NEWSLETTER
NDGS

Industrial Commission of North Dakota, North Dakota Geological Survey Vol. 20, No. 4, Winter 1993

NDGS geologist Mark Luther using a Global Positioning System (GPS) receiver to locate the geographic center of North Dakota. The geographic center of the state lies in this prairie pothole, about 2.8 miles southwest of McClusky. This area is characterized by hummocky, collapsed glacial topography with numerous lakes and sloughs. See related articles on pages 9 and 10. *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 if recognition is given.

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. 701-224-4109).

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FROM THE STATE GEOLOGIST

by John P. Bluemle

NDGS Centennial
- Reflection and Preparation -

The North Dakota Geological Survey was founded 98 years ago, in 1895. We moved to Bismarck in 1989, North Dakota's centennial year. As we come up on our own centennial year, I'd like to reflect on some of the things the Survey has accomplished over the past century — some of the "milestones of geology" in North Dakota.

I'll note just a few of our past accomplishments, many of which stem from the foresight of my predecessors. The first State Geologist was E. J. Babcock, from 1895 until 1900. He used the first small Survey appropriation (about $1,000), granted in 1899, to publish a summary of his own work, which included information on the State's topography and geology, water resources, clay deposits, lignite deposits, and an optimistic but, as it turned out, quite realistic, discussion of future natural resource possibilities. At the time it was published, Babcock's report was considered to be the best public document ever published in the State, and it created wide public interest.

Arthur Gray Leonard was State Geologist from 1903 until 1932. He was a true scholar, a man considered to be the father of geologic study in North Dakota. Leonard had little or no staff and almost no appropriation during most of his 30-year tenure, but in spite of that he accomplished systematic mapping of the state's mineral resources. Leonard published the first geologic map of North Dakota in 1906. He recognized that the NDGS had a duty 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. During the 1920's and 30's, various get-rich schemes — swindles — kept popping up. Most were related to oil-wells or sometimes gold mines, things the public didn't understand, except that they looked like easy money.

Leonard appreciated the educational role of the Survey and many of his publications were written so that they were understandable to school teachers. He also recognized the practical needs of people like water well drillers for good information on the geologic conditions with which they had to contend.

Along with Leonard, the name of Wilson Laird stands out as the person who made the largest contribution to North Dakota geology during the past century. Laird was 26 years old in 1941 when he became State Geologist, a position he held until 1969. It was due to his efforts that the State Legislature enacted an oil and gas conservation law in 1941; the law designated the State Geologist as enforcer of the regulations. This may not have seemed particularly important at the time, especially in view of the fact that North Dakota had no oil production then, but ten years later, when oil was discovered, it became very important because with a law already in place, regulation was fair and effective. If it had been necessary to enact a law after oil was discovered, competing interests would have made the task much more difficult.

The discovery of oil in 1951 brought about substantial increases in funding and personnel for the NDGS and with these came the Survey's long and continuing involvement with studying the rocks that produce oil and gas. Work by our petroleum geologists on the State's hydrocarbon-bearing rocks today accounts for about half of our work.

It seems to me that Wilson Laird's second major accomplishment was his initiation of a program in the late 1950's to map the geology of the entire state. As a result of the county mapping program, North Dakota became one of the first western states to be mapped in any detail. This 30-year project has only recently been completed. We expect to publish the last county map next year and we have just recently begun a much more detailed "second generation" mapping program.

Beginning in the 1950's, under Wilson Laird, the NDGS grew from a one- or two-person effort to the full-fledged regulatory and research organization it is today. E. A. Noble became State Geologist in 1969, the year the 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. Soon after Lee Gerhard became State Geologist, in 1978, a new and much larger core and sample library was designed and built on the University of North Dakota campus. It remains one of the finest facilities of its kind in the United States, housing cuttings and core from nearly all the wells ever drilled for oil in North Dakota, as well as other valuable samples.

In 1981, responsibility for regulation of exploration and production of oil and gas was transferred from the NDGS to a new Oil and Gas Division of the State Industrial Commission in Bismarck. The Geological Survey remained at the University in Grand Forks until 1989, when we also moved to Bismarck. Since our arrival in Bismarck, and our much closer tie to the State Industrial Commission, we have greatly improved our regulatory function, while continuing our studies of North Dakota geology. Our public service function has also grown. Elsewhere in this issue is an article on the awarding of the Governor's Award for Excellence in Public Service to Dr. John Hoganson, the Survey's paleontologist.

Finally, I'd like to announce a contest, beginning immediately, for an NDGS Centennial Logo that we might use to call attention to the benefits geology and geologists bring to the State. As we near our 100th year, I'd like to hear your ideas for specific "centennial projects" the Survey might undertake or promote. For example, one such project that has been suggested is a new bibliography of all geologic work that has been accomplished in North Dakota to date. Not too exciting, perhaps, but certainly something that would be valuable. It's also been suggested that the Survey hold a symposium — a "birthday party" — to examine the state of geology in North Dakota. Other suggestions include compiling a history of the Survey or perhaps publishing a series of isopach and structure maps, or writing a history of development of various aspects of geology in North Dakota.

NORTH DAKOTA GEOLOGICAL SURVEY

CENTENNIAL LOGO CONTEST

In 1995, the North Dakota Geological Survey will celebrate its 100th anniversary. We are at work on a series of special publications to commorate the event, and will also plan other activities.

In order to commorate this historic occasion, the North Dakota Geological Survey is conducting a logo contest. The logo will be used on promotional material and publications. Rules of the contests are as follows:

Eligibility: All persons are eligible to enter this contest, except members of the judging committee.

Prize: Recognition for your effort!

Logo Entry Deadline: May 2, 1994.

Logo Restrictions: Logo can be up to 3 colors, must fit within a 4" x 4" area, and be designed for possible reduction and reproduction in black and white. The design must be submitted on 8½" x 11" paper, but does not need to be camera ready. All entries will become the property of the North Dakota Geological Survey.

Submit entries to (or for more information, contact):
John P. Bluemle, State Geologist
North Dakota Geological Survey
600 E. Boulevard Avenue
Bismarck, ND 58505-0840
(701) 224-4109

JOHN HOGANSON RECEIVES GOVERNOR'S AWARD

John Hoganson, NDGS paleontologist (at right), recently received the Governor's Award for Excellence in Public Service. The award was presented by Governor Schafer on September 22 during State Employees Recognition Week. Mary Lee, executive secretary for North Dakota's court administrator, also received the award.

The award is given twice a year and recognizes state employees who make outstanding contributions to their jobs and in their communities. Award winners receive a plaque and a traveling trophy.

In addition to his research (see page 17), John is curator of the State Fossil Collection and has responsibility for North Dakota's Fossil Resource Management Program. This year alone, he has helped to create six museum exhibits and has given several dozen public service presentations. Congratulations John!

Photo by Gary Redmann, North Dakota Department of Transportation.

HORIZONTAL DRILLING

by Bill McClellan

Anyone interested in applied research projects related to horizontal drilling in the Williston basin may wish to contact the Saskatchewan Research Council. They work on multi-client projects or individual company contracts from small to large, and may also have some completed projects whose availability is no longer restricted. Their considerable experience in engineering and geology in Saskatchewan reservoirs may be applicable to situations in North Dakota as well. For further information contact the horizontal-well project leader, Brian Kristoff, at (306) 787-9400.

SECOND WILLISTON BASIN HORIZONTAL-WELL WORKSHOP April 25-26, 1994 Minot, North Dakota

The North Dakota Geological Survey and Saskatchewan Energy and Mines will again co-sponsor a Williston basin horizontal-well workshop for those interested in horizontal drilling in North Dakota and Saskatchewan. The format will be expanded to two days to provide more time for papers and discussion of ideas and projects. Informal poster/discussion presentations are invited on geologic or engineering aspects of horizontal wells in the Williston Basin. Contact Bill McClellan at (701-224-4109) or Ken Stalwick at (306-787-2571) for more information.

NDGS HOLDS QUATERNARY MAPPING WORKSHOP

On September 26-28, 1993, the NDGS (with assistance from the Minnesota Geological Survey) sponsored a workshop and fieldtrip for persons interested in mapping Quaternary deposits. The focus of the workshop was a day-long meeting wherein participants discussed automated map production and transfer of digital geologic data, glacial stratigraphy, and mapping of Quaternary deposits. Thirty-two people from North Dakota, Minnesota, South Dakota, and Colorado participated in the workshop.

Quaternary Mapping Workshop participants on a lunch break at the David Thompson Memorial Ball near Verendrye.

THE PETROLEUM EXPLORER

The Petroleum Explorer is a new monthly publication geared to the interests of professionals exploring and developing oil and gas reserves in western Canada and internationally. The premier issue of this 24-page geotechnical periodical appeared in December 1992. Peter Harrington, Senior Editor and Publisher, anticipates readership of several thousand within a couple of years.

Subscription rates for 1994 are $25.68 to Canadian addresses, $36.00 to international addresses, and $96.30 for corporate subscriptions (all prices include GST). All subscriptions are sold on a calendar year (January to December) basis. Subscriptions that begin part way through the year will be sent back issues to the beginning of the year. 1993 back issues, including the premier issue while supplies last, are available for $25.68. Checks should be made payable to The Petroleum Explorer and sent to P.O. Box 84009, Market Mall P.O., Calgary, Alta T3A 5C4. Editors at *The Petroleum Explorer* can be reached at (403) 237-8837.

