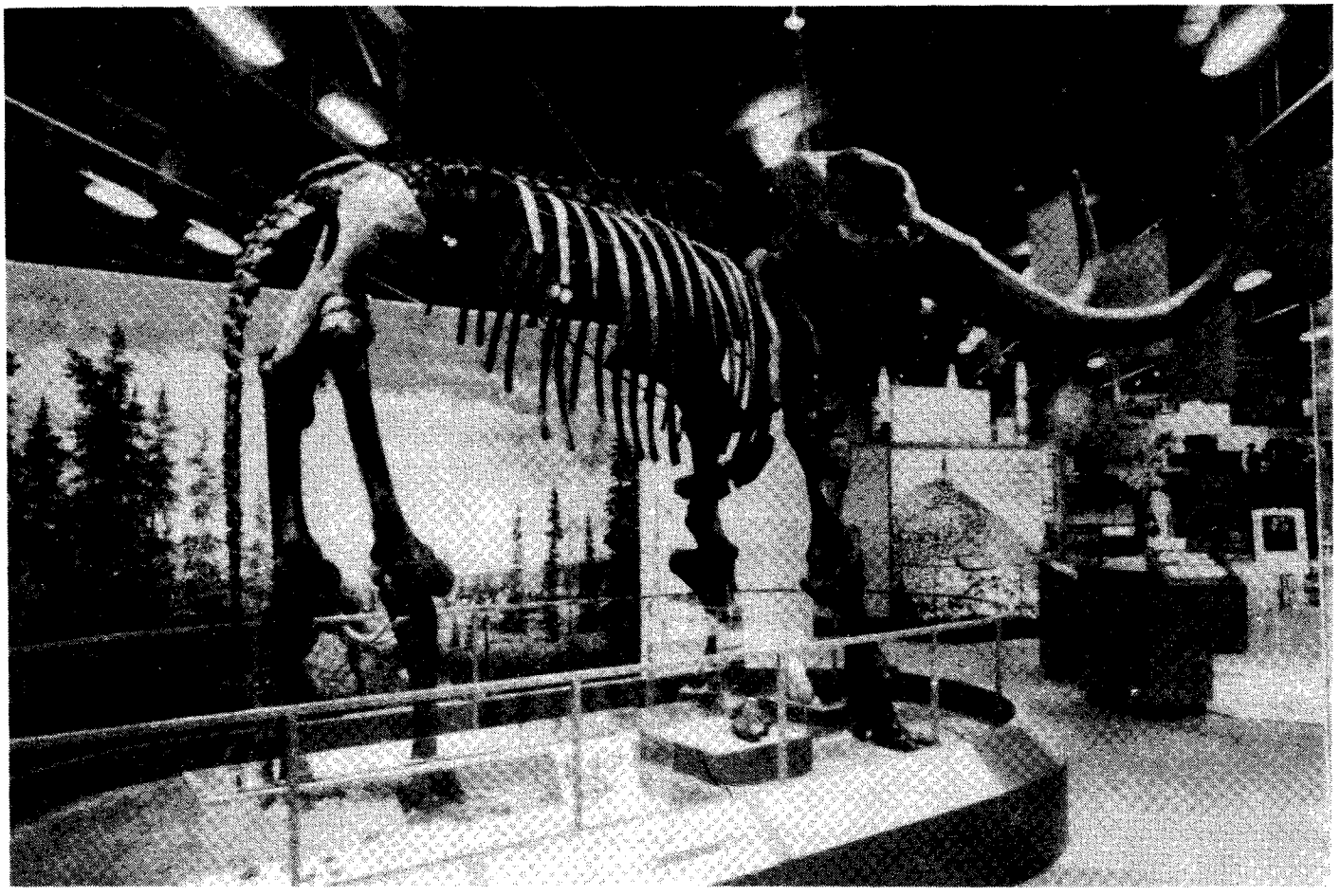
NEWSLETTER

NDGS

Industrial Commission of North Dakota, North Dakota Geological Survey Vol. 19, No. 2, Winter 1992



Restored skeleton of the Highgate Mastodon, on permanent display at the North Dakota Heritage Center in Bismarck. Mastodons were elephant-like animals that became extinct at the end of the last Ice Age. This specimen, a male, is over 20 feet long and stands 10 feet high at the shoulder. The restoration was accomplished by John Hoganson (NDGS) assisted by George Lammers (Curator of Geology at the Manitoba Museum of Man and Nature in Winnipeg) with the help of several volunteers and specialists, and was made possible by a grant from the North Dakota Heritage Foundation. *Photo by Todd Strand, Photo Archivist, State Historical Society of North Dakota.*

TABLE OF CONTENTS

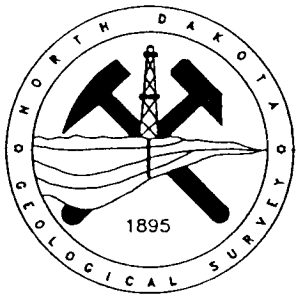
REGULAR FEATURES

NDGS Newsletter (ISSN: 0889-3594) is published twice per year 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).

When requesting a change of address, please include the number on the upper right hand corner of the mailing label.

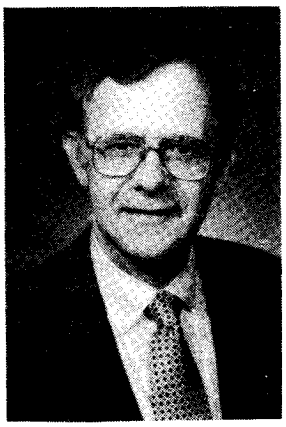
NEWSLETTER
NDGS



FROM THE STATE GEOLOGIST

by John P. Bluemle

Service to the Public



Once in awhile it's a good idea to stand back and take a look at where we are. After 94 years in Grand Forks at the University of North Dakota, the North Dakota Geological Survey was transferred to the State Industrial Commission and moved to Bismarck in 1989. Since that move, our operations have changed substantially and our service to the public has improved. I'd like to take a few minutes to examine the Survey's public service role.

At recent meetings I've attended with other State Geologists, the expanding service function of the various State Geological Surveys has been stressed. Our own activities in this regard reflect this changing pattern. Our geologists are increasingly called upon to speak to service groups and conduct workshops in various parts of the state. The number of requests for information is growing dramatically. People are demanding geologic information of all kinds -- whether it be identification of a rock or fossil, advice on maps available for the area they live in, a request for one of our geologists to lead a field trip, or perhaps the need for basic geologic knowledge required to site a landfill.

Many of the things we do are basically "educational;" they either make the public aware of problems and possibilities, or sometimes they may simply add to our store of knowledge. One of the most visible and satisfying things we've done recently has been our work with the Heritage Center. Our paleontologist, John Hoganson, has worked with the staff at the Heritage Center to restore the first mastodon skeleton in North Dakota. The results are definitely worth seeing and I encourage anyone who hasn't already done so to stop by the Heritage Center soon. We are now working with the Heritage Center on a more inclusive display of North Dakota's geologic history.

Although our involvement in studying Williston Basin geology and its relationship to oil and gas has served to "identify" the NDGS for many years, I expect our developing Geographic Information Systems (GIS) program to become vitally important to us. Our GIS lab is basically a way for us to vastly improve our own operation, but it is also a service we provide to other state agencies. We are working closely with several state agencies, especially the Department of Health and the Agriculture Department, on programs utilizing GIS technology, including, for example, the pesticides, endangered species, and water quality programs.

Nearly two years ago, the NDGS accepted the lead role among state agencies in coordinating and developing the state's GIS capability. We recently hired two people experienced in GIS work who are helping us to make much more rapid progress. Our new GIS employees are in temporary slots partially funded by money from the U.S. EPA and the North Dakota Department of Agriculture. We do need to have permanent GIS technicians in these positions.

