	OL
Pembina	PE
Pierce	PI
Ramsey	RA
Ransom	RN
Renville	RE
Rickland	RI
Rolette	RO
Sargent	SA
Sheridan	SH
Sioux	SI
Slope	SL
Stark	SK
Steele	ST
Stutsman	SM
Towner	TO
Traill	TR
Walsh	WA
Ward	WD
Wells	WE
Williams	WI
Statewide	SW
Minnesota	MN
Montana	MT
South Dakota	SD
Manitoba	MB
Saskatchewan	SK

Type of Study Codes

Economic Geology:	
a. General	EC
b. Coal	CG
c. Nonfuel minerals	NF
d. Petroleum	PG
Engineering Geology	EG
Environmental Geology	EV
Geochemistry	GC
Geochronology	GR
Geologic Hazards	GH
Geologic Mapping	GM
Geomorphology	GO
Geophysics	GP
Hydrogeology	HG
Mineralogy	MN
Paleomagnetism	PM
Paleontology	PA
Palynology/Paleobotany	PY
Petrology	PT
Quaternary Geology	QG
Sedimentology	SD
Soils	SO
Stratigraphy	ST
Structural Geology/Tectonics	SG

dominated by fibrous calcite cemented, bryozoan boundstones and bafflestones with packstone to grainstone matrix. The Frenzel 79 vertical hole cored a 60-foot interval and recovered 55.5 feet that included 26 feet of packstone and grainstone dominated flanking beds and 34 feet of wackestone dominated sub- or off-mound deposits. Two cores were cut in the State A-83; the first recovered 6 feet of core and rubble, and the second recovered 60 feet of non-reservoir rock. The first core is from the upper part of a low radioactive, 151-foot thick clean carbonate unit interpreted to include proximal flank beds near the edge of the mound. These core textures consist of crinoid, bryozoan grainstones and packstones. The second core recovered sub- or off-mound wackestones and packstones, the upper Bakken shale, and most of the middle Bakken siltstone that included pyritized ooids.

Production History

The Lodgepole pool has produced 913,899 BO and 545 MMCFG through January 1995. Prior to unitization in June 1994, the pool produced 548,089 BO and 295 MMCFG of which the State 74 produced the largest volume, 69%, the Kadrmas 75, 23%, with the remaining 8% from the State A-83 and the Frenzel 79. Reservoir pressure maintenance by water injection was initiated in October 1994 by conversion of the Frenzel 79 and the State A-83 to injection wells. The Kadrmas 75 and the State 74 have produced 365,810 BO and 251 MMCFG since unitization, averaging 1520 BOPD and 1521 BOPD each in December 1994 and January 1995 respectively. Production at this rate should continue since Conoco testified they would produce the unit at about 3000 BOPD once pressure maintenance was initiated.

TABLE 2. INFORMATION FROM CONOCO TESTS, DICKINSON LODGEPOLE POOL

Test	Mound Interval & Thickness (Log Depths)	Cored Interval (Drilling Depth)	Core Recovered	Perforated Interval	Results
Dickinson State #74	9722′ - 10018′ (296′)	No Lodgepole Core		9721′ - 9850′	Oil & Gas
Kadrmas #75	9720′ - 10004′ (284′)	9750′ - 9771′	21′	9722′ - 9824′ 9946′ - 9959′	Oil & Gas Fm. Water
Frenzel #79 (vertical hole)	9972′ - 9998′ (26′)	9980′ - 10040′	55.5′	None	Dry Hole
Frenzel #79 (sidetrack Hole; up to 48° deviation)	10048′ - 10274+ (226′+)	No Core		10050′ - 10107′	Oil & Gas
State #A-83	9801′ -9952′ (151′)	9824′ - 9879′ 9955′ - 10015′	6′ & Rubble 60′	9800′ - 9807′	Oil & Gas
Filiipi #76	No Mound	No Core		None	Dry Hole
Walton #84	No Mound	No Core		None	Dry Hole

Lodgepole Fm. Play, Williston Basin

Since development of the Lodgepole pool at Dickinson Field, twenty-two additional Lodgepole tests have been drilled or permitted within a four-township radius. The status of these tests at press time is shown in Table 1 as is the date when confidential information from these tests will be released. Although 3-D seismic interpretations are believed to have been used to locate many of these drill sites, little is publicly known about the effectiveness of 3-D seismic methods in locating Lodgepole carbonate buildups. Because the mounds and the beds surrounding them are both limestones, one might not expect an acoustic contrast sufficient to resolve these broad, relatively low-relief features (Fig. 2b) at a depth of 10,000 feet beneath salt beds of highly variable thickness. The technique, however, is reported to be successful for discovering similar carbonate buildups in the Hardeman Basin, Texas (Shirely, 1994a, 1994b). Differences in regional geology may account for their success. Duncan's success has been attributed in part to their ability to correctly interpret their 3D seismic data (Anonymous, 1995b).

Duncan's Successful Lodgepole Wildcat

Insight into the production potential and characteristics of the Knopik 1-11 were provided at a hearing before the North Dakota Oil and Gas Commission although other official records remain confidential. North Dakota Industrial Commission monthly production figures are confidential now too, but they do report Knopik 1-11 "runs and lease use" of 65,210 BO for January 1995. The Rocky Mountain Oil Journal (Anonymous, 1995a) reported the Knopik had an initial flowing potential of 2707 BOPD and 1.55 MMCFGPD. Duncan requested the hearing to ask for removal of production restrictions until a gas pipeline was laid to the location. Supporting documentation from pressure tests presented at the hearing indicated that the Knopik reservoir was separate from the Conoco Dickinson pool and that there is vertical pressure communication throughout the pay zone. Other reports stated the pay zone is 185 feet thick (Anonymous, 1995b) and in a carbonate mound. Estimates of original reservoir pressure in the pay zone are 4426 psi with a bubble point of 1500 psi according to Commission exhibits. Reservoir limits tests indicated a pressure drop of 1 psi/1142 BO. Given these conditions, Duncan projected three wells could produce at a rate of 2500 BOPD each for at least three months without the reservoir reaching critical pressure.