GEOREF AT NDGS

The NDGS recently subscribed to *GeoRef*, the CD-ROM version of the American Geological Institute's geoscience database. The *GeoRef* database contains over 1.5 million references and selected abstracts to the world's literature in geology. *GeoRef* largely replaces its useful though cumbersome predecessor, *Bibliography and Index of Geology* (still published monthly by the AGI). Literature searches that once took hours are now possible in minutes. Finding additional references through the use of key words and obtaining a printout of references needed are some of the other advantages of this relatively new computerized database.

ERRATUM: The Conoco testimony referred to in "Waulsortian Mounds and Conoco's New Lodgepole Well," (*NDGS Newsletter*, Summer 1993, vol. 20, no. 2, page 9) is based on a seismic structure map by Conoco geophysicist, Ian Gordon. The reference was incorrectly cited as "Anonymous."

DICKINSON LODGEPOLE UPDATE

by Paul Diehl

The Conoco, Inc. Dickinson State #74 Lodgepole discovery well reported on in the Summer 1993 *NDGS Newsletter* ("Waulsortian Mounds and Conoco's New Lodgepole Well", by Randy Burke and Paul Diehl, v. 20, no. 2, p. 6-17) continued to produce at an average rate of 1,486 barrels of oil per day in September. As shown in figure 1, through September 1993 the Dickinson State #74 has produced 285,685 barrels of oil and 164 million cubic feet of natural gas in just 234 days.

Conoco has drilled one stepout and three development tests and is completing the fourth development test. The Conoco Privratsky #77, drilled about 2.4 miles southwest of the discovery well, has been abandoned according to the *Montana Oil Journal*. The three offset tests in order of their drilling are the Kadrmas #75 (nw se sec. 31-140N-96W), the Frenzel #79 (nw ne sec. 31-140N-96W), and the Filipi #76 (sw ne sec. 32-140N-96W). The Dickinson State A-83 in the nw nw of section 5-139N-96W, approximately 0.6 miles south of the discovery well, had reached total depth in mid-November. Although test results and data are still confidential, industry publications indicate that the Kadrmas #75 and the Frenzel #79 have been completed as Lodgepole producers, but that the Filipi #76 was unsuccessful in finding Lodgepole production. Published production figures show the Kadrmas #75 has produced 38,354 barrels of oil in 29 days through September 1993. Tests and undrilled permitted locations are shown in figure 2. Table 1 shows the dates on which confidential information and logs from each of the tests are to be available to the public.

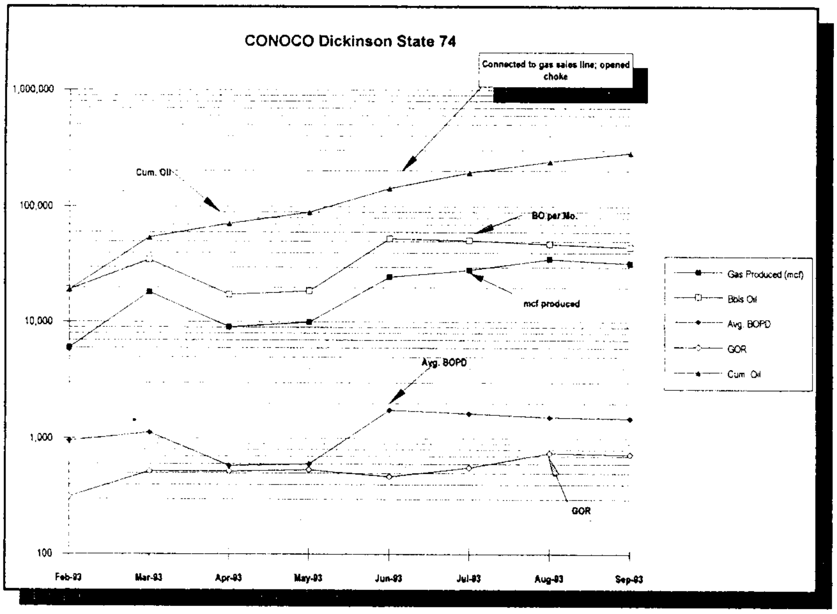


Figure 1. Production record for the Conoco, Inc. Dickinson State #74 Lodgepole discovery well.

TABLE 1

Release Dates of Confidential Data		
Test Name	**File No.**	**Release Date**
Dickinson State #74	13447	released
Privratsky #77	13531	11/30/93
Kadrmas #75	13514	1/19/94
Frenzel #79	13554	2/21/94
Filipi #76	13513	3/28/94
Dickinson State A-83	13598	4/20/94

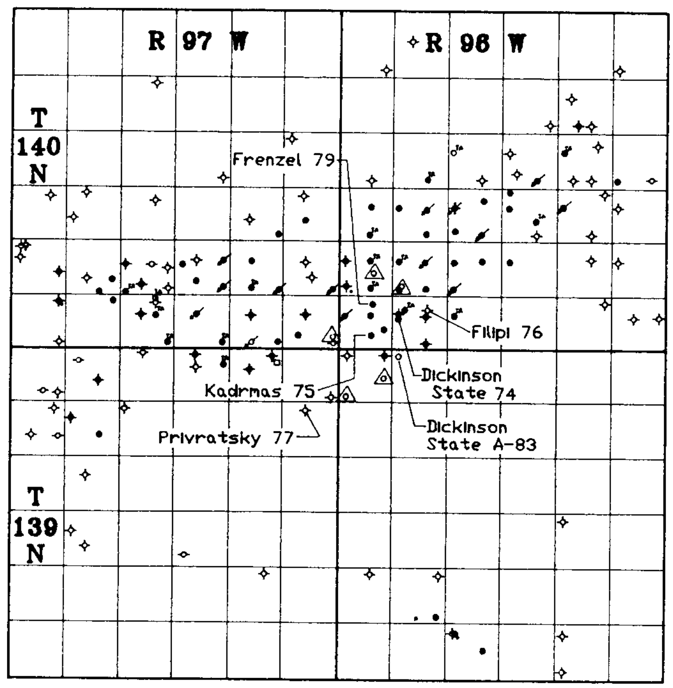


Figure 2. Conoco's Lodgepole development.
Conoco permitted location
• oil well
dry hole

TWO MAJOR COLLECTIONS DONATED TO THE STATE FOSSIL and STATE ROCK, MINERAL, AND GEMSTONE COLLECTIONS

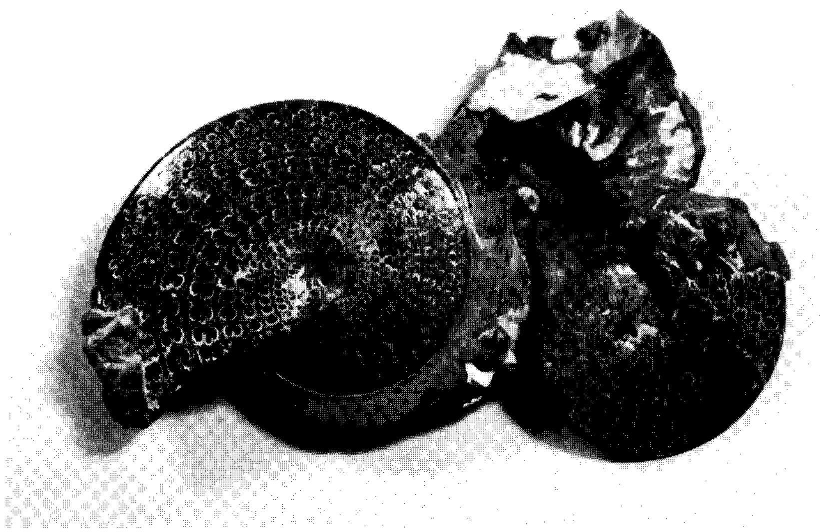
by John Hoganson

This year two collections of fossils, rocks, minerals, gemstones, and lapidary pieces have been donated to the Survey to be curated into the State Fossil and State Rock, Mineral, and Gemstone Collections housed at the State Museum--Heritage Center. Specimens from these collections, the Melvin "Mel" Anderson Collection and Blossomae Campbell Collection, will be exhibited at the Heritage Center soon.

Blossomae Campbell at her and Earle's rock, mineral, and fossil "museum" at their home in Bismarck. *Photo by Mike McCleary, Bismarck Tribune.*

The Blossomae Campbell Collection

The Blossomae Campbell Collection consists of more than 3,500 cataloged specimens of minerals, rocks, and fossils collected over the past 20 years. Blossomae's main interest was in minerals and the collection contains specimens from around the world. Her favorite mineral was calcite and her exhibits of this and other minerals brought many awards at gem and mineral shows around the country. Other specimens in her collection include several fluorescent minerals, many different types of quartz, many unusual rock and mineral types from North Dakota, and a piece of black marble from North Dakota's first capital building that burned many years ago. Blossomae was also fond of ammonites (fossil shells of marine animals related to the living *Nautilus*) and had several dozen exquisite specimens in her collection, primarily from the Fox Hills Formation. Beautiful specimens of North Dakota's state fossil, *Teredo*-bored petrified wood, are also in the collection. Many of the fossils from Blossomae's collection will be included in the "Corridor of Time" exhibit currently being planned at the Heritage Center.



Ammonites (*Sphenodiscus lenticularis*) from the Fox Hills Formation (Blossomae Campbell Collection).

Minerals and rocks from the Blossomae Campbell Collection were donated to the Survey by her husband Earle, the fossils by her grandson Johnathan Campbell. Her passing, on October 3, 1993, saddened us all who knew Blossomae as a vibrant, friendly, and knowledgeable person. Earle and Johnathan believe that Blossomae would have wanted her collection to remain intact and decided to donate it to the Survey for safe keeping and display.