I believe that working more closely with other state agencies is one of the most important ways we can provide better service to the public. Since moving to Bismarck, we've been able to forge stronger ties with a number of state agencies. It has become clear to almost everyone concerned, I think, that the NDGS is the single source of reliable geologic information for all state agencies. We are now providing a variety of geologic information to those who need it.

The North Dakota Geological Survey's specified mission, to foster and promote environmentally sustainable economic development of North Dakota's energy and mineral resources, is accomplished by each of our three functions: regulatory, research, and public service. Of these, public service may be the most important. Please let us know the kind of information and services you need and we will do our best to deliver!

NEWS IN BRIEF

compiled by Bob Biek

NDGS Newsletter

Beginning next March, the *NDGS Newsletter* will be published on a quarterly basis in the spring, summer, fall, and winter. By issuing the newsletter quarterly, we will better be able to provide timely information about North Dakota's geology and mineral resources. Look for your Spring issue in late March!

RESTORED SKELETON OF THE HIGHGATE MASTODON UNVEILED AT THE "FIRST PEOPLE" OPENING

by John Hoganson

The first restored prehistoric animal skeleton ever displayed in North Dakota now stands as part of the recently completed "First People" exhibit at the Heritage Center (see cover photo). The restoration of the Highgate Mastodon that I wrote about in the December, 1991 *NDGS Newsletter* is completed. The ribbon cutting ceremony for the "First People" exhibit and unveiling of the mastodon skeleton occurred on June 20, 1992. The exhibit's opening was attended by more than 1,100 people.

The "First People" exhibit is an interpretive display of artifacts of the earliest inhabitants of North Dakota spanning the time interval from 9600 B.C. to A.D. 1738. Featured along with the artifacts is a model of the head of a woman that lived in North Dakota about 5,700 years ago, recreated from archeological evidence using forensic techniques; a full scale replica of North Dakota's earliest permanent dwelling--a bark covered, circular lodge; a full scale tipi that can be viewed from the inside as well as the out; and the Highgate Mastodon skeletal mount. The 11,000 year old mastodon fossil was included in the exhibit because it is believed that early inhabitants of North Dakota hunted these elephant-like animals for food.

The "First People" exhibit was accomplished through cooperation between the State Historical Society of North Dakota and the North Dakota Geological Survey and was underwritten with a $600,000 grant from the North Dakota Heritage Foundation.

GEOTHERMAL REGULATIONS REVISED

- ground source heat pumps impacted -

On December 1, 1992 several amendments to N. D. Administrative Code ch. 43-02-07 "Geothermal Energy Production" will become effective. The State Geologist is responsible for administering these regulations, which require a permit prior to the installation of geothermal (ground source) heating and/or cooling systems; a permit is not required for private residential systems. The amendments are designed to clarify existing regulations, simplify reporting requirements, and provide technical standards that must be met when constructing or abandoning geothermal heating and cooling systems.

The amendments make specific mention of, and require a permit for, "substantial modification" of existing systems and for systems laid horizontally in trenches. In addition, the heat transfer fluid in any system must be approved for use by the State Geologist. Propylene gylcol, calcium chloride, and "GS4" (a potassium acetate solution) are the only fluids approved for use at this time. Methanol and other toxic fluids are not approved for use in ground source heating and/or cooling systems.

To learn more about these and other changes, or to obtain a copy of the new geothermal regulations, please contact Bob Biek.

GIS UPDATE

by Mark Luther

Mark Luther has worked closely with the State Department of Health and Consolidated Laboratories, the State Department of Agriculture, and the U.S. Environmental Protection Agency to acquire needed Geographic Information Systems (GIS) equipment and funding. In addition to our Data General and SUN workstations, the NDGS has recently acquired a large digitizer (36" X 48"),

an additional copy of ARC/INFO (version 6.1) and ArcView software, and a large scanner, capable of scanning electric logs or an entire 7.5 minute quad map at 500 dpi. As this issue goes to press, we anticipate receiving a read/write optical disc drive system. This system will allow the NDGS to inexpensively store several gigabytes of digital map and tabular data. Most importantly, we were recently able to hire two individuals (see article on page 7) with extensive experience in GIS!

The GIS/CAD group is currently working on several projects. These projects are varied and include the creation of figures for NDGS publications and presentations, an update of the geologic map postcard of the state, a digital shaded-relief map of the Devils Lake area, and a GIS prototype project in Grand Forks County.

GEOLOGICAL ASSISTANTS

by Ed Murphy

This past summer, the North Dakota Geological Survey hired six students, listed below, as temporary help. Initially, two students were hired to work on the Geological Survey/Water Commission landfill assessment project, two for the Bureau of Land Management grant (see story below), one to assist with the coal exploration program, and one to work with John Hoganson on the paleontological program. Despite the initial delay in getting the BLM agreement signed and the subsequent delays with the grant prior to its termination, the Survey was able to keep the two students initially dedicated to the BLM project busy.

The Survey was reimbursed from a special fund for the salaries and per diem of students working on the landfill and BLM projects. The U.S. Office of Surface Mining also reimbursed the Survey for 73% of the salaries and per diem of students working on the coal exploration program. The students gained valuable experience over the summer and freed Survey geologists to work on other, more technical projects.

Student	*College*
Eric Brevik	University of North Dakota
John Campbell	University of North Dakota
John Hardy	University of Kansas
Jeff Herman	Minot State University
Mark McDonald	University of North Dakota
Asuka Tsuru	North Dakota State University

BLOATING CLAYS FROM THE RED RIVER VALLEY

Research being conducted by Julie Oreskovich and her colleagues at the Natural Resources Research Institute at the University of Minnesota, Duluth has revealed that Glacial Lake Agassiz clays from Kittson County in northwestern Minneosta exhibit a characteristic spherical bloating habit when fired to 2,050 degrees Fahrenheit. Their research was presented at an Industrial Minerals Workshop held in Minneapolis last September (U.S.G.S. Open-File Report 92-514 is a "Program with Abstracts" for that meeting; a complete Proceedings Volume will be published in mid 1993).

The bloating characteristics of Kittson County clays were identified in 1989 during a regional study of the characteristics of Minnesota's clay resources. Oreskovich said, "The expanded state of the Kittson clays makes them ideal for use in lightweight aggregate suitable for structural concrete and landscaping materials. Further processing of the dried raw clay will produce a uniform spheroidal aggregate with potential use in insulating concrete, as a filler, and as a substitute for perlite in horticultural growing mixes."

The bloating clays belong to the Sherack and Brenna Formations that underlie the central and northern Red River Valley in both Minnesota and North Dakota. The clays are widespread, flat-lying, and within 30 feet of the surface. Some of the clays expand as much as 300 percent when fired to temperatures ranging from 1,900 to 2,200 degrees Fahrenheit.

Currently, most of the lightweight aggregate consumed in the northern plains states comes from Missouri and Tennessee. Development of these Red River Valley clays could bring jobs and a necessary resource closer to home.

INDUSTRIAL MINERAL INFORMATION AND REGULATION

Information about the regulation of industrial (nonfuel) minerals in North Dakota and other upper midwest and Great Lakes states, a list of state and federal agencies involved with these resources, and abstracts of presentations are available in the recently released USGS Open-File Report 92-514. The report is a "Program with Abstracts" for a workshop held September 10, 11, and 12, 1992 in Minneapolis. The workshop - "Industrial

Minerals Today and Tomorrow: The Raw Materials to Build the Upper Midwest" - was sponsored by the USGS, the USBM, and the Minnesota Geological Survey in cooperation with the Geological Surveys of Illinois, Indiana, Michigan, North Dakota, Ohio, South Dakota, and Wisconsin.

The 144 page report is available for $23 (paper copy) or $4 (microfiche) from the U.S. Geological Survey, Open-File Reports, Box 25286, MS 517, Denver Federal Center, Denver, CO 80225 (303-236-7476). Prepayment or purchase order is required.