The Rocky Mountain Oil Journal (Anonymous, 1995b) reported that 174 feet of core was cut in the Lodgepole Knopik well and all but 9 feet exhibited oil shows. The core reportedly was "highly fractured with large vugs" and porosities ranged from 6-13% (Anonymous, 1995b), similar to those in the Conoco Kadrmas 75 (Burke and Diehl, 1994). Another similarity to the Dickinson Lodgepole reservoir is an oil/water contact indicated in the Knopik by the recovery of "gassy water" near the bottom of the buildup (Anonymous, 1995b). Water coning, however, is not indicated to be a problem by Duncan's reservoir models even at production rates of up to 4000 BOPD in the Knopik.

If the Duncan Knopik is producing from a carbonate mound, as reported, it would be significant to expansion of the play because the Knopik is in a separate reservoir from the Dickinson pool. The first successful offset from the Knopik has been reported in the Conoco Kadrmas 3-1 (Anonymous, 1995c), but no specifics were given. Field observations indicate that production casing has been run on another Raymond T. Duncan test two miles southeast of the Knopik 1-11 and completion is in progress. Undocumented reports suggest casing has been run in two other Lodgepole tests in this area.

The fact that Waulsortian-like mounds in the Williston Basin occur in clusters has recently been recognized from outcrops in Montana (Burke and Diehl, in press). Numerous clusters were observed in three widely separated mountain ranges in central Montana. In the Big Snowy Mountains four clusters of mounds were observed with a spacing between clusters of 2.5, 0.85, and 3.6 miles. These observations can be interpreted to suggest that not only will more mounds be found around Dickinson, but also that mounds in the Lodgepole are likely outside of the Dickinson area.

Burke and Diehl (in press) also observed that not only is there a significant diversity in composition and architectural style in Lodgepole buildups, but that they vary vertically in their stratigraphic position. A depositional model showing potential environments suitable for development of Lodgepole buildups was proposed based on this information and comparison between Waulsortian facies of central Montana, and the Williston and Illinois Basins (Burke and Lasemi, in press). The Williston Basin model shows buildups could occur from the top of the shelf slope to the basin floor and on and around raised intrabasinal blocks. An association of the Dickinson Lodgepole buildups and faulting has been documented (Shurr et. al., in press).

Most of the land in the immediate Dickinson area has been leased, including minerals under their airport. A proposal to lease minerals under the city has been submitted to the Dickinson City Council. Bids on both the airport and city minerals are to be taken soon. Development in this general area should continue at least for the next few years, and if a Lodgepole discovery is made outside of the Dickinson area, the play will continue well into the future. It looks like the days of well-site geologists "going to town" while the Lodgepole is being drilled are over.

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By Mark Luther

For several years the NDGS has been an affiliate office of the Earth Science Information Center (ESIC) network. Coordinated by the U.S. Geological Survey (USGS), this nationwide ESIC network provides information about geologic, hydrologic, topographic, and landuse maps, books, and reports; aerial, satellite, and radar images and related products; earth science and map data in digital form and related applications software; and geodetic data. As an ESIC office, the NDGS can assist the public in locating those earth science materials dealing with North Dakota, as well as other states.

Revised/New Map Products

In addition to providing information about the availability of various earth science materials, the NDGS's ESIC office operates a distribution center for federally produced cartographic products. The following 1:24,000 scale (7.5-minute quad), USGS topographic maps have recently been revised and are available for purchase from the NDGS at a cost of $2.50 each (plus shipping).

* Cando
* Starkweather NE
* Cando SE
* Starkweather SE
* Churchs Ferry
* Sweetwater
* Derrick NW
* Tilden
* Starkweather
* Webster

The following 1:100,000 scale (30 X 60-minute quad), USGS, **metric topographic** maps have recently been produced and will replace the earlier planimetric (non-topographic) map version. These maps are available from the NDGS at a cost of $4.00 each (plus shipping). Until our current stock of planimetric (PL) maps is depleted, they will be sent unless the topographic (TM) version is requested.

* Ada
* Hillsboro
* Carrington
* Leeds
* Devils Lake
* Rock Lake
* Grafton
* Steele
* Grand Forks

To place map orders or receive additional information, contact our publications clerk or the ESIC Coordinator. Shipping costs on federally produced paper maps purchased from the NDGS are:

1 to 5 maps	$2.75
6 to 30 maps	$4.00
31 or more maps	$6.00

A New Digital Map Product

The development of geographic information systems (GIS) is a rapidly growing industry that supports natural resources studies, land management, environmental analysis, marketing, and urban and transportation planning. The increasing use of computers for storing and analyzing earth science information has greatly expanded the demand for digital cartographic and geographic (spatial) data.

The ESIC network distributes digital cartographic/geographic data files produced by the U.S. Geological Survey (USGS) as part of the National Mapping Program. Digital cartographic data files may be grouped into five basic types. The newest of these, the **Digital Raster Graphic (DRG)** is described below. The second of these, called a Digital Line Graph (DLG), is the line map information in digital form (discussed in the Fall, 1993 *NDGS Newsletter*). These data files include information on planimetric base categories, such as public-land survey, transportation, hydrography, and boundaries. The third type, called a Digital Elevation Model (discussed in the Winter, 1992 *NDGS Newsletter*), consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals. The fourth type is Land Use and Land Cover digital data which provides information on nine major classes of land use such as urban, agricultural, or forest as well as associated map data such as political units and Federal land ownership. The fifth type, the Geographic Names Information System (discussed in the Summer, 1992 *NDGS Newsletter*), provides primary information for all known places, features, and areas in the United States identified by a proper name.