Blossomae was born in Buhler, Kansas, on April, 29, 1920. Earl and Blossomae lived in Tennessee after their marriage on December 31, 1942 where Earl was stationed in the Navy. In 1960 they moved to Moorhead, Minnesota where Blossomae was administrative assistant to the athletic director at Concordia College. They moved to Bismarck in 1969. Blossomae worked for the Workers Compensation Department and Health and Human Services Department until her retirement in 1986.

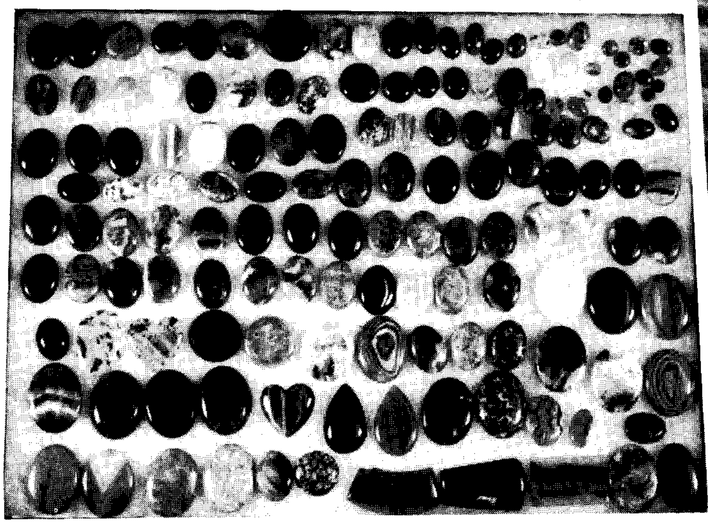
Blossomae was an active promoter of rock, mineral, and fossil clubs in the Bismarck-Mandan area. She was a member of the North Dakota Paleontological Society and Central Dakota Gem and Mineral Society and was scholarship chairperson for the Rocky Mountain Federation of Mineralogical Societies. Blossomae was also editor of the informative and award-winning bulletin of the North Dakota Paleontological Society, *Paleodiscovery*.

The Blossomae Campbell Collection has been on display in the basement of Earle and Blossomae's house in Bismarck for many years. Over the years, the Campbell's hosted countless tours of the collection for school children, university classes and other interested groups. I am sure that exhibits of this collection will draw considerable interest at the Heritage Center. Thanks Blossomae, Earle, and Johnathan for sharing this extraordinary collection with the citizens of the state.

The Melvin "Mel" Anderson Collection

The Mel Anderson Collection consists of several hundred specimens of rocks, minerals, fossils, and lapidary pieces. Many of the rock and fossil specimens, including some rare, large, Paleocene conifer cones, were collected by Mel from sites in North Dakota. A complete Eocene fish fossil is part of the collection. Mel's primary interest, however, has been in lapidary, particularly making cabochons ("cabs" are precious stones cut in convex shapes, polished but not faceted, that are often made into jewelry) from rocks and minerals from around

Mel Anderson working on a rib of the Highgate Mastodon at the Survey's paleontology laboratory at the Heritage Center.



Part of the cabochon collection made by Mel Anderson and donated to the State Rock, Mineral, and Gemstone Collection.

the world. The collection includes hundreds of beautiful pieces made by Mel. Mel has won many awards at local and national gem and mineral shows for his lapidary art work.

Mel is from Arnegard, North Dakota. He and his wife Viola have lived in Bismarck since 1958. It was in 1958 that Mel starting working for the Federal Highway Administration. He retired from the Highway Administration in 1974. It was after his retirement that Mel became interested in lapidary and "rockhounding" and began operating Andy's Gem Shop out of his home. Mel has been an active member of the Central Dakota Gem and Mineral Society since 1976 and was state representative to the Rocky Mountain Federation of Mineralogical Societies for several years. He also served as Treasurer for the Central Dakota Gem and Mineral Society and Rocky Mountain Federation of Mineralogical Societies.

In 1985, Mel became a volunteer at the North Dakota Heritage Center and has contributed hundreds of hours of his time to various projects. Mel was one of our first volunteers in the Survey's paleontology laboratory at the Heritage Center and spent many hours on the restoration of the Highgate Mastodon. He worked with us until he had to resign because of health reasons. Thanks Mel for your help with the mastodon restoration and the donation of your outstanding collection to the Survey. Both will be enjoyed for a long time by visitors of the museum.

NDGS GEOLOGISTS ATTEND FIELD CONFERENCE

Last summer, NDGS geologists Randy Burke and Paul Diehl wrote about the Conoco Inc., Dickinson State #74 Lodgepole discovery well and the idea that production there could be coming from a type of reef structure known as a Waulsortian mound. The article, "Waulsortian Mounds and Conoco's New Lodgepole Well," stirred widespread interest in the oil industry, as evidenced by the fact that we had well over one hundred requests for additional copies of the *NDGS Newsletter* in which it appeared. That issue is now out of stock, but photocopies are available.

The article also lead to invited talks by Randy Burke about the Conoco well and the characteristics of Waulsortian mounds. One of the talks coincided with the annual Montana Geological Society field conference, which both Randy and Paul attended. A major part of that conference dealt with the Tyler Formation, an important petroleum producing sequence of rocks in western North Dakota. After the conference, Randy and Paul spent a day examining Waulsortian mound outcrops in Swimming Woman Canyon. Studying these exposures in the field offered an invaluable opportunity to observe features that cannot be seen in well cores and that will be useful in their petroleum resource studies.

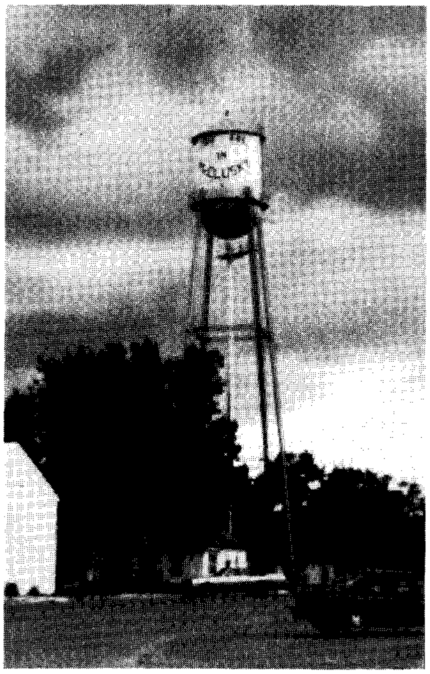
Randy also took annual and unpaid leave to prepare and present a paper at an international colloquium and forum on Global Aspects of Reefs. The paper he presented was about structural controls of modern reef development, a characteristic important to predicting the location of Waulsortian mounds.

NDGS geologists Paul Diehl (center) and Randy Burke (right) at outcrops considered to be the Tyler Fm. type section, Fergus County, Montana.

THE CENTER OF NORTH DAKOTA

by Bob Biek

Where would you be if you were at the center of North Dakota? If you said the Town of McClusky, you would be close. Actually, the geographic center of North Dakota lies about 2.8 miles southwest of McClusky, in a prairie pothole (in Township 146 north, Range 77 west, Section 22). The coordinates of the geographic center of North Dakota are longitude 100^0 28' 07.896" west and latitude 47^0 26' 46.824" north.

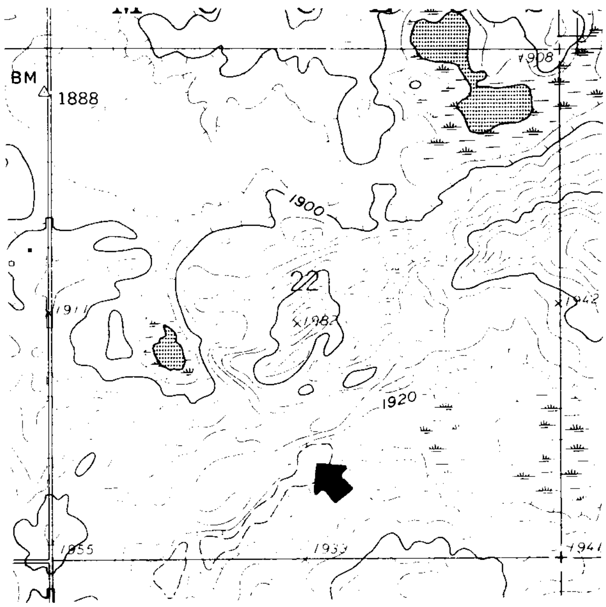


It is a simple matter to determine the exact center of a square, rectangle, or other regular geometric shape. It is less obvious how to determine the center of an irregular shape such as the State of North Dakota, with its ragged eastern border.

To locate the center, a digital outline of the state was retrieved from the survey's Geographic Information System (GIS). A computer program then calculated the longitude and latitude of the geographic center of North Dakota by giving a weighted value to all parts of the state. NDGS geologist Mark Luther later located the center of the state by using a Magellan GPS NAV 5000 PRO receiver (see cover photo).

McClusky residents have long known that their town was the closest to the geographic center of the state, and a sign proclaims that fact. The location of the exact center has been somewhat controversial, however, with some people in the surrounding countryside believing the unique spot lies on their property.

This area is characterized by hummocky, collapsed glacial topography. Such hilly areas are characterized by lakes and sloughs - "prairie potholes" - of all sizes. The potholes occur in depressions between hills (hummocks) that formed when highly fluid till slumped and slid into place as the ice stagnated and melted. Still others occur in depressions known as kettles. Kettles form when buried or partly buried blocks of stagnant glacial ice melt, leaving behind a hole or depression once occupied by the ice.