BOOKLETS AVAILABLE

The Geology of Radon

Published by the U.S. Geological Survey, this booklet presents important geological information about radon; how it forms, the kind of rocks and soils it comes from, and how it moves through the ground or is carried by water into buildings. The booklet also explains the way geologists estimate the radon potential of an area, and tells you where you can get more information on radon. The booklet is available free through the North Dakota Geological Survey.

North Dakota Groundwater: A Resource to Protect

The State Department of Health and Consolidated Laboratories Division of Water Quality and the U.S. EPA recently published (in July, 1992) a non-technical introduction to groundwater. The 13 page booklet discusses where groundwater is found, potential sources of contamination, and ways to protect it. State agencies that have authority over various aspects of groundwater management, remediation, and pollution prevention are also listed. The booklet is available free of charge from the Department of Health and Consolidated Laboratories, Division of Water Quality, 1200 Missouri Avenue, Bismarck, ND 58502-5520 (701-221-5210).

BLM GRANT REVOKED

by Ed Murphy

The Summer, 1992 *NDGS Newsletter* (p.31) reported that we were anticipating receiving a grant from the U.S. Bureau of Land Management (BLM). On June 3, 1992, Assistance Agreement No. 1422-E950-A2-0010 between the BLM and the North Dakota Geological Survey was signed. The agreement, which awarded the Geological Survey $250,000, was to be in effect until December 31, 1994. The purpose of the project was to study oil-and-gas drilling mud, the reclamation of drilling sites, and the old Rugby landfill. The agreement was a culmination of three project proposals, two from the Geological Survey totaling $140,000 and one from the Energy and Environmental Resource Center (EERC) totaling $110,000. The three projects were combined into one by the BLM to cut down on their paperwork. As a result of this combination, the Geological Survey had two subcontracts to complete this project, one with Dan Daly (EERC) and one with Phil Gerla, a Professor in the Department of Geology and Geological Engineering at UND. Dr. Gerla and a graduate student were to investigate the migration of drilling-mud leachate in the unsaturated zone and Mr. Daly was to take samples of drilling mud from pits prior to reclamation for mud chemistry analyses.

Shortly after signing our contract with the BLM, we began our fieldwork at the old Rugby landfill by installing monitoring wells in mid-June. The BLM was interested in this site because it is located on federal land. Shortly after instrumentation of the landfill, we received word from the BLM that there were misgivings at both the federal and state levels concerning the purpose of our study. Oil-and-gas drilling mud was specifically exempted from consideration as a potential hazardous waste by Congress in the late 1970s. However, some questions had recently been raised within the BLM concerning the interpretation of this exemption. As a result of BLM's legal interpretations, there was concern that the results of our study might be used by the BLM to reopen this issue. Despite attempts to save the project, the BLM terminated the contract on August 14.

WILSON M. LAIRD HONORED

by Ed Murphy

Wilson M. Laird (North Dakota State Geologist from 1941 to 1969) became the first recipient of the Arthur Gray Leonard Award on October 23, 1992. E. A. "Ned" Noble (North Dakota State Geologist from 1969 to 1977) was Master of Ceremonies at the reunion banquet which honored Dr. Laird. The banquet was attended by over one hundred people including faculty and alumni of the UND Department of Geology and Geological Engineering, former and current Geological Survey employees, and friends of Dr. Laird.

In addition to the Leonard Medal, Clarence "Kelly" Carlson, president of the North Dakota Geological Society, presented Dr. Laird with a plaque commemorating his efforts as a founding father of the Geological Society in 1951. John Bluemle, North Dakota State Geologist, also presented Dr. Laird with a plaque from the Association of American State Geologists recognizing his many years of valuable service as State Geologist of North Dakota.

The Arthur Gray Leonard Award is awarded by the University of North Dakota Department of Geology and Geological Engineering to recognize outstanding contributions to the geoscience field.

Figure 1. Former State Geologists Wilson M. Laird (left) and E. A. "Ned" Noble (right). Photo courtesy of UND Alumni Association.

Figure 2. State Geologist John Bluemle presents Wilson M. Laird with a plaque from the Association of American State Geologists while Mrs. Margaret Ray Laird looks on. Photo courtesy of UND Alumni Association.

NDGS Subsurface Division Activities

by
William A. McClellan and Paul E. Diehl

The geologists in the Subsurface division of the Survey are currently working on several studies that are directly applicable to present and potential petroleum industry activity. These studies are intended to provide information and ideas that individuals and companies can use for exploration, development, and enhanced oil recovery. Before the end of this year we should have a field study of Wabek field in press as well as a detailed study of Lucky Mound field, both of which should be useful to anyone working the Sherwood trend; a regional study of Sherwood stratigraphy will also be available.

These studies are among the first in a new program designed to provide representative field studies that can be used as models for exploration or field extension, or comparison to other fields being reviewed for secondary recovery work. Another such study, of the Tyler Formation, is outlined below and is expected to be completed in mid 1993. The Survey intends to maintain a significant portion of time working on such projects that are directly related to petroleum industry activity.

We are also initiating a program of describing each core as it arrives at the Survey. The descriptions are available to the public on request, and are also placed in each open well file. Researchers can now access a basic core description without physically going to the Core Library, thus saving time and transportation costs. This will also allow one to predetermine if an individual well core might warrent more detailed study.

In order to help industry improve oil production from older fields in the State, the Survey hopes to work with operators on enhanced oil recovery projects. Our intention is to jointly apply for DOE matching fund grants that are available for programs using new methods to recover more reserves from old fields. The Survey would provide geological expertise and coordination of the grant, and would play a primary role in technology transfer to general industry after the method has been proven. Grant proposals from operators are currently being reviewed for projects scheduled to start next spring.

Tyler Formation Sandstones

Paul Diehl has begun a study on the petrography of Tyler Formation sandstones with mapping of these sandstone bodies in various productive Tyler fields. The objective of the study is to quantatively describe the sandstones found within the Lower Pennsylvannian Tyler Formation. A petrographic database is fundamental to the foundation on which further investigations involving sandstone compositional and textural variability, depositional environments, reservoir characterization, and reservoir stimulation and flooding fluids are built. Mineralogical composition may also be important in choosing parameters for wireline log interpretations.

This study will address questions such as:

* Is there a compositional and/or textural difference between oil productive and non-productive Tyler sandstones in a given field? What are these differences?

* How does the petrography of a particular sandstone vary within a field?

* What is the variability of composition and texture of both productive and non-productive sandstones between fields?

* Are there specific criteria by which to recognize potentially productive Tyler sandstones?

* What kinds of treatment fluids should be used to stimulate the sandstones in order to minimize formation damage and maximize recovery? What fluids should not be used?

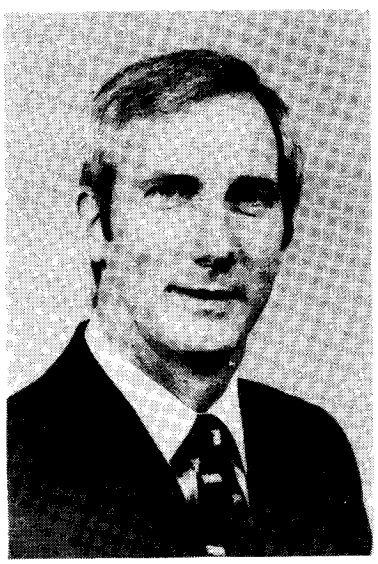
Field studies of Tyler sandstone oil fields will begin with the Rocky Ridge and North Rocky Ridge fields in Billings and Slope Counties. The studies will include structure and isopach maps of critical horizons, stratigraphic and structural cross-sections, historical production information, and engineering data pertinent to the reservoir.