Digital Raster Graphic (DRG)

The USGS's newest digital map product, and one which the NDGS had a hand in initiating, is the Digital Raster Graphic (DRG). Simply, a DRG is a digital file containing an image of a standard, USGS paper topographic map. The DRG is produced by scanning the paper topographic map with a high-resolution scanner, then using computer software to correct distortion and georeference the map image to ground coordinates. The USGS plans to produce DRG's from maps of several scales, but is initially producing DRG's from 1:24,000 scale (7.5-minute quad) maps only. The standard USGS 7.5-minute DRG has the following specifications:

- The paper USGS topographic map (including the text within the map collar) is scanned at a minimum resolution of 500 dpi.

- The digital image **within** the map neatline is georeferenced to the true ground coordinates of the 2.5-minute grid ticks and projected to the UTM projection for consistency with other USGS digital map products. Text outside the map neatline is not georeferenced and frequently looks distorted. The datum of the source materials is preserved in the DRG.

- The image is resampled to 250 dpi and converted to an 8-bit color image in a packbit-compressed TIFF file.

- Color values are standard between DRG quadrangles. A maximum of 12 indexed colors are possible.

- The size of the compressed files range from 5 to 15 megabytes, with 9 megabytes being the average size.

- As 1-degree by 1-degree (of latitude and longitude) blocks of DRG's are completed, they will be put on CD-ROM's for distribution.

When the NDGS made a recommendation to the USGS's National Mapping Division in September 1993, to create a "digital topographic map," it was with the idea that there was a need for an easy to produce, raster based, "dumb map" that could be used as an accurate backdrop for both GIS and CAD applications. DRG's are the resultant product. DRG's will be useful for a wide variety of applications, including: backdrops for other digital data; validation for DLG's; and combining with other digital data like DEM's, to name just a few uses.

The DRG's currently being produced are easily displayed and manipulated by GIS software such as ARC/INFO, but are not easily brought into CAD packages (a potential major user of this type of map product). However, DRG's are still in an evaluation period and changes to make DRG's more compatible with CAD packages may still be possible. Questions or comments about DRG's can be addressed to:

Rolla-ESIC
U.S. Geological Survey
1400 Independence Rd., MS 231
Rolla, MO 65401-2602
Phone 314-341-0851; FAX 314-341-9375
E-mail to esic@mcdgs01.cr.usgs.gov

During the fall of 1994, the NDGS entered into a Joint Funding Agreement (JFA) with the USGS to produce DRG's for several North Dakota cities. The following DRG's (names based on 7.5 minute quadrangle map names) have been completed and are available for sale from the NDGS:

Beulah	Kelly
Bismarck	Lehigh
Bottineau	Mandan
Burlington SE	Menoken SW
Davis Buttes	Minot
Deering SW	Surrey
Dickinson North	Wahpeton
Dickinson South	Watford City
Fargo North	West Fargo North
Fargo South	West Fargo South
Grafton	Williston East
Grand Forks	Williston West
Jamestown	

To purchase DRG's or other USGS digital data products from the NDGS, contact the NDGS' ESIC Coordinator to receive information about pricing and available media types.

(The NDGS' ESIC Coordinator is Mark R. Luther)

Geothermal Heat Pumps

By Bob Biek

Geothermal, ground source, groundwater, water source, earth energy, earth coupled, ... they are known by many names, but whatever they are called, these heat pump systems are reported to be among the most energy efficient heating and cooling systems available. Geothermal heat pumps differ from conventional gas, electric, or oil heating systems in that heat pumps, as their name implies, do not make heat, they simply move it. With a geothermal heat pump system, the renewable heat energy of normal temperature shallow ground (about 43° to 50° F in North Dakota) can be tapped to provide all the heating and air conditioning needs of a single home or the largest of buildings.

Geothermal heat pumps use normal-temperature earth or groundwater for heating during the winter, cooling during the summer, and supplying hot water year round. The heat pump itself operates on the same principle as the home refrigerator or air conditioner, which are actually one-way heat pumps. The geothermal heat pump, however, can move heat in either direction. In the winter, heat is moved from the earth and delivered to the home or building (heating mode). In the summer, heat is removed from the home or building and delivered for storage into the earth (air-conditioning mode). As an added benefit on either cycle, water can be heated and stored, supplying all or part of the function of a separate hot-water heater.

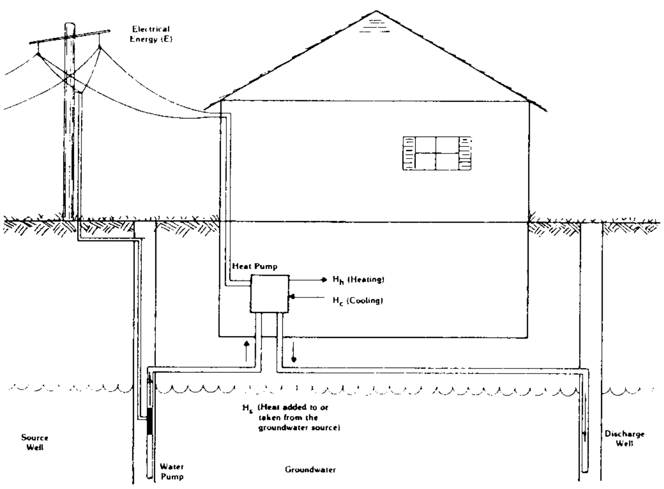

Figure 1. *Sketch showing typical open-loop geothermal system. Groundwater is used as a source or sink for heat, after which it is recharged back to the aquifer or discharged at the surface.*

Types of Geothermal Systems

There are three types of geothermal heat pump systems used in North Dakota: 1) open-loop systems, 2) closed-loop systems, and 3) direct exchange systems. In an open-loop geothermal system, water is withdrawn from a well, heat is either extracted from (heating mode) or added to (cooling mode) the water, and then the water is either returned to the aquifer or discharged at the surface (Figure 1). Most geothermal systems installed in North Dakota prior to the mid-1980's are open-loop systems.