Geographic center of North Dakota, Section 22, T146N R77W.

Global Positioning Systems (GPS)

by Mark Luther

How useful would it be to be able to take a small, battery operated, radio wave receiver and calculator (about the size of a 1970's vintage CB radio) into the field, and in a matter of minutes determine your position and elevation on the earth's surface with accuracies of greater than 1 centimeter (0.4 inches)? Extremely useful! Quickly determining exactly where you currently are, or being able to go to an exact location on the surface of the earth has become so important that the United States and other countries have spent 10's of billions of dollars to develop and implement such a system. This system has already been used for its primary purpose, military use, and has been credited with greatly aiding in our quick victory over Iraq during "Operation Desert Storm". This system is also increasingly being used by surveyors, map makers, natural resource managers, and nearly everyone involved with collecting data about outdoor features with locatable positions (spatial data). The system developed by the former Soviet Union is called GLONASS. The system developed by the United States is called the Global Positioning System (GPS).

Components of the GPS

Before going into how it works, lets first talk about the various component pieces of the system. The Global Positioning System (GPS) is an earth-surface positioning system that utilizes a constellation of 24 earth-orbiting satellites deployed and maintained by the Department of Defense (DOD). These satellites each orbit the earth every 12 hours at an altitude of about 11,000 miles. The 24 satellites are arrayed in 6 orbital planes inclined 55 degrees to the equator. An accurate, operational GPS complex requires three major elements: the satellite ground-control segment, the satellite segment, and the ground-receiver/user segment. The first two elements are controlled by the DOD, the third, by users of the system.

Ground Control Segment

The satellite ground-control segment consists of five monitoring stations (Colorado Springs, Ascension Island, Diego Garcia, Hawaii, and Kwajalein Island). Colorado Springs serves as the master control station. The DOD monitoring stations track all GPS signals emitted by the satellites to evaluate their orbital positions and the accuracy of their atomic clocks. If needed, the control stations can reposition the satellites or adjust their clocks. The monitoring stations also transmit ephemerides (predictions of satellite positions related to times) and status of satellite health, which are then transmitted by the satellites back to earth for use by ground receivers.

Satellite Segment

The satellite segment consists of the 24 NAVSTAR earth-orbiting satellites. The current full constellation of 24 satellites provides 24-hour-a-day, 3-D position coverage worldwide. The full constellation was only realized this year (1993). Prior to 1993, the partial constellation provided a variable number of hours of 3-D coverage based on the number of "visible" satellites. The satellites are powered by a combination of solar cells and batteries, and transmit their signals over two, wide radio frequency bands. In addition to ephemeris data, the satellites transmit a signal that includes very precise information about the timing of the signal transmission. The timing is controlled by an on-board atomic clock that measures time with nanosecond (0.000000001 second) accuracy.

Ground-Receiver/User Segment

The ground-receiver/user segment consists of all GPS receivers and associated software and storage devices. This may include GPS receivers mounted on aircraft and vehicles, as well as stationary or manually transported receivers. Although there are a great variety of receiver types with varying degrees of accuracy and storage capacity, there is a basic design common to all. The basic design consists of an antenna, a signal amplifier, a radio signal microprocessor, a keypad for controlling the receiver, a display screen, a data storage device, and a power supply. Differences in the prices and capabilities of receivers are primarily based on the number of satellites that they can continuously record data from, the amount of storage, and the amount and type of data that the receiver can collect and process from each satellite.

How GPS Works

Although GPS requires some of the most advanced technology currently available, it is really based on a couple of very simple, and very old principles. The first basic equation is the velocity X travel time = distance equation. An example would be the question:

"If a train goes 70 miles per hour for 4 hours, how far has it gone?" The answer is a simple calculation of velocity (70 mph) times travel time (4 hours) equals distance (280 miles). Determining the distance between a satellite orbiting the earth, and a GPS receiver on the ground is based on the same principles; i.e., knowing the velocity of the radio signal (186,000 miles per second) times the amount of time it took the signal to travel from the satellite to the GPS receiver (usually around 1/10th of a second or less) equals the distance between the two points.

Determining how long it takes for the radio signal to reach the GPS receiver is the problem. Fortunately, the problem was solved by the development of a unique, binary code that could be generated by both the satellite and the GPS receiver in a synchronized manner (at exactly the same time). Measuring the time difference between generation of the code by the GPS receiver and its receiving the <u>same</u> code from the satellite (Figure 1) is a measure of the time that the radio signal takes to travel from the satellite to the ground. Knowing the precise velocity of the radio signal and the amount of time required to travel from the satellite to the GPS receiver allows the accurate calculation of distance between the two points.

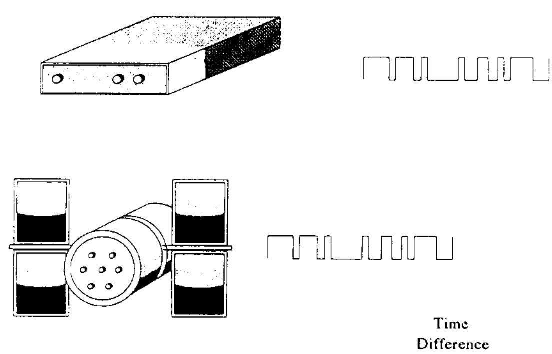


Figure 1

The second principle required to determine ones position on earth using GPS technology is the principle of triangulation. Triangulation is the methodology employed by surveyors and nearly everyone needing to determine the location of an unknown point on a map. It works by comparing the position (angle, distance, or both) of the unknown location to the position of known points (a minimum of 2 points for 2-D positions, 3 points for 3-D). In a traditional use of triangulation the instrument may be a theodolite or compass, and the known point may be an object/point such as a benchmark, building, mountain, or other object shown on a map or for which the location is known.

Because of their stable orbits, satellites are the known points in a GPS survey, and the GPS receiver is the unknown point. Since the GPS receiver can accurately determine the distance between itself and the orbiting satellites, it can use those distances (in practice 3 distances for 2-D, 4 distances for 3-D) to determine its position. This works because there is only one point (a unique and precise location on earth) where the distances measured from the satellites can intersect (Figure 2). That location of intersection would be the location of the GPS receiver antenna.

Locations determined by GPS are usually based on the World Geodetic System of 1984 (WGS 84) map datum using the Latitude-Longitude coordinate system, and elevations calculated as height in meters above the WGS 84 ellipsoid (HAE). Most receivers are then able to convert those positions into more commonly used formats such as elevations measured in feet above mean sea level, and position based on the North American Datum of 1927 (NAD 27) or NAD 83.

Selective Availability

As stated previously, the DOD controls the operation of the NAVSTAR satellites and has the option of intentionally degrading the signals transmitted from them. This mode of degraded operation is called Selective Availability (S/A). The DOD wanted this option because it felt that accurate determination of locations was a critical component of military success, and it wanted the option to deny the use of this technology to potential enemies. Since the end of Operation Desert Storm, the DOD has exercised its option to implement S/A. As a result, the coordinates (location) currently given by a single GPS receiver may be off by several hundred feet. This is done by introducing slight timing errors or false ephemeris data into the satellite signal. Fortunately, there is a method to get-around S/A, although it takes additional time and equipment; this method is called differential correction.

Differential Correction

Although it requires a computer and the appropriate software, differential correction is a relatively straightforward concept. Differential correction requires the use of a minimum of two GPS receivers; a stationary "base station", and the mobile or field unit. It works this

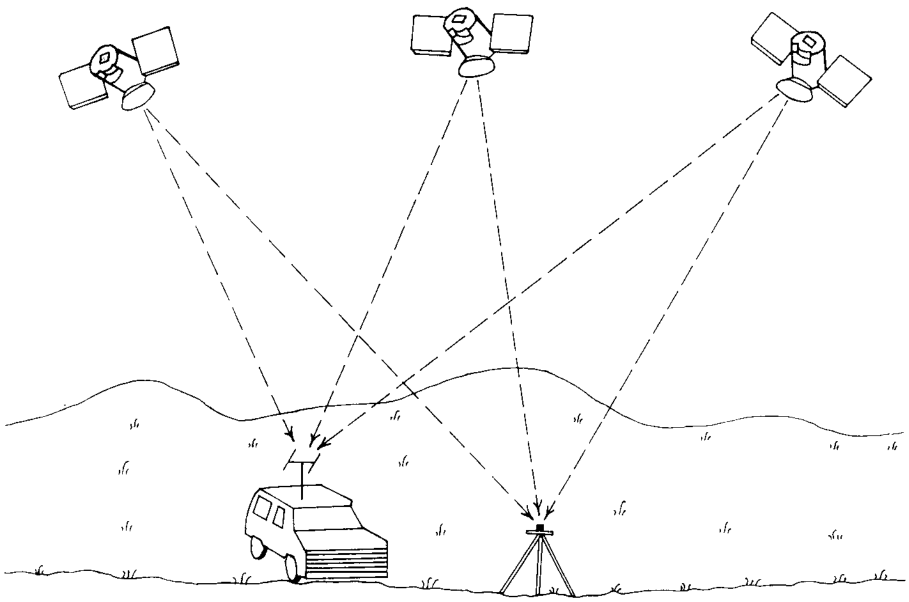


Figure 2

way. First, the base-station receiver is set up on a point with previously established, known coordinates, and begins collecting satellite data. The second receiver, or mobile receiver, can at the same time collect satellite-derived coordinate data at locations with unknown coordinates. By collecting data from the same satellites at the same time at both the known and unknown locations, the large error produced by S/A (and the small error that can be caused by atmospheric conditions) can be removed from the data collected at the known point, and subsequently subtracted from the unknown point, thus giving the correct coordinates of the unknown location. The big drawback to this method is that you don't find out the exact coordinates of your unknown location until the data collected there has been compared to that collected at the known or base-station location; in other words, it's not "real time" coordinate determination. Fortunately (once again), there is a method of acquiring "real time" GPS-derived coordinates, but this method requires additional equipment and investment (of course).