SURVEY HIRES NEW EMPLOYEES

Dr. Paul E. Diehl began work for the North Dakota Geological Survey as a stratigrapher/petroleum geologist on the first of August. He came to the Survey with 17 years experience in the petroleum industry. Paul moved to Bismarck from Norman, Oklahoma where he was employed by the Holden Energy Corporation for the past 9 1/2 years. While with Holden, Paul worked primarily in central and southern Oklahoma where he generated numerous oil and gas prospects in both clastic and carbonate Paleozoic sediments. He also directed Holden's logging operations and was responsible for well log interpretation and for selection of intervals to be production tested. On many occassions Paul appeared before the Oklahoma Corporation Commission as an expert witness in causes for Holden Energy.

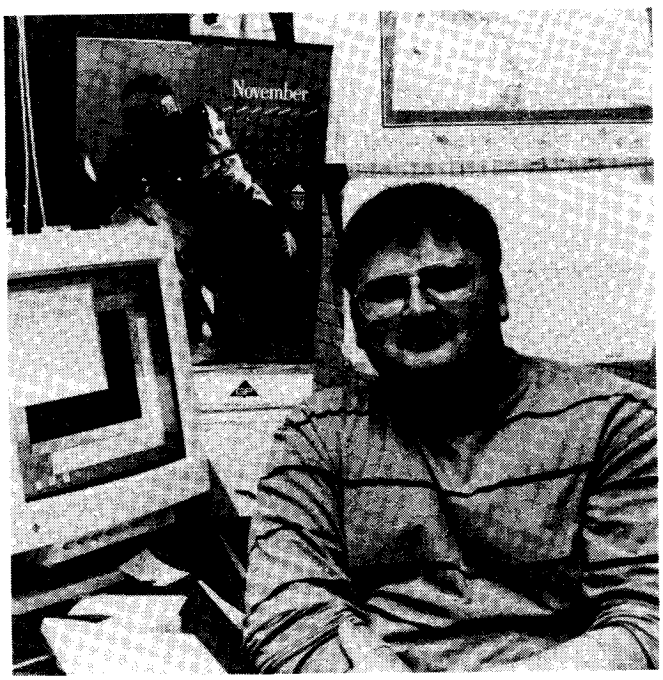
Prior to joining Holden Energy, Paul had been employed by ANSON Corporation in Oklahoma City where he was involved in exploration and production in the Anadarko Basin of Oklahoma and Texas. Paul also worked for Conoco for nearly five years as an exploration and production geologist in international exploration and in domestic locations in Ponca City, Casper, Houston, and Oklahoma City.

In addition to his petroleum industry experience, Paul was Adjunct Professor of Geology at the University of Oklahoma from 1985 to 1989; there, he taught subsurface geologic methods and well-site geology. He also served four years active duty as an officer in the U.S. Air Force 1st Geodetic Survey Squadron, rising from Survey Field Chief to acting Commander of the detachment at Cape Kennedy, Florida. Paul received a B.S. in Geological Science from Penn State, a M.S. in Structural Geology from Franklin and Marshall College, and a Ph.D. in Geology from Penn State.



As a stratigrapher/petroleum geologist, Paul will be concerned primarily with the stratigraphy of clastic strata in the Willsiton Basin that either produce or have the potential to produce hydrocarbons (see article on page 6).

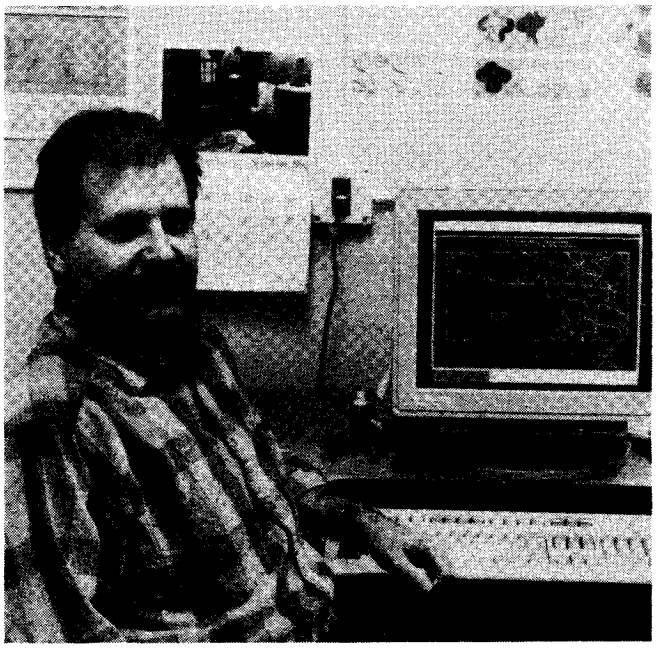
Darin Scherr, a Bismarck native, began working part-time as a draftsman for the Survey in June. Darin uses Autocad release 12 on a SUN workstation. Recently, he began working with the Survey's Atlas GIS as well.



Darin has an Associate in Science degree from Bismarck State College and is currently attending BSC as a pre-engineering student. There, he is also working as a Math/Engineering Tutor and is actively involved in the Society of Professional Engineers and the Engineering Club. He was past President of the Engineering Club at BSC. Darin plans to continue his education at the University of North Dakota.

Sharon Murfield-Tyler came to the North Dakota Geological Survey from Brookings, South Dakota where she had been employed by the Soil Conservation Service Area Office. While there she was responsible for coordinating field office participation in the 1992 Natural Resources Inventory (NRI), and for the editing and input of primary sampling unit (PSU) data. Sharon was also involved in the design of maps for inclusion in the "Oregon Coast Recreational Atlas" for E&S Geographic Information Systems. As a scientist at the EROS Data Center, she monitored vegetation dry-down (one of the indicators used in the calculation of a fire hazard index) across the northern Great Plains; she also monitored vegetation green-up across the southern Sahel of northern Africa. Sharon has a B.S. degree in Technical Geography from South Dakota State University and is currently completing the requirements for a M.S. degree in Geographic Techniques from Oregon State University.

Dean Tyler came to the North Dakota Geological Survey from Brookings, South Dakota where he had been employed by South Dakota State University. While there he participated in the creation of a state-wide cartographic database for South Dakota and produced maps for landfill site suitability. Prior to that he was employed at the EROS Data Center where he was involved, in an effort to locate potential locust breeding sites, in mapping vegetation green-up across



the southern Sahel of northern Africa. Other projects that Dean worked on at EROS included vector data interchange and ground control point selection for geometric correction of images. Dean has a B.A. degree in Geography from Augustana College in Sioux Falls, South Dakota.

Dean and Sharon are currently working on several projects, including: a shaded-relief map of the Devils Lake area, highlighting glacial landforms; conversion of endangered species maps into digital form; and manipulating digital data and producing maps of oil production information for a test area in western North Dakota. Dean and Sharon are also assisting the State Department of Health and Consolidated Laboratories and the State Department of Agriculture in getting their Geographic Information Systems operational.

ESIC NEWS

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 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.

New Map Products

In addition to providing information about the availability of various earth science materials, the NDGS' ESIC office operates a distribution center for federally produced cartographic products. Descriptions of recently produced or reprinted maps that are available follows.

* National Atlas Map - U.S. Satellite View; a double-sided map of the United States illustrating a mosaic of 16 Advanced Very High Resolution Radiometer (AVHRR) images taken between 1984 and 1986. The images cover the conterminous States. The map includes explanatory captions on a duplicate image on the reverse side. 1990. Scale 1:7,500,000. Sheet 19 by 28 inches. Price = $4.00 plus shipping.

* National Atlas Map - United States Shaded Relief; a colored map illustrating the landforms of the conterminous United States, with insets of Alaska and Hawaii. 1969. This is the "classic" map of the U.S., showing mountain ranges, rivers, etc. Scale 1:7,500,000. Sheet size 19 by 28 inches. Price = $4.00 plus shipping.