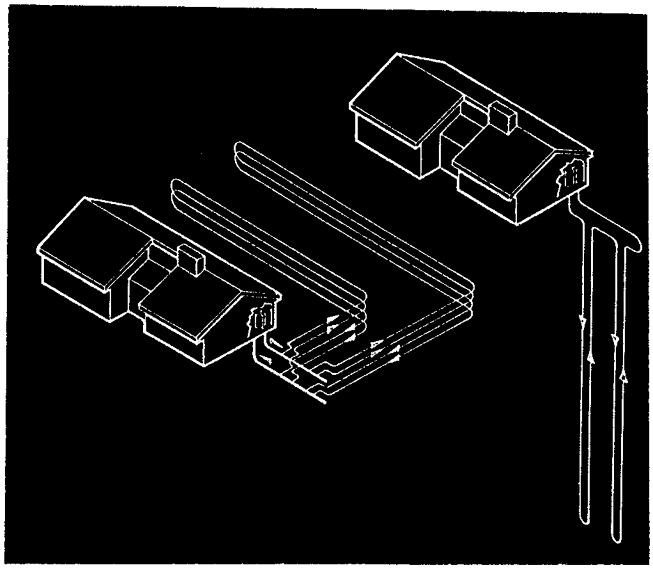

Figure 2. *Sketch showing common configurations of closed-loop geothermal systems. The loop field, whether installed horizontally in a trench or vertically in a well boring, is completely buried and out of sight. The loop field acts a vehicle, transporting heat to and from the earth.*

In a typical closed-loop system, a U-shaped loop of fusion-welded, small-diameter plastic pipe (high density polyethylene or high strength polybutylene) is placed in a vertical drill hole 150 to 200 feet deep and the hole is filled with clay (Figure 2). A water/antifreeze solution is circulated through the loop(s) and heat is either extracted from or added to this solution depending again on whether heating or cooling is desired. Loops can also be installed that radiate from a single point, forming a cone shape underground. Closed-loop systems have also been developed wherein the loops are placed horizontally in trenches (from 5 to 10 feet deep) or in ponds or lakes; sometimes the loops themselves are coiled, which reduces the surface area required by a horizontal system. Horizontal systems obviate the need for comparatively expensive well drilling, but require a larger surface area for the loop field than do vertical systems.

Direct exchange geothermal systems are a relatively new type of closed-loop system that consists of loops of copper tubing buried horizontally in a trench or pit. The tubing is filled with a refrigerant gas rather than a water/antifreeze solution. This effectively eliminates one step in the heat transfer process, outlined below.

Since the mid 1980's, almost all geothermal systems installed in North Dakota have been of the closed-loop, water/antifreeze variety. One of the advantages of closed-loop systems over open-loop systems is that there is no consumptive use of groundwater. In fact, groundwater need not be present at all, as the heat is stored in and transferred from the earth itself. Closed-loop systems also avoid problems of scaling associated with typically hard, mineralized waters in North Dakota, and problems of disposal of the water once used, whether discharge at the surface or reinjection into the aquifer.

I have seen promotional brochures and reports that indicate open-loop and closed-loop (vertical, horizontal, lake/pond) geothermal systems provide similar levels of performance, but I have not seen technical reports that either support or disprove that statement. The type of system chosen depends on many factors, including the site location, topography, thermal characteristics of the rock and soil, as well as the space to be heated/cooled. A somewhat dated, though still very good report prepared for the U.S. Department of Energy ("Using the Earth to Heat and Cool Homes") reviews the relative advantages of different types of geothermal systems. That report is available from the Office of Intergovernmental Assistance. Although technical in scope and directed toward utilities, industry, and government agencies, "Space Conditioning: The Next Frontier" is another useful report. Subtitled "The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money," this 1993 EPA report (# 430-R-93-004) offers a useful assessment of conventional and heat pump and other advanced technologies.

How Geothermal Systems Work

That the thermal (heat) energy of normal temperature shallow ground (about 43 to 50 degrees Fahrenheit in North Dakota, Figure 3) can be used to heat a home, office building, or even the largest of warehouses, may at first seem paradoxical. After all, aren't basements and cellars, and