Real-time differential correction can be achieved by broadcasting the signal collected at a base station, via radio, to a mobile receiver that has the capability of receiving the signal and processing the correction on the spot. For many GPS uses, such as trying to travel to an exact location, real-time differential corrections are the only option - given the fact that S/A is implemented. Without real-time differential, you can only go to an approximate location, and later determine how close you were to the spot that you wanted to reach. Real-time differential requires several additional components beyond a basic GPS receiver, including: a base station capable of generating the proper signal; a radio broadcasting system and availability of the proper radio-wave band; and mobile GPS receivers capable of receiving the correctional signal and processing it.

That's a basic overview of GPS technology. As GPS receivers continue to become smaller, less expensive, more accurate, and more user friendly, they will eventually become as commonplace as cellular phones. The multitude of uses that can take advantage of GPS technology are too numerous to mention here, but already a monthly publication, *GPS World*, is available that presents several different real-world applications every month. These applications run the gamut from engineering applications, to mapping natural resources, to vehicle tracking, to in-car navigational systems to name just a few. GPS technology will soon be used to enable aircraft to make absolutely blind - no visibility - precision landings.

Future uses of GPS (along with Geographic Information Systems - GIS) seem almost limitless. These technologies will be used for emergency vehicle routing and tracking, and could become as common a tool to engineers as a theodolite is currently. For regulatory agencies there are also many potential uses. Imagine being able to place a GPS receiver/data logger on an interstate truck. One could obtain an exact record of where that truck went, where it stopped, how fast it was going (such as on roads with frost-limits), etc. This kind of information could potentially help regulatory agencies prevent 10's of thousands of dollars of damage yearly to North Dakota's road system.

GPS is a new and very useful technology. As with many technologies whose primary purpose was military, the civilian use of GPS will almost certainly far outweigh its military uses.

(A discussion of GPS in North Dakota can be found in the Fall 1993 *NDGS Newsletter*. An update of GPS activities in North Dakota will follow in the Spring 1994 *NDGS Newsletter*).

FLOODING IN NORTH DAKOTA IN 1994?

by John Bluemle

Many parts of North Dakota experienced their wettest-ever summer in 1993 and, as a result, flooding was common throughout the state. A total of 39 counties were declared disaster areas because of the heavy summer rainfall (Figure 1). Here in Bismarck and Mandan, where we had about 13 inches of rain in July alone (more than twice the average monthly July precipitation), nearly everyone has stories of flood damage or, at the least, seepage problems caused by the high water table.

Places like Glen Ullin, Williston, Bismarck and many other communities had flash floods. The Red River Valley also experienced flooding, and although crests along the Red River were not excessive, crop damage was extensive in that part of the state.

In recent weeks, we have heard considerable speculation about the potential for severe flooding next spring. We are entering the winter with the ground nearly saturated and, although this is certainly an important factor in contributing to a potential flood, it's not the only thing that matters in determining whether the state will have severe spring flooding.

My purpose in this article is simply to comment on some of the factors that affect flooding, above and beyond the obvious one of "too much" rain or snow — it's rarely that simple. Flooding in North Dakota is the result of a number of factors. The most important factors can be divided into two groups: "constant" and "variable" factors.

"Constant" Factors That Affect Flooding

Among the "constant" factors are the stream gradient. This is an especially important consideration in the Red River Valley where a gentle gradient, less than 6 inches per mile downstream from Grand Forks, results in low stream flow velocities, causing the area to drain slowly, and thereby increasing the likelihood of prolonged flooding. Obstructions, such as bridge foundations, dams and dikes restrict the flow of water by constricting the channel. They also greatly increase the likelihood of ice jams. Although dikes do, in many cases, prevent floodwaters from inundating lowlands along a river, they also tend to restrict the river to a narrow, artificial channel. The net result is a slight increase in the height of the river just upstream from the dikes as the river is forced through a relatively narrow neck in the channel during floods.

Artificial drainage ditches facilitate draining of valuable farmland, but they also result in faster and more complete transfer of rainfall and snow melt to the main stream or river. Water that was once stored on flatlands bordering the river can pour into the river quickly during spring thaws. Similarly, drained wetlands, which were once available to hold back water, can release water quickly, thereby contributing to the flooding problem.

The road system, in both rural and urban areas, plays an important role in determining the manner in which runoff moves. In many places where culverts are too small to handle a large flow, water becomes dammed against the roads. Water then pours over the roads, stripping gravel off the road surface, or even washing out roads and bridges. The expansion of urban areas has resulted in a decrease in the area available for infiltration (seepage into the ground), and the streets and sewers

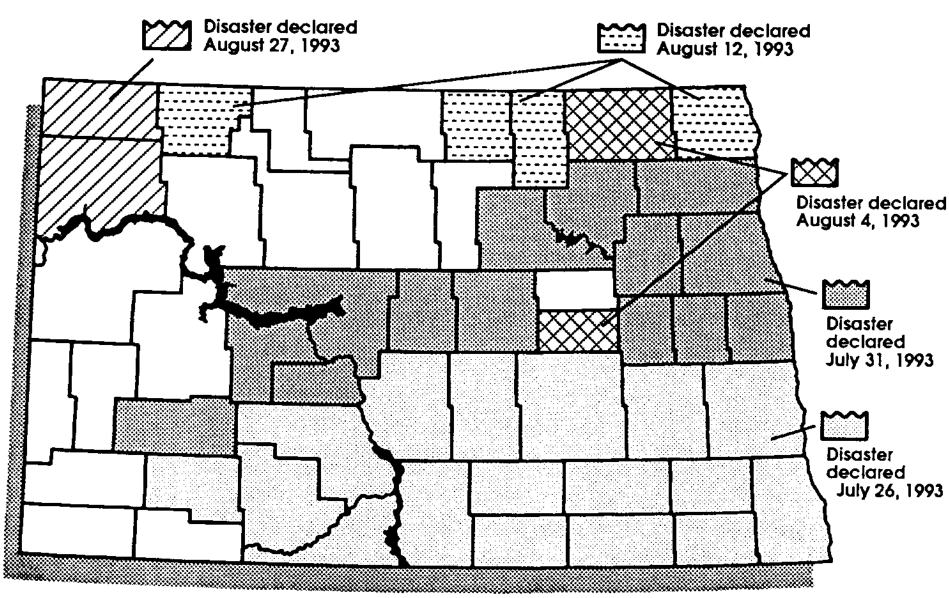


Figure 1. Due to heavy rainfall, a total of 39 counties in North Dakota were declared disaster areas in the summer of 1993. From *The Oxbow* v. 13, no. 9, September 1993.

have increased the speed with which an area can drain. The street I live on in Bismarck acted as a conduit for three "flash floods" during June and July, since the street system north of my neighborhood, a hilly area, directed a disproportionately large amount of the runoff. The runoff from the neighborhood north of my home is supposed to be carried by a storm sewer beneath the street; instead the water in the sewer blew off the manhole covers and lifted the pavement, with the excess water flowing through the street as a "flash flood."

"Variable" Factors That Affect Flooding

I've just noted a few of the "constant" factors, things that remain essentially the same from year to year (although we do, obviously, continue to make permanent changes in these factors — new roads, more paved shopping centers, more wetlands drained, more dikes, etc.). It is the interplay of climatological — "variable" — factors from year to year that largely determine the magnitude of individual floods. Flooding can occur at any time of year that temperatures are generally above freezing. In most of North Dakota, local flooding is most frequently the result of heavy summer showers, as it was this year. In the eastern part of the state, in the Red River Valley, most of the serious floods occur in early spring, the result of the sudden melting of snow and ice that accumulated during the winter.

Several climatological factors affect spring flooding. These include snow accumulation. In our northern climate, snow can accumulate in considerable amounts over the entire state, with essentially no melting for several months. As a result, much of the snow and ice is retained until spring, when it is released more or less suddenly when melting finally occurs. The effect is as if the precipitation for several months fell within a few days time. The magnitude of flooding depends on factors such as the amount of moisture in the snow pack, how fast it is released by melting, how much moisture is added by precipitation during the melt, whether the weather is cloudy, windy, etc. during the melt, and how much water can be absorbed by the ground (depending upon whether the ground is frozen, saturated, etc.).

The history of flooding in the Red River Valley shows that nearly all serious spring floods were preceded by unusually heavy winter snowfall or late spring precipitation or both. Thaw rate is also important. Following a winter of unusually heavy snowfall, the factor that is then most important in determining whether or not a large flood will occur is the rate at which the snow melts. The shorter the melting period, the greater the flow of the rivers must be to carry meltwater away. Cool days with temperatures in the low 30s and night temperatures below freezing allow for slow release of the meltwater. However, an unusually cold or late spring with temperatures remaining below freezing is likely to be followed by a sudden warming trend that causes a rapid release of moisture. Floods occurring after April 15 in the Red River Valley, for example, are likely to be more severe than are earlier floods.

The amount and kind of precipitation that falls during the thawing period is also important. Any precipitation, even snow, increases the quantity of water that must be drained by the rivers and streams. Moreover, a warm rain during the thawing period results in much faster melting of snow and ice on the ground than does warm air. Also, damp, cloudy weather during the thaw inhibits evaporation and contributes to increased runoff.