* Digital Elevation Models (DEM) - The NDGS, through a joint funding agreement with the USGS, has had DEM coverages completed for four 7.5 minute quad maps, covering two cities in North Dakota. The completed quads are: Valley City East, Valley City West, Dickinson North, and Dickinson South (a description of DEM's follows). The DEM files, which are approximately 1 megabyte in size for each quad, are available from the NDGS for a cost of $10 per quad, plus the cost of the media (or bring your own).

* Four of the 1:100,000 scale (30 X 60 Minute Series) maps for North Dakota are currently undergoing revision and should be available by the end of 1992. The four maps - Cavalier, Cooperstown, Langdon, and Stump Lake - are currently available only in planimetric (no contour lines) form. The revised maps will be topographic editions with contour lines in metric intervals.

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

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

US GeoData

The development of geographic information systems (GIS) is a rapidly growing industry that supports natural resource studies, land management, environmental analysis, 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 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 four basic types. The first of these, called a Digital Line Graph (DLG), is the line map information in digital form. These data files include information on planimetric base categories, such as public-land survey, transportation, hydrography, and boundaries. The second type, called a Digital Elevation Model (DEM), consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals. The third 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 fourth 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.

For this issue of the *NDGS Newsletter*, I'd like to concentrate on DEM's. DEM's are very useful files that can be used for a wide variety of modeling and mapping applications. A DEM consists of a large number of elevation values for uniform, grid-based points on a map. With the proper computer software (such as a GIS package), a computer can perform functions such as contouring, 3-D modeling, shaded-relief mapping, percent slope, slope aspect, or watershed delineation, to name a few. The NDGS is currently using DEM's to create a shaded-relief map of the Devils Lake area that accentuates the glacial geomorphology of the area.

DEM coverages in North Dakota are available in two distinct products; the 7.5 minute DEM, and the 1-degree DEM. Data contained in the DEM files are written in ANSI-standard ASCII characters. First, 7.5 minute DEM's.

7.5 minute DEM files are based on, and cover the same area as, a standard USGS 7.5 minute topographic map quadrangle. Other characteristics of a 7.5 minute DEM include:

* The data consist of a regular array of elevations referenced horizontally in the Universal Transverse Mercator (UTM) coordinate system (Figure 1). The reference datum may be North American Datum of 1927 (NAD 27) or the North American Datum of 1983 (NAD 83).

* The data are stored as profiles in which the spacing of the elevations along and between each profile is 30 meters.

* The profiles do not always have the same number of elevations because of the variable angle between the quadrangle's true north and the grid north of the UTM coordinate system.

* Elevations for the continental U.S. are in either meters or feet referenced to the National Geodetic Vertical Datum of 1929. DEM's of low-relief terrain or generated from contour maps with intervals of 10 feet or less are generally recorded in feet. DEM's of moderate to high-relief terrain or generated from maps with terrain contour intervals greater than 10 feet are generally recorded in meters.

* The accuracy of 7.5 minute DEM data is derived by comparing linear interpolated elevations in the DEM with corres-

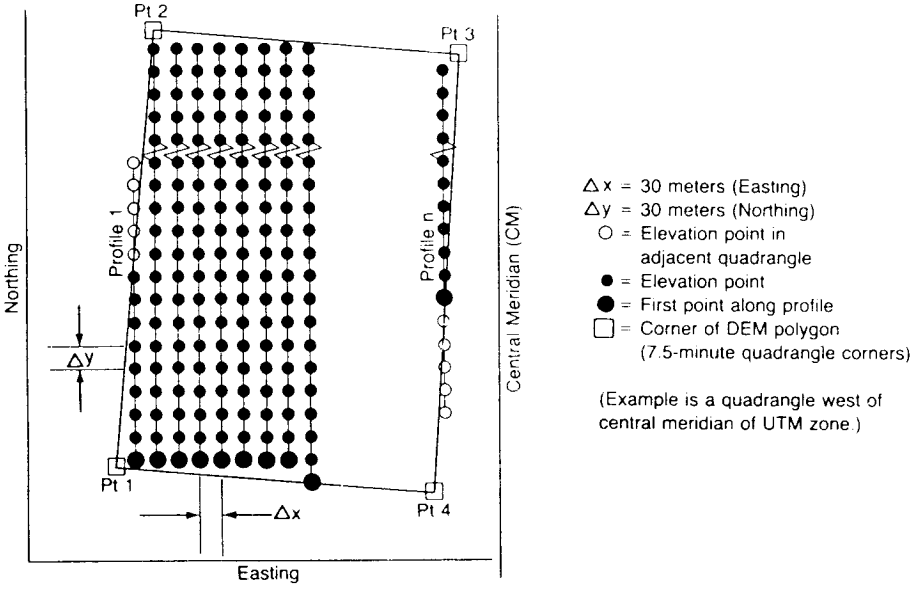


Figure 1. Structure of a 7.5-minute Digital Elevation Model, UTM meter grid.

ponding map location elevations and computing the statistical standard deviation or root-mean-square error (RMSE). The RMSE is used to describe the DEM accuracy. The vertical accuracy of most DEM's created for North Dakota is 7 meters or better; a few are 15 meters or better.

* Approximately 20% of North Dakota has 7.5 minute DEM coverage available.

The second DEM product commonly available is the 1-degree DEM. 1-degree DEM data is produced by the Defense Mapping Agency (DMA) in 1-degree latitude by 1-degree longitude blocks which correspond to the east half or west half of USGS 1- by 2-degree (1:250,000 scale) topographic quadrangle maps. Other characteristics of 1-degree DEM's are:

* The product consists of a regular array of elevations referenced horizontally on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum (WGS 72) or the World Geodetic System of 1984 (WGS 84).

* Elevations are in meters relative to NGVD 29 in the Continental U.S.

* Spacing of the elevations along each profile is 3 arc-seconds (about 215 feet east-west by 300 feet north-south in North Dakota). The first and last data points are at the integer degrees of latitude (Figure 2). A profile will therefore contain 1,201 elevations.

* 1-Degree DEM's are derived from DLG data by using selected elements from both hypsography (contours, spot elevations) and hydrography (lakes, shorelines, drainage). If necessary, ridge lines and hypsographic effects of major transportation features are also included in the derivation. A RMSE of one-third of the contour interval is the maximum permitted. There are no errors greater than two-thirds contour interval in magnitude (an absolute accuracy of 130 meters horizontally and 30 meters vertically).

* 1-Degree DEM coverage is available for the entire state of North Dakota.

DEM's are a very useful data source that will be used extensively in the future by the NDGS and others involved with GIS, automated mapping, and natural resource management.