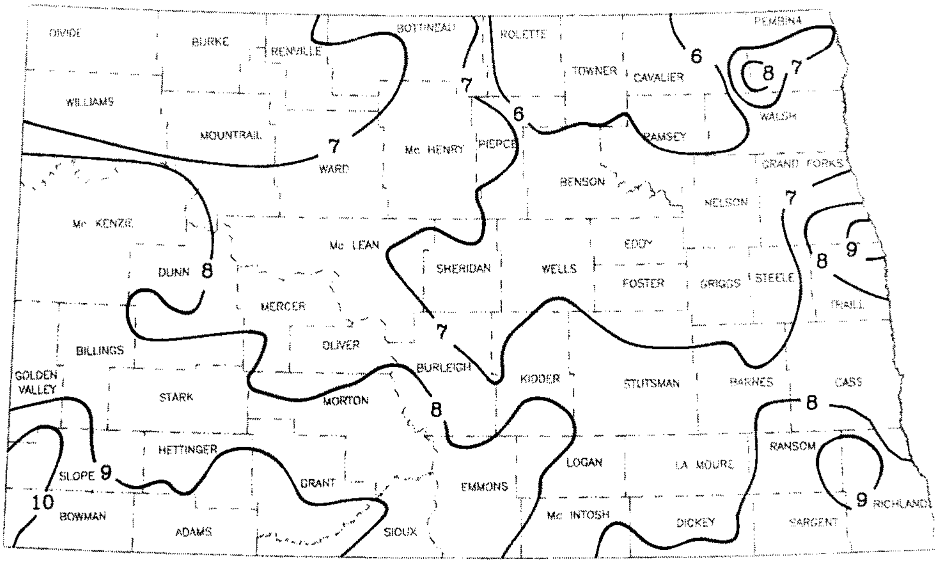

Figure 3. *Map showing expected ground temperatures (degrees Celsius) at a depth of 30 meters (100 feet). 6°C = 42.8°F, 7°C = 44.6°F, 8°C = 46.4°F, 9°C = 48.2°F, 10°C = 50°F. Modified from Harris, K.L., Howell, F.L., Wartman, B.L., and Anderson, S.B., 1982,* An Evaluation of Hydrothermal Resources of North Dakota, Phase III Final Technical Report, *UND Engineering Experiment Station Bulletin No. 82-08-EES-01, p. 22.*

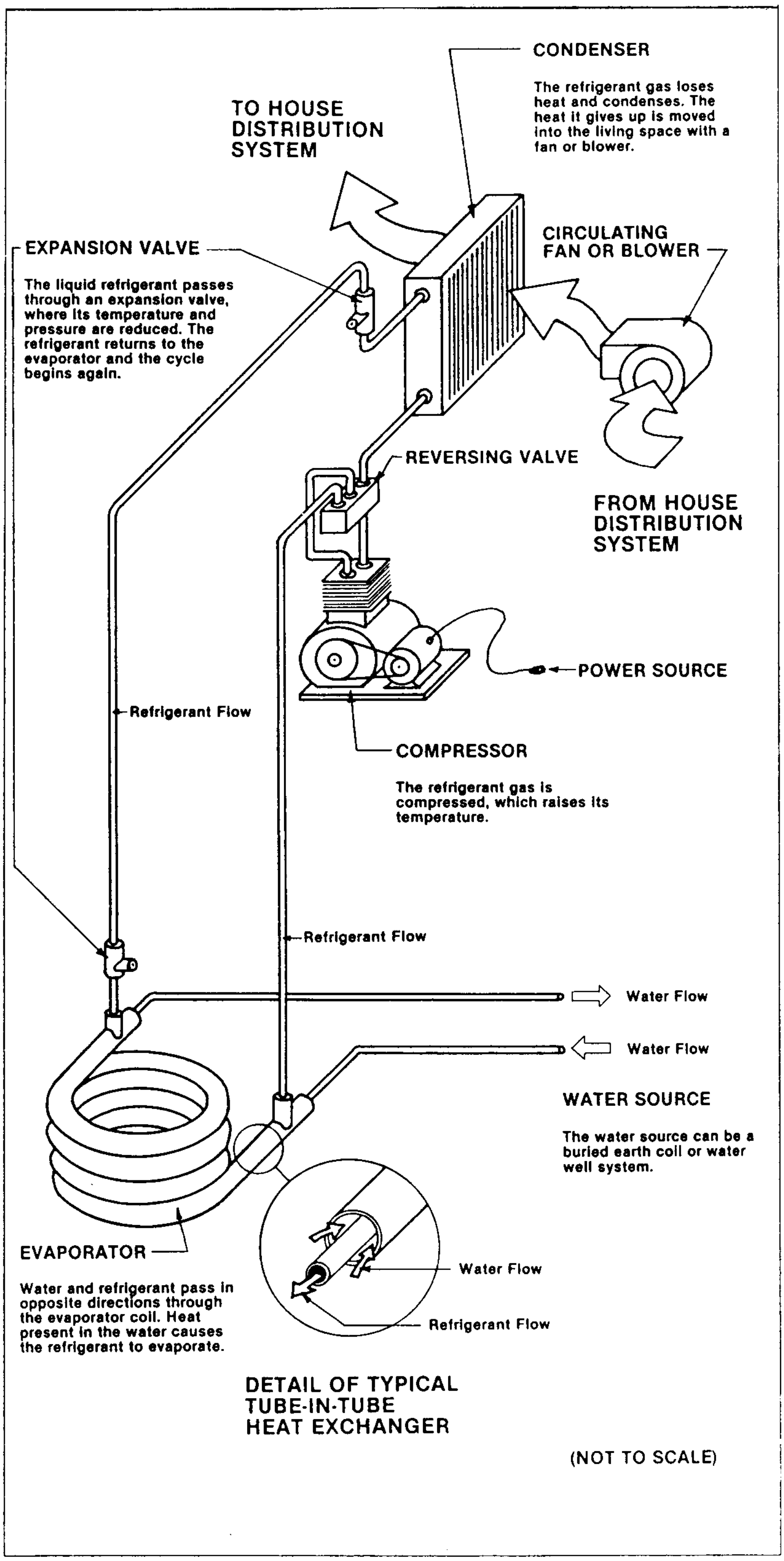

Figure 4. *Typical geothermal heat pump operating in the heating mode. From* Using the Earth to Heat and Cool Homes, *a December, 1983 report available from the Office of Intergovernmental Assistance.*

caves for that matter, always cold? How can something that feels cold to us provide the heat necessary to warm our homes and buildings?