The condition of the soil can be an important factor. As I noted already, there has been considerable speculation about the fact that soil moisture is much higher this fall than during the past several years. If the soil is saturated with water when it freezes, it cannot soak up much additional moisture during the spring thaw. Thus, a wet summer and fall may contribute to spring flooding by increasing the percentage of early spring moisture that must be carried by the rivers, since less can soak into the ground.

Like saturated ground, frozen soil is unable to soak up moisture, increasing the percentage of runoff to rivers. The colder the winter, the greater the depth of frost penetration into the soil, the slower the ground will thaw in the spring, and the greater the amount of runoff available to cause flooding. And of course the coldness of the winter also affects the amount of snow remaining when the spring thaw arrives (on the other hand, a heavy early snow cover prevents deep frost penetration — there are trade-offs).

Along some rivers and streams, the thickness of river ice may be a factor in local flooding. An unusually cold winter, especially if early winter snowfall is light, results in a greater-than-average thickness of ice on the rivers. The thicker the ice, the longer it will remain on the river in the spring. Until the ice is cleared from the river, flow of floodwaters is impeded and the threat of ice-jamming remains. In some situations, the ice on one river goes out before that on another, causing ice jams near the confluence. For example, the ice on the Yellowstone River may go out before that on the Missouri, resulting in damming upstream from the confluence area.

Generally, then, conditions that can lead to serious flood-potential include: 1) a wet prior summer and fall, 2) an unusually cold winter, 3) heavy winter snow accumulation, 4) an unusually late, cool spring followed by a sudden warming trend, and 5) widespread, heavy precipitation (especially warm rain) during the thawing period. No one of these factors alone can cause a large flood. It is the interplay of several of them that determines just how large each spring flood will be.

Types of Floods that Occur in North Dakota

Two, or possibly three kinds of floods occur in North Dakota. Over much of the western part of the state, where the land is hilly with deep ravines, flash floods are most common, the result of heavy local summer thunderstorms. During a typical North Dakota flash flood, a heavy shower that may be confined to a small drainage basin results in very rapid runoff down a small stream. Flash floods don't usually affect very large areas, but they can be spectacular, as the floods in Glen Ullin or on Stony Creek in Williston this past summer illustrate.

Another kind of flood is a "sheet flood," really just another kind of flash flood, except that sheets of water flow over flat land, commonly as a result of extremely rapid melting of snow in an area where drainage is very poorly developed. In North Dakota, most such areas are in the Red River Valley. The 1979 flood in the English Coulee Basin in the Grand Forks area was an example of such a sheet flood.

The more classical flood, the kind much of the central U.S. suffered this summer, are those that take days or weeks to crest. People know the water is coming and have time to prepare for it. In fact, it's been argued that much of the "cost" of such a flood is in the preparation; if the floodplains were not developed as, in theory, they should not be, little preparation for a large river flood would be necessary and damage (except to crops on the floodplain) would be minimal. So much for theory!

The 1979 Grand Forks Flood

In 1980, following the worst flood along the Red River since 1897, the NDGS issued a publication dealing with the flooding problems in the Grand Forks area and the Red River Valley (Figure 2). The publication included descriptions of past floods along the Red River, as well as a discussion of the various factors that are most important in determining flooding. That area hasn't had a severe flood since 1979, but an analysis of the problem might be useful now, especially in view of recent speculation about flooding next spring.

To provide a "case history" of a classic Red River Valley flood, I'll comment on the conditions that led to the 1979 flood on the Red River. Many, but not all, of the "variable" factors just described entered into determining the magnitude of that flood.

The soil throughout the Red River drainage area was reported to be low in subsurface moisture prior to the first snowfall in November, 1978. This condition would normally have helped to minimize flooding. However, several factors combined to more than offset this single favorable factor. The winter of 1978-79 was unusually

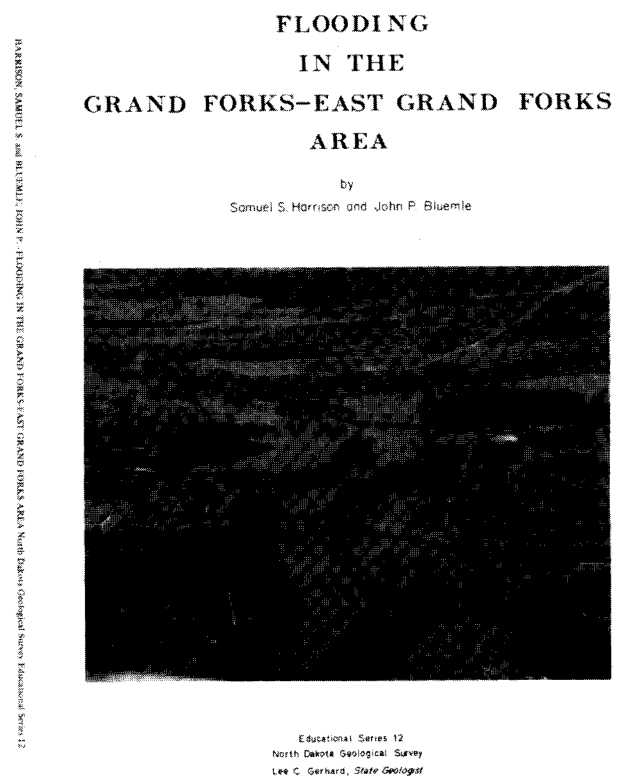


Figure 2. One of the NDGS's popular Educational Series publications, this report includes descriptions of past floods along the Red River, as well as a discussion of the various factors that are most important in determining flood characteristics.

long and unremitting, with above-normal snowfall and a very late thaw. Winter unofficially arrived on November 10, with snow and cold. Except for a few days in mid-December, temperatures were below freezing continually for about five months. The Grand Forks area received about 54 inches of snow, about 20 inches more than normal, during the winter. This was equivalent to about 5 inches of water in the snowpack when the melt began during the second week of April, about a month later than usual. Virtually all of the snow that fell through the winter was still on the ground when the spring thaw arrived. The base of the snowpack had been transformed into a layer of ice several inches thick. Finally, nearly two inches of rain accompanied the mid-April thaw and very little sunshine was available during the thaw to help evaporate snow and runoff.

When temperatures rose suddenly into the 50s and 60s on April 16, the snow cover melted rapidly. Apparently, much of the water from the melting snow flowed over the frozen ground and over the basal icepack so rapidly that almost none of it was absorbed by the supposedly dry subsoil. Furthermore, the very rapid melt immediately saturated the uppermost fraction of an inch of topsoil wherever ice was not present. This resulted in swelling of the clay-rich soil, forming an essentially impermeable seal at the top of the soil zone. The meltwater flowed off over the sealed soil surface instead of replenishing the subsoil moisture supply. Had the melting been only slightly less rapid, the swelling of the surficial clay layer would have been much less effective in forming a seal. It would have dissociated and broken down, allowing a far greater percentage of the water to penetrate the soil zone. The soil did become saturated in areas where the runoff water accumulated, against the south and west sides of roads in the northeast corners of nearly all sections. Interestingly, even after the entire snowpack had melted, in many areas the near-surface soil was still dry. Virtually none of the water soaked into the ground.

The April 1979 flood was characterized by an extremely rapid rise of the Red River (Figure 3). The crest of 48.81 feet came on April 26. Also, many farmsteads and communities were inundated by "sheet" floods of runoff water from nearby fields, not by the river itself. In Grand Forks, the rapid runoff caused a severe

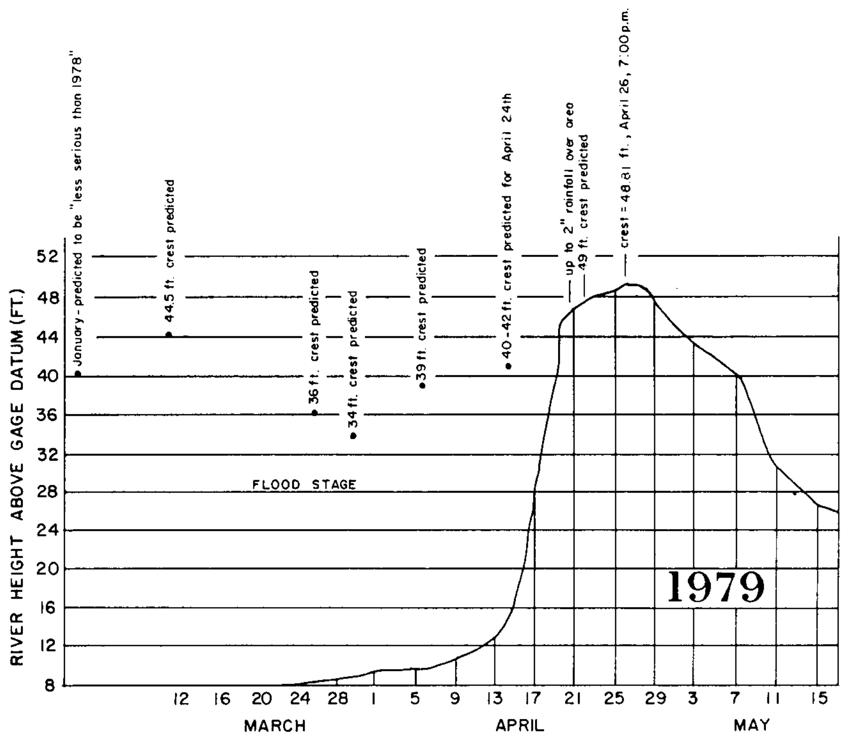


Figure 3. Hydrograph of the 1979 flood on the Red River at Grand Forks.

flood on the English Coulee, a situation few people anticipated.