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

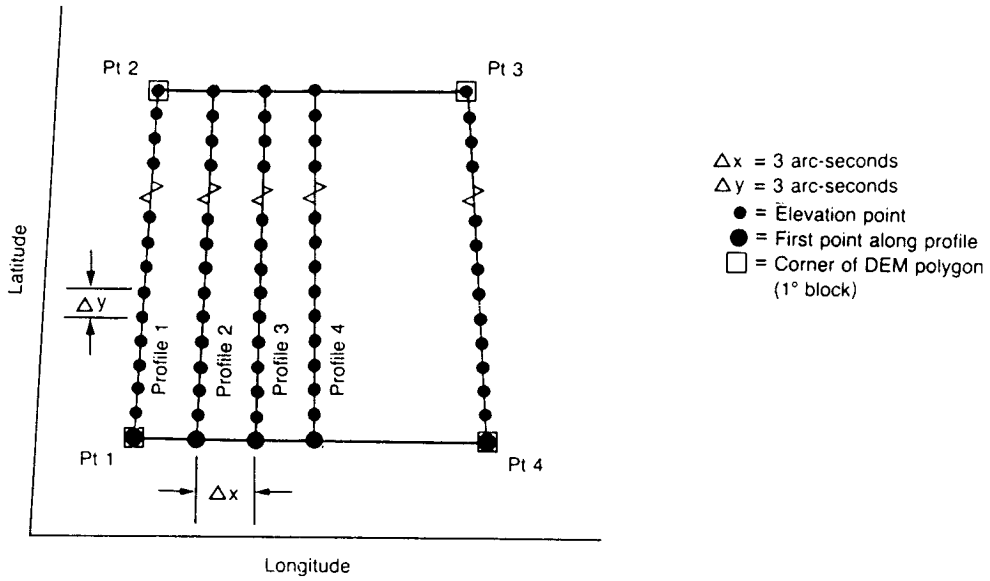
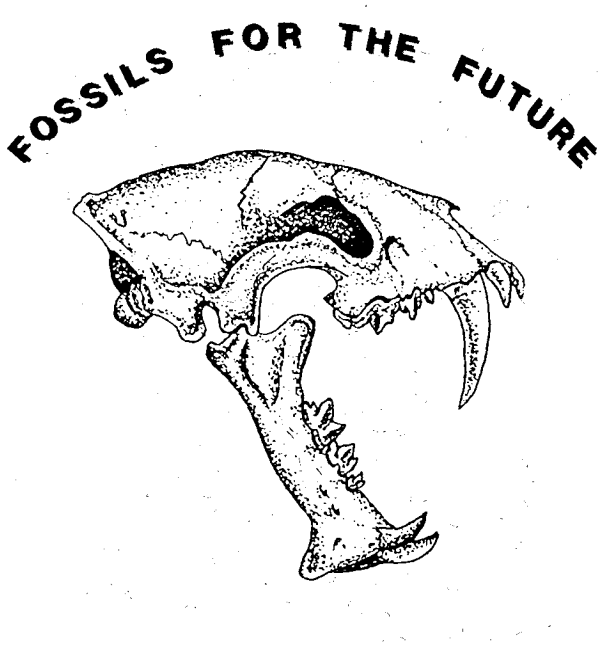


Figure 2. Structure of a 1-degree Digital Elevation Model, arc-second grid.

THE NORTHERN PLAINS GOVERNORS' CONFERENCE:



by John Hoganson

On August 24, 1992 the *Northern Plains Governors' Conference: Fossils for the Future* convened in Rapid City, South Dakota. The Conference was organized by the United States Forest Service primarily to inform the governors and citizens of the states of South Dakota, Nebraska, Montana, Wyoming, Kansas, Colorado and North Dakota of the alarming depletion of fossil resources in the Northern Great Plains and the Rocky Mountains because of the increasing commercial value of fossils. Governor George S. Mickelson of South Dakota was host governor for the conference. The popularity of dinosaurs has created an aggressive domestic and international market for fossils. This summer for example, I was contacted by a receptionist for a physician in La Jolla, California inquiring about buying North Dakota fossils to decorate his office. The problem has become acute, and the main topic of the conference was to discuss approaches for effective fossil resource management.

The conference was meant to be a public forum where fossil resource managers, professional paleontologists, amateur fossil collectors, educators, private landowners, commercial collectors, and other interested citizens could gather to identify issues and exchange ideas concerning management, protection, and economic development of fossil resources. The goal was to establish groundwork for a coordinated regional approach for effective management of our fossil resources. Governors'representatives from each of the seven states and about 150 other people attended.

The first day of the conference was for presentations concerning five main issues pertaining to fossils:

1) Public awareness and education: bringing fossils to life,

2) Conservation and preservation: connecting the pieces,

3) Economic development: the fossil market,

4) Private landowner rights: harvest or headache, and

5) Public land management: public property for public benefit.

I was invited to speak about North Dakota's Fossil Resource Management Program and landowners rights in the fourth of these sessions. I have included a copy of that speech at the end of this article. In the afternoon there was a panel discussion on current topics concerning fossils. The panel included professional paleontologists, commercial collectors, amateur collectors, para-paleontologists, museum representatives, private landowners, tribal representatives, and public land managers.

The second day, the most important day of the conference, was to be for discussions by all conference participants of the five topics presented during the preceding day. Unfortunately, the conference had to be terminated before the discussion groups could meet because of a hostage situation at the conference hotel. Not all of the controversial views were therefore heard and discussed. The conference organizers have decided to proceed with publication of a conference proceedings and all participants were asked to submit in writing their views on the issues. The proceedings will be published this year or early next year. Please contact me if you are interested in obtaining a copy.

NORTH DAKOTA'S FOSSIL RESOURCE MANAGEMENT PROGRAM and the PRIVATE LANDOWNER

by
John W. Hoganson

Editor's Note: Reprinted below is the text of a talk presented by John Hoganson at the Northern Plains Governors' Conference: Fossils for the Future.

I would like to begin this morning by briefly reviewing North Dakota's Fossil Resource Management Program because I strongly believe that each state, as well as the federal government, must have well thought-out, comprehensive fossil resource management programs before state or federal fossil resource managers can effectively deal with the issue of fossils on privately owned land, or fossils on public land for that matter. Briefly, this is what we are doing in North Dakota.

North Dakota's Fossil Resource Management Program was inaugurated in 1983 primarily in response to concern about the historic and ongoing removal of fossils from the state. This program has evolved to include three primary objectives:

1) Education to promote public understanding and awareness of the importance of North Dakota's fossil resources. Education is an extremely important aspect of our program in dealing with privately owned fossils and fossil sites.

2) Research to determine the types of organisms that inhabited North Dakota at various times in the geologic past and to determine the types of climates and environments in which they lived.

3) Identification and preservation of North Dakota's significant fossil sites and specimens.

The program is administered by the North Dakota Geological Survey, an agency of the State Industrial Commission.

There are four, separately administered, categories of lands in North Dakota: 1) lands administered by agencies of the federal government, 2) lands administered by the State of North Dakota, 3) privately owned lands, and 4) tribal lands. The North Dakota Geological Survey assumes an active role in managing paleontological resources on the first three of these lands, and we are hoping to become an adviser on fossil resources to the various tribal councils in North Dakota.

FOSSIL RESOURCES ON FEDERALLY ADMINISTERED LANDS

The North Dakota Geological Survey has signed formal agreements with the U. S. Forest Service--Custer National Forest (1986), Federal Bureau of Land Management (1988), and the U. S. Army Corps of Engineers (1991) to cooperatively identify, manage, and protect paleontological resources found on lands in North Dakota under the jurisdiction of these federal agencies. These are excellent agreements, and I would like to stress that I believe cooperation between federal and state fossil resource managers is essential to effectively manage fossil resources. I hope that there is much discussion at this conference about the need for state and federal interaction.

FOSSIL RESOURCES ON STATE ADMINISTERED LANDS

In 1989 North Dakota's Paleontological Resource Protection Act became law. The salient points of our law are similar to ones in the recently introduced federal bill, the Vertebrate Paleontological Resources Protection Act (S. 3107).

1) Significant paleontological resources, primarily vertebrate fossils, are identified in our law as being an important part of North Dakota's natural heritage and that they should be protected.

2) Our law places responsibility for management of fossil resources in the hands of the North Dakota

Geological Survey. Previously, fossils had been grouped with Indian artifacts and considered cultural resources. At that time, fossil resources were managed by archaeologists with the State Historical Society.

3) As a result of this law, a permit is required to collect significant paleontological resources on state lands in North Dakota. Significant paleontological resources generally means vertebrate fossils although there is enough flexibility in our law to allow for protection of significant invertebrate and plant fossil resources too. I am pleased to say that because of this law, hobbyists can, with a permit, collect fossils on state lands.

4) Significant paleontological resources collected from state owned lands remain the property of the State of North Dakota; that is, they remain public property.

5) Commercial collecting of fossils is prohibited on state lands in North Dakota.

FOSSIL RESOURCES ON PRIVATELY OWNED LANDS

The State of North Dakota has no jurisdiction over paleontological resources found on privately owned land. Collecting fossils from private property is, therefore, at the discretion of the landowner. I believe that is the way it should be. Private landowners should retain the right to determine what is to be done with fossils found on their property. This philosophy, however, creates problems primarily because of the increasing commercial value of fossils, particularly on the foreign market.