The answer hinges on the fact that refrigerants, like those used in refrigerators, air conditioners, and other heat pumps, have extremely low boiling points. Under the right circumstances, it takes very little heat to make the refrigerant vaporize. The refrigerant gas can then be compressed, which raises its temperature. Heat is then extracted from the compressed, hot gas by a condenser and used to warm the building. The cycle is reversed in the cooling mode, in effect removing heat from a building rather than the earth. The entire process works on the principle that heat flows naturally from warm to colder areas. Figure 4 summarizes the heat exchanger cycle for a closed-loop, water/antifreeze system.

1. In the heating cycle, refrigerant in its condensed (cold liquid) state enters the evaporator (water/antifreeze-to-refrigerant heat exchanger). The water/antifreeze solution gives up heat to the refrigerant; as the water/antifreeze solution leaves the evaporator, it is typically 5^0 to 10^0 F cooler. The refrigerant absorbs heat from the water/antifreeze solution and vaporizes.

2. Gaseous refrigerant enters the compressor where it is compressed into an extremely hot gas.

3. Refrigerant as a hot gas travels to the condenser (air-to-refrigerant heat exchanger). Return air from the house or building is blown across the hot gas in the condenser; the air absorbs heat from the gas and then moves out into the home. The refrigerant, having given up heat to the air, condenses back into a liquid.

4. Condensed refrigerant then moves through the capillary tubes or expansion valve where its pressure and boiling point are lowered.

5. The refrigerant returns to the evaporator and the cycle begins again.

6. The cycle is reversed to operate in the air conditioning mode, wherein the evaporator operates as a condenser and the condenser becomes an evaporator. Heat from the living space is blown across the condenser and the liquid refrigerant evaporates. The compressor then pumps the heated gas to the evaporator where the heat flows from the refrigerant to the cooler water/antifreeze solution; the refrigerant condenses. The water/antifreeze solution is then pumped through the loop field where it gives off heat to the ground. In either mode, a desuperheater (a domestic hot water exchanger) can extract additional heat from the refrigerant to provide all or part of domestic hot water needs.

How "Efficient" are Geothermal Heat Pumps?

Heating systems are evaluated by comparing the amount of energy delivered (i.e., heat) with the amount of energy consumed to deliver that heat. This is known as the Coefficient of Performance or COP. Electric resistance heaters have a COP of 1, which means it takes 1 watt of electricity to deliver the heat equivalent of 1 watt. Air-source heat pumps generally have COPs of about 2; they deliver twice as much energy as they consume. Geothermal heat pumps generally have COPs of 3 to 4. For comparison, the best natural gas furnaces have COPs of 0.9 to 0.95.

The COP is not the same as efficiency. Nothing can work at an efficiency greater than 100%. The First Law of Thermodynamics states that energy cannot be created, only changed from one form to another. (There is no free lunch, at least in the world of energy production.) Efficiency applies to the conversion of one form of energy to another and can never be greater than 100%. But remember, heat pumps do not create or convert energy, they simply transport it from one location to another. If a gasoline tank truck is used to move gasoline from one location to another, could more gasoline be moved than consumed during the trip? I certainly hope so. That is a measure of a system's performance (here the COP), not its efficiency.

In actual use, the COP of heat pumps will vary depending on the temperature of the source. For example, the efficiency of an air-source heat pump in the heating mode declines as the outside temperature drops because there is less heat in the air. Geothermal heat pumps buried horizontally in a shallow trench will be similarly affected, but to a lesser degree (this is why horizontal systems typically require twice as much pipe in a loop field than do vertical systems; below about 20 feet deep, the ground temperature remains essentially constant throughout the year).

A Comparison of Costs

Outlined below is a summary of installation and operating costs for two vertical closed-loop geothermal systems in North Dakota. Although actual costs and savings will vary depending on the system type and design, these examples are representative of the savings to be gained by using geothermal heat pump technology.

I do not have actual figures for a typical residential installation. However, industry specialists indicate that the complete installation cost — including the loop field, heat pump, plumbing, and all costs up to the ductwork — for a top-of-the-line residential geothermal heat pump system may be about $1600 per Ton[1]. A well insulated 3,000 sq.ft. house, which would probably require about a 4 Ton system, would thus cost about $7,000. A natural gas furnace with central air conditioning might cost $4,500 for the same home. This difference in cost is typically recouped in 3 to 5 years because of the lower operating costs of the geothermal heat pump system.

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[1] *Geothermal heat pump systems are normally designed based on the cooling load of a building. Cooling equipment is rated in one of two ways, either by Btu/hr or tons of cooling. A ton of cooling is 12,000 Btu/hr. This definition can be traced back to before the development of mechanical refrigeration, when ice was the principal means of cooling. At 32°F, the ice melted and removed heat from the surrounding area at the rate of 144 Btu/lb. A ton (2,000 lbs) of ice removed 288,000 Btu's of heat. If the ton of 32°F ice completely melted in one day, the hourly rate would be 288,000 divided by 24, or 12,000 Btu/hr. A ton of cooling, therefore, is the equivalent cooling capacity per hour of 1 ton of ice melting at an even pace over a 24 hour period.*

A Medium-size System

Farmers and Merchants Bank of Valley City

This 33 Ton geothermal system came online in February, 1992 when an addition to the bank was completed. The system, which cost about $59,000, consists of 44 loops each 150 feet deep. The addition doubled the size of the building to 6,300 sq.ft., yet heating and cooling costs were cut by 78%. It cost just $1,053 to heat and cool the building in 1993. The system cost about $15,000 more than a conventional heating and cooling system, but that difference in cost is expected to be recovered in about 2.5 years.