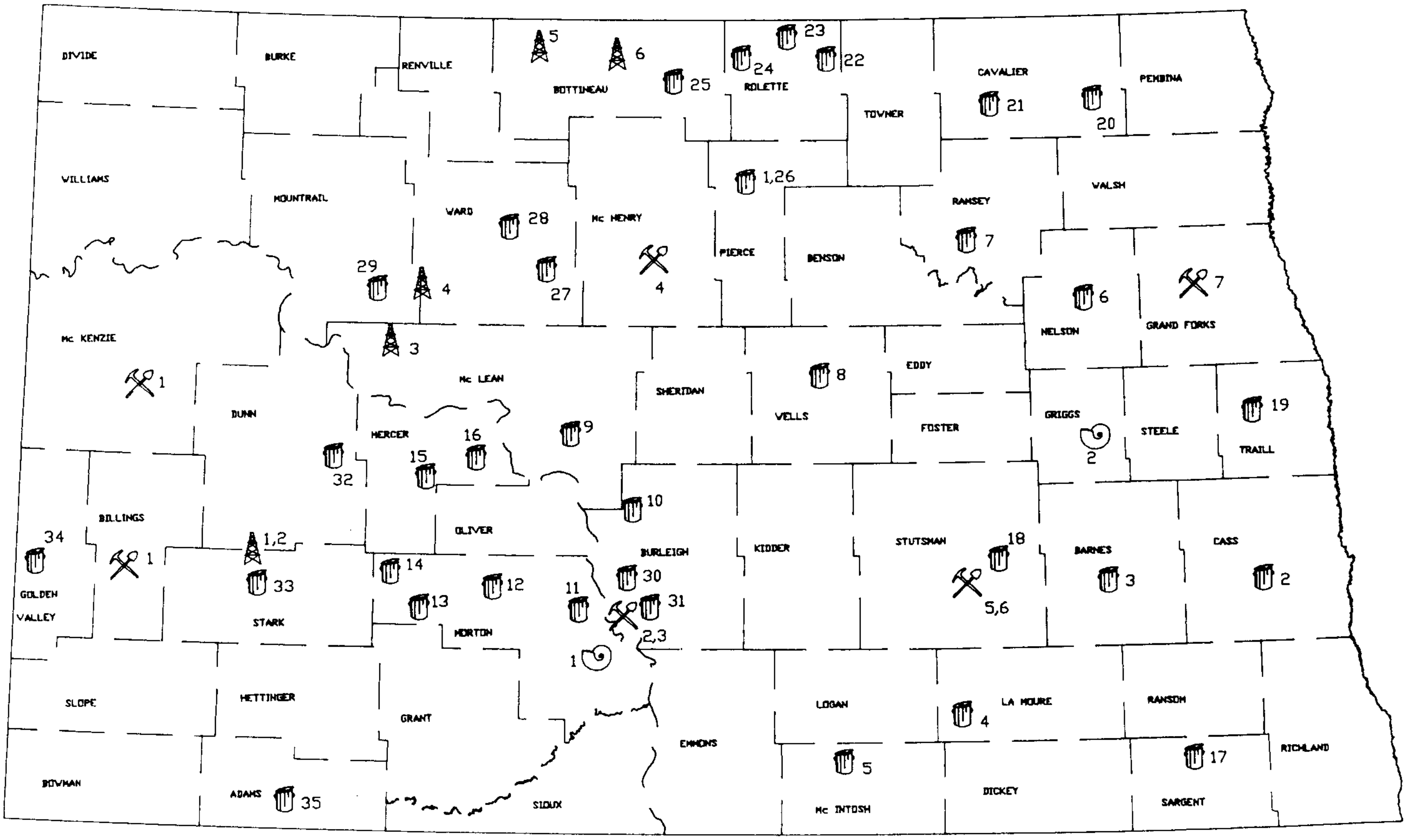
Summary

If it seems as though I've concentrated on the Red River Valley in this article, it's because the flooding there is at least somewhat "predictable." As we saw this past summer, the smaller streams of western North Dakota can produce spectacular, but nearly totally unpredictable, flash floods. And the prolonged effects of an extremely high water table — basement seepage or even flooding — are just additional kinds of flood damage. Perhaps the high water table caused by prolonged heavy precipitation should be categorized as a fourth kind of flood.

It is the interplay of a variety of variable factors, the most important of which is precipitation (although other factors that enter in are sometimes extremely important), with certain constant factors that determine whether a flood will occur. Will we have a flooding problem in North Dakota in 1994? Have we already been "set-up" for a new disaster next March or April? Not yet, but a lot of people are going to be watching carefully.

compiled by Bob Biek

The next two pages contain a list of current geologic investigations and NDGS staff involved. Titles of projects that have been completed are italicized; all other investigations are in progress.

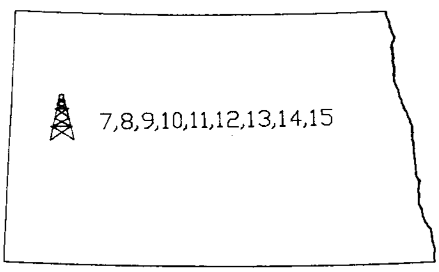


Oil and Gas

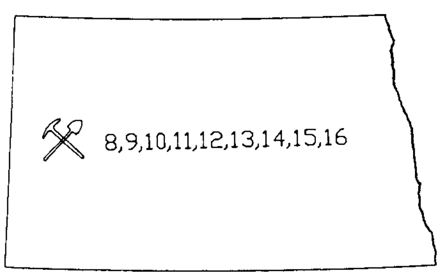
Geologic Projects

Paleontology

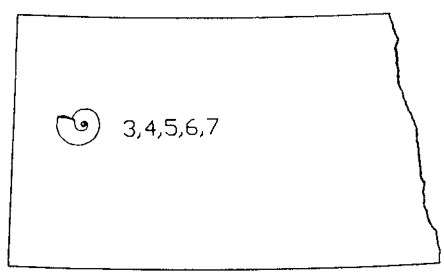
Environmental



Regional Oil and Gas Investigations



Regional Geologic Projects



Regional Paleontologic Projects

Oil and Gas

1. Lodgepole reservoir characterization - Paul Diehl.

2. *Waulsortian Mounds and Conoco's New Lodgepole well*, by Randy Burke and Paul Diehl, NDGS Newsletter, v.20, no. 2, Summer 1993.

3. Lucky Mound Field Study - Randy Burke.

4. *Wabek and Plaza Fields: Carbonate Shoreline Traps in the Williston Basin of North Dakota*, 1993, by Jay T. Sperr, Steven G. Stancel, William A. McClellan, and Michael L. Hendricks, NDGS Field Study 1.

5. South Antler Creek Field Study - Tom Heck.

6. Landa Field Study - Julie LeFever.

7. Sherwood Shoreline play - Bill McClellan.

8. Rocky Ridge-Tracy Mountain Field Study - Paul Diehl.

9. *Williston Basin: Potential Natural Gas Supply*, by Tom Heck, published by the Potential Gas Agency, 1993.

10. *Estimated proved reserves of Natural Gas - North Dakota*, by Tom Heck, published by the AGA-CPA, 1993.

11. Oil-Potential Assessment - Tom Heck and Rich LeFever (UND).

12. Migration of Bakken and Madison oils and correlation to source rocks - Julie LeFever and Leigh Price (USGS). See Canadian Bulletin Petroleum Geology, March 1994 for Phase I summary.

13. Bakken Fm. lithofacies and petroleum potential of the middle member - Julie Lefever.

14. Silurian stratigraphic problems - Randy Burke and Fran Haidl (Saskatchewan Energy and Mines).

15. Tyler Fm. stratigraphy and petrography and relationship to petroleum production - Paul Diehl.

Geologic Projects

1. *Auto Tour Guide to the North and South Units, Theodore Roosevelt National Park*, by Edward C. Murphy, John P. Bluemle, and Bruce Kaye (NPS), in press.

2. *Building Stones of the North Dakota Capitol Grounds*, by Bob Biek, in press.

3. GPS Community Base Station in Bismarck - Mark Luther.

4. *Exceptionally long, narrow drumlins formed in subglacial cavities, North Dakota*, 1993, by John P. Bluemle, Mark L. Lord, and Nathan T. Hunke, Boreas, v. 22.

5. Geologic Mapping of the Jamestown-Spiritwood Lake area - Bob Biek.

6. Guidebook to the geology of the Jamestown area - Bob Biek.

7. GIS prototype project, Grand Forks County - Mark Luther.

8. *The Chadron, Brule, and Arikaree Formations in North Dakota: The Buttes of Southwestern North Dakota*, 1993, by Edward C. Murphy, John W. Hoganson, and Nels F. Forsman (UND), NDGS Report of Investigation 96.

9. *Hydrodynamic blowouts in North Dakota*, 1993, by John P. Bluemle, *in* Glaciotectonics and Mapping Glacial Deposits, CPRC Canadian Plains Proceedings, Regina, Saskatchewan, 1993.

10. *Glaciotectonic data base and mapping of North America*, 1993, by J.S. Aber, J.P. Bluemle, J. Brigham-Grette, D.L. Sauchyn, and D.L. Ackerman, *in* Glaciotectonics and Mapping Glacial Deposits, CPRC Canadian Plains Proceedings, Regina, Saskatchewan.