Private landowners are now being faced with the difficult decision to either sell their fossils to commercial dealers or donate them to public-supported institutions where they will remain in the public domain. This competition for fossils complicates management of fossil resources because most states interested in retaining their fossil heritage, like North Dakota, cannot compete with commercial dealers to pay for fossils found on private property. We must, therefore, appeal to the private landowner's sense of civic responsibility to donate these specimens to public institutions. At this we have varying degrees of success. About all we can offer is a handshake, a note of thanks, and a tax write-off.

I am convinced that landowners want to do what is right, and in North Dakota, at least, their primary concern is for what they believe is right for their family. Landowners often become confused, however, because of all the information or, let's say, misinformation they receive when they seek input about their options. This misinformation can cause major problems. Let me give you an example.

Early this summer I was contacted by a rancher from southwestern North Dakota who had some bones weathering out of the rock in one of his pastures. I visited the site and found that at least a partial skeleton of what appeared to me to be a *Triceratops* was being exposed in the Cretaceous Hell Creek Formation. Vertebrae, toe bones, part of the frill and so forth were already exposed. I informed the rancher that the find could be significant and offered to excavate the specimen, suggesting that he either donate the fossil to the State Fossil Collection, to a local museum, or to another public institution of his choice.

One of the first questions of the rancher was how much is the fossil worth. I told him that it would be difficult to assess the value before excavation and emphasized the importance of the involvement of qualified individuals in the excavation process. I explained to him that the state had no money to purchase the fossil but if donated some sort of tax credit could be arranged. The negotiations went on for some time by telephone.

By the time I revisited the site a few weeks later the rancher had been in contact with at least three commercial collectors. One of those collectors told him that if the skull was there and in good condition he would pay him several thousand dollars for the specimen. What did this mean to the rancher--a fishing trip to Alaska, a new swather, or perhaps even a new house? As a result, the rancher and several of his friends went to the site with spades and grain shovels to dig for the skull. Most of the skull was not there and much of the posterior part of the skeleton that was there was destroyed during the digging. Ironically, it appears that the fossil was not of the relatively common *Triceratops* but the rare *Torosaurus* and this would have been an important scientific specimen and possibly worth a great deal of money to the rancher.

Where does the problem lie in cases like this? Who is at fault? Is it the badland rancher surviving the fourth consecutive year of drought? I don't think so. What is the solution? Our educational approach failed in this case. These types of situations are the types of challenges that we face as custodians of fossil resources for future generations.

I would like to close with an optimistic note about a program that we have in North Dakota for preservation of fossil sites on private land--North Dakota's Natural Areas Registry Program. The North Dakota Natural Areas Registry Program was developed by the North Dakota State Parks Department and the North Dakota Chapter of the Nature Conservancy and when fossil sites are involved, the North Dakota Geological Survey takes an active role. The Registry is an important part of North Dakota's Nature Preserves program and relies on citizen-based conservation. The program was created to help preserve important natural areas, in this case, fossil sites in private ownership. Currently there are about 40 registered Natural Areas in North Dakota. Most of them are biological sites, sites of rare or endangered species of plants and animals or unique biological habitats. I am pleased to say that at this time three sites in North Dakota are on the Registry of Natural Areas because they are significant fossil sites.

The Registry is a totally volunteer, non-binding, non-regulatory program. State government officials and Nature Conservancy staff advise the landowner of the significance of their site and provide management advice to the landowner. We will also provide signs stating that the site is a natural area. No payment or receipt of funds is involved in the registry process. The landowners receive plaques from the Governor during a formal ceremony at the Capitol in appreciation for their commitment to protect part of the North Dakota's natural heritage. Owners of registry areas are asked to:

1) the best of their ability protect and preserve the registered area;

2) notify the State or Nature Conservancy of any threats to the area; and

3) notify the State or Nature Conservancy of any intent to sell or transfer ownership of the property.

The landowner may terminate participation in the program at any time, although he or she is asked to give a 30-day notice prior to cancellation.

Federal and state governments cannot and should not be held solely responsible for survival of our significant fossil sites and specimens. Individual landowners must play an integral role in conserving our fossil resources. Without their active participation and commitment we will lose, year by year, more and more portions of our fossil heritage. And we, as government fossil resource managers, must provide to these concerned landowners attractive options for preservation of fossil sites and specimens, such as the North Dakota Natural Areas Registry Program.

Meeting Announcement

INQUA Commission on Formation and Properties of Glacial Deposits Field Conference and GIS Workshop, coordinated by the Work Groups on Glacial Tectonics and Mapping Glacial Deposits, will be held May 9-15, in Regina, Saskatchewan, Canada. Papers will be presented on glaciotectonics, mapping glacial terrain, use of geographic information systems and remote sensing in glacial mapping, glacial sedimentology, glacial lakes and meltwater drainage systems, Holocene modification of glacial deposits, and related subjects. A workshop demonstration of Arc/Info GIS as used for the North American glaciotectonic map project and related mapping projects will be held. Field excursions across southern Saskatchewan are also scheduled. A registration fee of $500 CAN ($450 USA) provides six nights accommodation (double occupancy), meals, proceedings, maps, and transportation during field excursion.

For information, contact: D.J. Sauchyn, Dept. of Geography, University of Regina, Regina, Saskatchewan, S4S 0A2 Canada, (306) 585-4030, fax 306-585-4815; or J.S. Aber, Earth Science, Emporia State University, Emporia, KS 66801, (316) 341-5981, fax 316-314-5997. (*Manuscript deadline: June 1, 1992; abstract deadline: February 1, 1993*).

Ice-Thrust Topography In North Dakota

by John Bluemle

Introduction

In looking over past issues of the *NDGS Newsletter*, I see that I last wrote an article dealing specifically with ice thrusting and glaciotectonic processes in 1979. We've learned a lot about these landforms since then and it seems appropriate to provide an update now.

The landforms that resulted from the glacial thrusting process are among the most interesting found in North Dakota. As I noted in my 1979 article, it is intriguing to realize that the lake at the town of Anamoose (Steele Lake) occupies a depression that was formed when the glacier extracted--lifted or thrust--a large chunk of material, moved it as a single piece, and then set it down a tenth of a mile to the southeast. (When we first realized the origin of ice-thrust hills like the one at Anamoose in the late 1960's, we thought we would refer to the hill as an "anamoose." However, the grammatical problems arising from that name were soon apparent: Are three such hills "anameece?" "anamooses?" The name of the town "Anamoose," incidentally, is apparently an adaptation of a Chippewa word (uhnemoosh), meaning dog. The difficulties with the word soon led us to switch, simply, to "ice-thrust hills" or "ice-thrust topography." I should also add that the whole subsection of glacial geology dealing with processes such as those that result in thrusting is known as *glaciotectonics*).

Areas of ice-thrust topography are found in many places on the plains of North Dakota and throughout the prairie provinces of southern Canada (fig. 1). Three general types of ice-thrust landforms have been recognized in North Dakota: 1) roughly equidimensional hills containing thrust masses located downglacier from a source depression of similar size and shape (hill-hole pairs); 2) transverse or imbricate ridges above overturned folds or at the ends of thrust slabs; and 3) irregular, complex thrust forms.

The theory we developed ten years ago to explain ice-thrust topography goes something like this: large, intact blocks of material were incorporated into the advancing glaciers in places where the sediment or rock being overridden by the glacier contained beds of permeable materials (aquifers) confined by less permeable materials (fig. 2). This situation allowed elevated pore-water pressures to develop in the less permeable beds. Permanently frozen ground (permafrost) may have been involved as an impermeable, confining bed, but elevated pore-water pressures could result without the presence of permafrost if suitable confining conditions were otherwise present. Recently, some geologists have pointed out that the presence of aquifers is not absolutely necessary for the thrusting process to occur, and I agree that this is so. However, our observation in North Dakota is that nearly all of the thrust features we have seen are associated with aquifers. That doesn't prove a causal relationship, but it certainly suggests a correlation. Probably a somewhat more accurate statement would be that pressurized groundwater is necessary for thrusting to occur and the presence of an aquifer simply makes it more likely that the necessary groundwater conditions can be attained. I'll comment further on this at the end of this article.