A Large System

Wahpeton Middle School

This 220 Ton system was installed in 1988 when the school was built. The loop field covers an area of about 150 x 170 feet and consists of 286 loops each 150 feet deep. There are 69 individual heat pump units throughout the building, allowing teachers to control the temperature within their own classrooms. The building itself covers 57,400 square feet. The system cost about $452,000 (including the backup generator) to install; a natural gas boiler with cooling would have cost almost $700,000. Annual heating and cooling costs are about $16,500, roughly half of what it costs simply to heat a nearby slightly larger high school with natural gas.

What's Out There?

Since 1984 — when North Dakota began regulating geothermal systems used for other than private residential purposes — the NDGS has issued about 70 geothermal permits. In addition, a 1992 North Dakota Department of Health and Consolidated Laboratories survey of Class V injection wells (which include those used in open-loop geothermal systems that reinject water to an aquifer) indicates that at least 25 "non-residential" geothermal systems were installed prior to 1984. Figure 5 shows the distribution of these systems across North Dakota; the clustering of systems reflects the uneven distribution of installers and the fact that this is a comparatively new technology. These systems range in size from several ton units used in small churches and office buildings to the 520 Ton, 688-loop system at the new Fargo Middle School.

Because private residential systems are not now regulated (see below), the number of residential systems in the State is unknown. The 1992 Health Department survey mentioned above identified 89 open-loop residential systems. The installation date is not known for about a third of the systems; the remainder were installed between 1979 and 1985. According to Doug Mork, Member Services Director at Capitol Electric Cooperative Inc. in Bismarck, about 50 closed-loop residential geothermal systems have been installed within the coop's Burleigh County service area alone since 1987. Certainly there are several hundred private residential systems, and perhaps double that, throughout North Dakota.

Geothermal Regulatory Program

Before a geothermal system is installed, a permit must be obtained from the State Geologist; a permit is not required, however, for private residential systems[2]. Review of the geothermal permit, often accompanied by a site inspection, helps to ensure that geothermal systems are properly designed and constructed. Perhaps more importantly, by setting minimum design and material standards, it helps to ensure that geothermal system contractors all "play by the same set of rules." Slightly cheaper (though environmentally irresponsible) practices, such as substituting methanol for approved heat transfer fluids, are not allowed. Currently, the only NDGS-approved fluids for use in closed-loop geothermal systems are propylene glycol, GS4™ (a potassium acetate solution), and calcium chloride. Methyl alcohol or methanol, ethylene glycol (automobile antifreeze), or other potentially toxic antifreeze solutions are not approved for use in commercial systems and are not recommended for private residential systems.

The geothermal regulations, adopted in 1984, are contained in Chapters 38-19 and 43-02-07 of the North Dakota Century and Administrative codes, respectively. Copies of the regulations are available on request. In addition, open-loop geothermal systems may require permits from the North Dakota Department of Health and Consolidated Laboratories and State Water Commission depending on the size and design of the system[3]. The Water Commission regulates groundwater withdrawals in excess of 12.5 acre-feet per year. The Department of

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2 *The 1995 Legislature is considering a bill that would require registration of private residential geothermal systems. As now proposed, a permit for such systems would not be required, but all systems would have to meet minimum material and design specifications.*

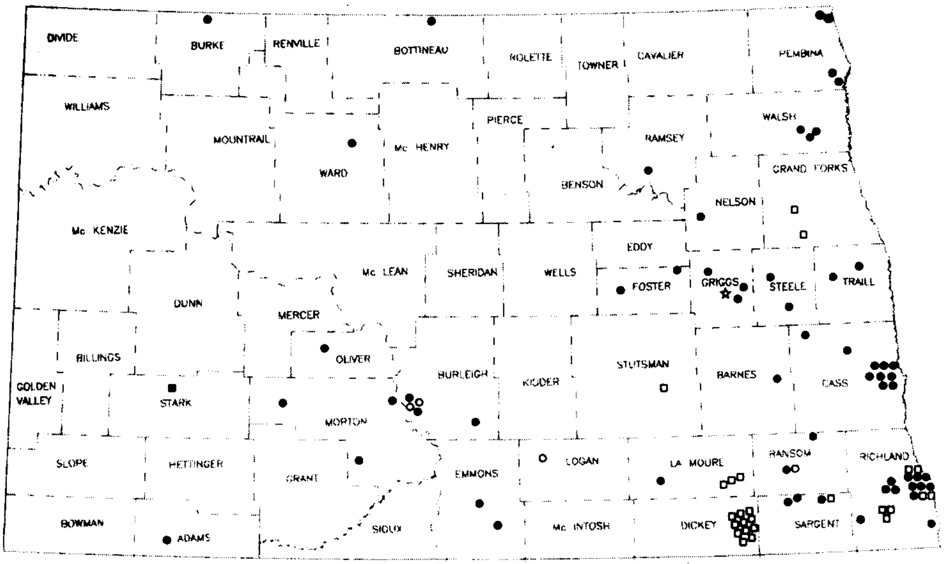

Figure 5. *Location of "commercial" geothermal systems in North Dakota; private residential systems are not shown. Each symbol represents a single geothermal system.*

Health is also responsible for the National Pollutant Discharge Elimination program (NPDES), which is concerned with the pollution — including thermal pollution — of surface waters, and the Underground Injection Control (UIC) program, which safeguards drinking water supplies and regulates underground injection of water and wastes. Generally, open-loop geothermal systems are not considered a threat to water quality, but each must be evaluated on a case-by-case basis.