11. Natural Science of North Dakota, *in* North Dakota Blue Book - John Bluemle.

12. Roadside Geology of North Dakota - John Hoganson, Ed Murphy, and Don Schwert (NDSU).

13. *The Cretaceous/Tertiary boundary in South-central North Dakota*, 1993, by Edward C. Murphy, John W. Hoganson, Doug J. Nichols (USGS), and Nels F. Forsman (UND), GSA Abstracts with Programs, v. 25, no. 6, p. A-113.

14. Flakable lithic resources in North Dakota - Mark Luther and Robert Christensen (NDDOT).

15. Red River Valley Quaternary stratigraphy - Ken Harris (MGS) and Mark Luther.

16. Red River Valley surficial geologic map - Ken Harris (MGS) and Mark Luther.

Paleontology

1. Paleontology and stratigraphy of the Hell Creek Fm. at the Stumpf site, Morton County - John Hoganson.

2. Paleontology of the Cooperstown Pierre Shale site - John Hoganson.

3. *Vertebrates of the Cannonball Formation (Paleocene) in North and South Dakota*, 1993, by Alan M. Cvancara and John W. Hoganson, Journal of Vertebrate Paleontology, v. 13, no. 1, p. 1-23.

4. Vertebrate paleontology of the Fox Hills Fm. in North Dakota - John Hoganson.

5. Paleontology of the Brien Member of the Hell Creek Fm. in North Dakota - John Hoganson.

6. see Geologic Projects #8.

7. see Geologic Projects #13.

Environmental

1. *Geologic and Hydrogeologic Conditions at the Old Rugby Landfill*, 1993, by Edward C. Murphy, Final Report to the U.S. Bureau of Land Management.

The following landfill investigations, by Phil Greer and Jeff Olson (State Water Commission) were completed in 1993 and published jointly with the State Water Commission as *Site Suitability Reviews*:

2. Casselton landfill
3. Valley City landfill
4. Gahner landfill near Kulm
5. Jahner landfill near Wishek
6. Nelson County landfill
7. Devils Lake landfill
8. Lloyd landfill near Fessenden
9. Missouri River Sanitation landfill near Underwood
10. Bauer landfill near Wilton
11. Mandan landfill
12. New Salem landfill
13. Glen Ullin landfill
14. Hebron landfill
15. Beulah landfill
16. Hazen landfill

The following landfill investigations, by Phil Greer and Jeff Olson (SWC), are in progress.

17. Dakota landfill near Gwinner
18. Jamestown landfill
19. Mayville landfill
20. Osnabrock landfill
21. Alsen landfill
22. Murphy Services landfill at Rolla
23. Murphy Services landfill at St. John
24. Murphy Services landfill at Dunseith
25. Bottineau landfill
26. Volk landfill at Rugby
27. McDaniel landfill near Sawyer
28. Minot landfill
29. Geving Sanitation landfill near Parshall
30. Dakota Sanitation landfill north of Bismarck
31. Bismarck landfill
32. Halliday landfill
33. Dickinson landfill
34. Beach landfill
35. Adams County landfill

Geologic Guidebooks

Perhaps the best to way learn about geology, about the landscape in which you live, is to see it in person. Recognizing this, years ago the NDGS published a series of guidebooks that highlight geologic features throughout North Dakota.

Each guidebook begins with a summary of North Dakota geology and a review of the landforms and natural resources of the area, and each comes with a full-color geologic map (scale about 1" = 8 miles). This introduction sets the stage for a series of roadlogs that describe the geology of the region. Most roadlogs cover a distance of about 30 miles and are thus ideal for short excursions. They can also be linked together to create longer trips.

Ideally, the guidebooks could be used for science class fieldtrips. Yet in these times of especially lean school budgets, they could also be used during other trips, such as excursions out of town for sporting events or other extracurricular activities. Travelers should also find the guidebooks interesting, and through their use develop a greater appreciation for the North Dakota landscape.

Single copies of the guidebooks are free on request.

Educational Series #8
Guide to the Geology of Northwest North Dakota, 1981, by John P. Bluemle, 38 p., 1 plate.

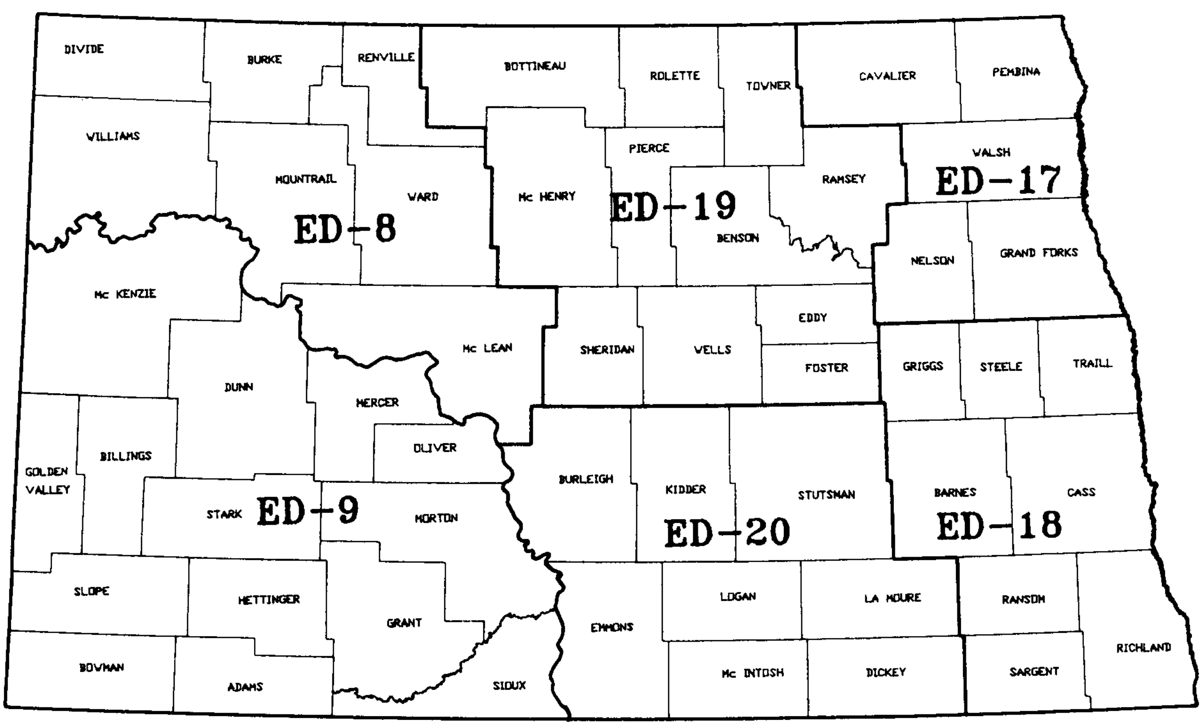
Educational Series #9
Guide to the Geology of Southwest North Dakota, 1981, by John P. Bluemle, 37 p., 1 plate.

Educational Series #17
Guide to the Geology of Northeastern North Dakota, 1988, by Mary E. Bluemle, 32 p., 1 plate.

Educational Series #18
Guide to the Geology of Southeastern North Dakota, 1988, by John P. Bluemle, 36 p., 1 plate.

Educational Series #19
Guide to the Geology of North-central North Dakota, 1988, by John P. Bluemle, 42 p., 1 plate.

Educational Series #20
Guide to the Geology of South-central North Dakota, 1988, by John P. Bluemle, 44 p., 1 plate.



NEW PUBLICATIONS

Wabek and Plaza Fields: Carbonate Shoreline Traps in the Williston Basin of North Dakota, by Jay T. Sperr, Steven G. Stancel, William A. McClellan, and Michael L. Hendricks, NDGS Field Study 1, (1993), 24 pages, $3.00.

This report summarizes the geology, geophysics, and production of the Wabek and Plaza Fields in Mountrail and Ward Counties, North Dakota. It also summarizes exploration techniques used to locate these fields and that should be useful in delineating and evaluating similar Mission Canyon (Mississippian) shoreline traps.

Outside Publications

Aber, J.S., Bluemle, J.P., J. Brigham-Grette, Sauchyn, D.L., and Ackerman, D.L., 1993, *Glaciotectonic data base and mapping of North America: in* Glaciotectonics and Mapping Glacial Deposits, CPRC Canadian Plains Proceedings, Regina, Saskatchewan.

Ashworth, Alan C. and Hoganson, John W., 1993, *The magnitude and rapidity of the climate change marking the end of the Pleistocene in the mid-latitudes of South America*: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 101, p. 263-270.

Bluemle, John P., 1993, *Hydrodynamic blowouts in North Dakota: in* Glaciotectonics and Mapping Glacial Deposits, CPRC Canadian Plains Proceedings, Regina, Saskatchewan.

Heck, Thomas J., 1993, Williston Basin: *in* Brown, B. D., et al., eds., Potential Supply of Natural Gas in the United States, December 31, 1992, Potential Gas Agency, Colorado School of Mines, p. 77-79.

Heck, Thomas J., 1993, Estimated Proved Reserves of Natural Gas - North Dakota, as of December 31, 1992: *in* Natural Gas Reserves of Selected Fields in the U.S. and Canada, American Gas Assoc. and the Canadian Petroleum Assoc., p. 44-49.

Murphy, Edward C., Hoganson, John W., and Forsman, Nels F., 1993, *The stratigraphy and biochronology of the Chadron, Brule, and Arikaree Formations in North Dakota* (abstract): *in* Kihm, A. J. and Hartman J. H., eds., The Marshall Lambert Symposium, North Dakota Geological Society, p. 20.

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