Summary

Geothermal heat pumps can adapt to residential and commercial buildings all across the country, both in new buildings and as retrofits in existing buildings. Heat pumps are efficient, durable, and easy to operate — they are much like that old refrigerator in the basement that has been running undisturbed for the past 30 or 40 years. While actual savings will vary depending on system type and design, operating expenses of a geothermal system are typically 40% to 70% less than that of conventional systems; payback periods (the time it takes to pay off the difference in installation costs of conventional and geothermal systems) averages 3 to 5 years.

A properly sized geothermal heat pump system does not require the use of supplementary resistance heat. Natural gas backup furnaces or generators are sometimes installed, however, to take advantage of duel fuel rates offered by electric utilities. (For a retrofit, existing furnaces, if they are in good condition, are normally left in place to take advantage of the same rate structure.) At times of peak demand for electricity, a utility can reduce demand by automatically switching duel-fuel-rate customers to backup heating systems. This allows the utility to sell electricity at a higher rate elsewhere, or conversely buy less electricity from another utility at a higher rate during peak demand periods. Duel fuel rates provide the lowest possible energy rates to consumers.

The State of North Dakota offers an individual and corporate state tax credit for geothermal system owners. The credit amounts to 5% of the actual cost of the system (including installation) and may be taken for the first three years.

Still, most people are inherently driven by upfront installation costs, and geothermal heat pump systems are typically 25 to 30% more expensive than conventional heating systems to install (this relationship breaks down with very large commercial systems, where the installation costs (not to mention operating costs) of a geothermal system can be less than that of a large boiler and air conditioning system). Still, with payback periods averaging 3 to 5 years, it is hard to imagine a better investment.

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3 *The EPA has introduced legislation that would prohibit open-loop geothermal systems used for other than private residential purposes.*

For more information about geothermal heat pumps, contact:

* your local electric utility

* your local heat pump installer

* International Ground-Source Heat Pump Association
  Oklahoma State University
  482 Cordell South
  Stillwater, OK 74078
  (405-744-5175)

* North Dakota Office of Intergovernmental Affairs
  Energy Programs
  600 E. Blvd. Ave. 14th floor State Capitol Building
  Bismarck, ND 58505-0170
  (701-328-4137)

For information about North Dakota's Geothermal Regulatory Program, contact Bob Biek at the North Dakota Geological Survey.

NDGS publications and USGS topographic maps are available at our sales office (1022 E. Divide Ave, Bismarck), by telephone (701-328-4109), by FAX (701-328-3682), or by mail (see address below). Cash, money order, or check, payable to the North Dakota Geological Survey, will be accepted. Minimum charge per order is $1.00. Reasonable requests for items for which no price is quoted are sent free of charge. Customers will be invoiced for materials plus shipping costs, if applicable. A free copy of *NDGS List of Publications* will be sent upon request.

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NEW PUBLICATIONS

A Visitor's Guide to the North Dakota Capitol Grounds: Buildings, Monuments, and Stones, 1995, by Robert F. Biek: State Historical Society of North Dakota, 55 p., $3.00. (Available from the NDGS while supplies last, and from the State Historical Society of North Dakota, North Dakota Heritage Center, 612 East Boulevard Avenue, Bismarck, ND 58505-0830, Tel. 701-328-2666.)

This guidebook was written to help visitors learn more about the buildings, statues, and monuments found on the North Dakota capitol grounds, with particular attention paid to the kinds of building stones used, when and how they were formed, and where they were quarried. Stones from Italy, Belgium, Zimbabwe, and throughout the U.S. are found at the capitol grounds; they range in age from the geologically very young Yellowstone Travertine to the 2.0-2.5 billion-year-old Milbank Granite. Many stones contain easily identifiable fossils and all come wrapped in a history steeped in geological and human intrigue.

The guidebook begins with a stop at the capitol itself and follows the path of the paved arboretum trail that winds across the grounds. Photographs of each building or monument accompany the descriptions. The guidebook was a joint project of the NDGS, the State Historical Society of North Dakota, and the Facility Management Division of the Office of Management and Budget.

An Introduction
North Dakota Geological Survey
100 Years of Service
1895-1995

Compiled by Robert F. Biek, November, 1994, 16 p., free on request.

This updated brochure summarizes the wide variety of activities undertaken by, and services available from, the North Dakota Geological Survey.

Coal and Subsurface Mineral Exploration Drill Hole Maps

These maps, by NDGS geologist Ed Murphy and former NDGS cartographer Harlan Jirges, show the locations of electric logs in Geological Survey files from holes drilled for coal exploration, subsurface minerals, oil and gas, and the county bulletin series maps. The maps are available by county and are produced in color at a scale of 1:125,000. The following maps are now available:

County	NDGS Open-File Map No.	Cost
Adams	OF 94-4	$ 3.00
Bowman	OF 94-3	$ 3.00
Dunn	OF 94-2	$ 3.00
Mercer	OF-94-6	$ 3.00
Slope	OF-94-5	$ 3.00

Oliver and McLean Counties are nearing completion. We plan to have maps available for every western county in North Dakota.

The following publications were reviewed in the previous *NDGS Newsletter*. Prices, not then available, are now listed below.

North Dakota Clays - An Historical Review of Clay Utilization in North Dakota, 1995, by Edward C. Murphy: NDGS Miscellaneous Series No. 79, 18 p., $2.00.

Sherwood Subinterval of the Mission Canyon Formation in Central Western North Dakota, 1995, by William A. McClellan: NDGS Report of Investigation No. 99, 11 p., 7 plates, $7.00.

Oil Exploration and Development in the North Dakota Williston Basin: 1992-1993 Update, 1995, by Thomas J. Heck: NDGS Miscellaneous Series No. 80, 23 p., $3.00.