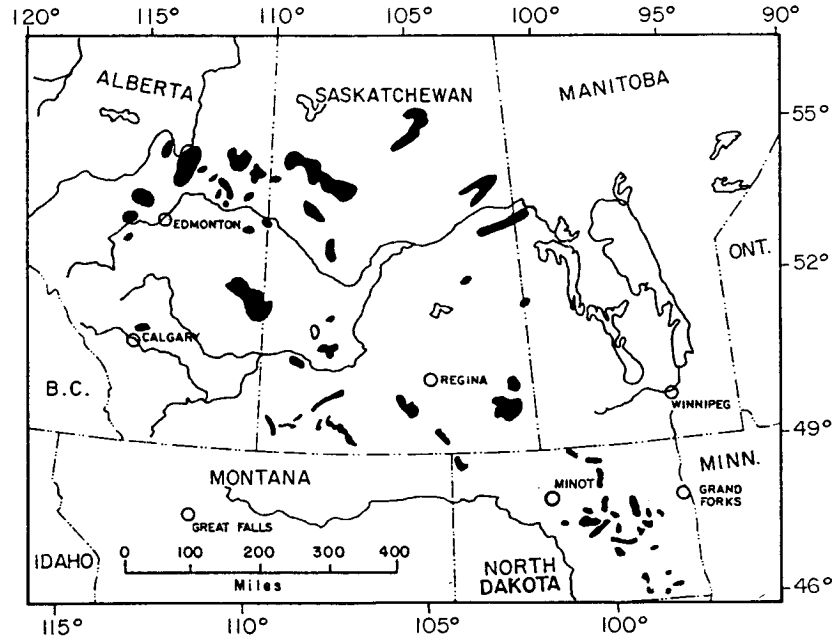


Figure 1. Locations of areas where large numbers of ice-thrust masses occur in the mid-continent region. From Bluemle (1991).

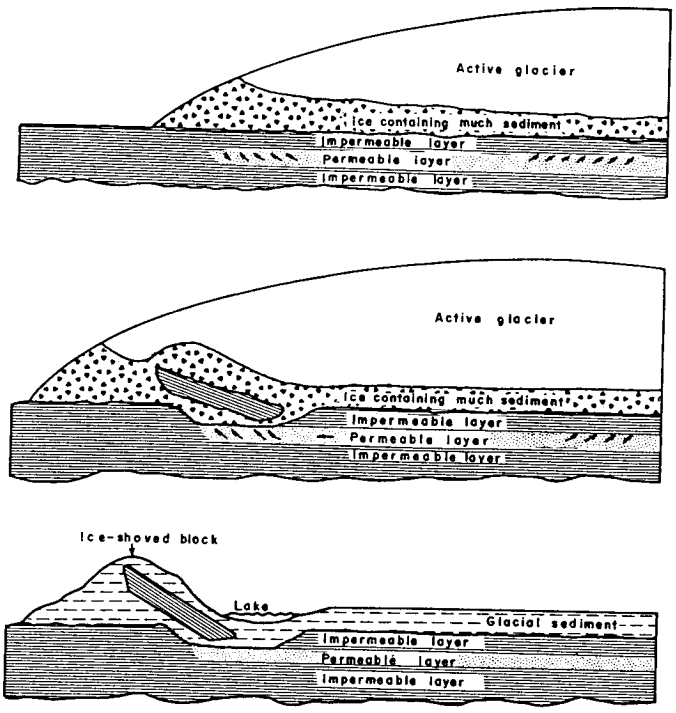


Figure 2. Three-part diagram showing how ice thrusts form. The top diagram shows water beneath the glacier being forced into a permeable zone. This water, under great pressure due to the weight of the overlying ice, moves toward the margin of the glacier to zones of decreased pressure. If the water reaches an area where the overlying, impermeable materials are weaker, it may force these overlying materials up into the path of the advancing glacier (second diagram). As a result, a large block is shoved up and a lake-filled depression forms in the area from which the block was moved (third diagram).

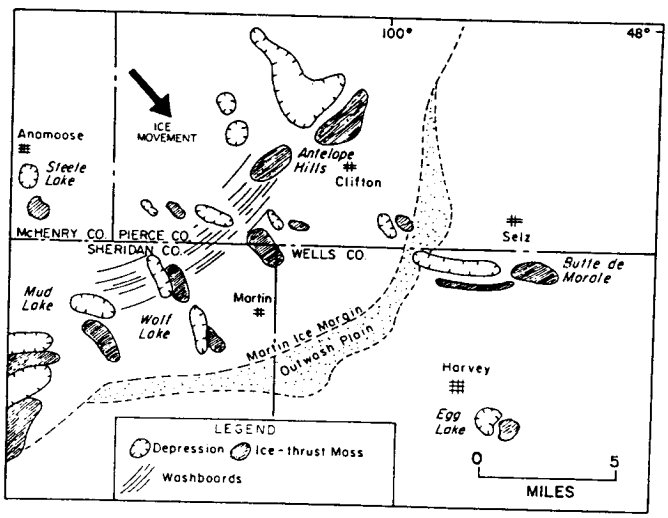


Figure 3. Map of a part of central North Dakota where intense ice thrusting resulted in numerous hill-depression thrust masses. Only the hill-depression forms are shown on the map, although other ice-thrust forms do occur in the 400-square-mile area. Most of the hill-depression thrust masses are located behind the Martin ice margin position, which marks the outer extent of a glacial advance. The shaded areas represent ice-thrust masses and the tic-marked areas represent the depressions from which the masses were derived. From Bluemle (1991).

Hill-Hole Pairs

Perhaps the most striking and obvious of the several types of thrust features found in North Dakota are those consisting of discrete hills of ice-thrust material, often slightly crumpled, situated a short distance downglacier from depressions of similar size and shape (hill-hole pairs) (figs. 2, 3, and 4). The depressions (the "holes") commonly contain lakes or ponds. A typical ice-thrust hill of this type is about 100 feet high and less than a mile across. It may be located immediately adjacent to the hole or it may be as much as three miles downglacier from it. An esker may start in the source depression and meander downglacier, around the side of the thrust mass.

The hill at Anamoose is positioned at the southeast edge of a partly buried glacial meltwater trench, which contains an aquifer consisting of about 115 to 150 feet of gravel and sand. The glacier that thrust the hill at Anamoose advanced over the one-half-mile-wide aquifer during the thrusting episode. We believe that the small esker that extends downglacier (southeastward) from the depression at Anamoose (fig. 4) was deposited by large volumes of groundwater released from the aquifer when the pore-water pressure was relieved at the time of thrusting. The esker extends about two miles to the southeast, probably to the point where the glacier's edge was located at the time. Similar eskers are found associated with many of the ice-thrust masses in the area. The formation of thrust features like the one near Anamoose might be likened to popping the cork from a bottle of champagne; after the initial release, the groundwater pressure dissipated. The pressure in the bottle (aquifer) was released when the cork (hill) was removed from the bottle (depression). The water in the aquifer, as it escaped during the thrusting process, deposited the esker beneath the glacier.

Hill-hole pairs are particularly numerous and abundant in certain parts of central North Dakota. Some

Figure 4. Air photo of ice-thrust hill with source depression (Steele Lake) at Anamoose. The shape and size of the depression occupied by Steele Lake is almost identical to that of the hill, which was derived from the depression. The diagram on the left helps to explain the relationships shown on the photo. From Bluemle (1991).

of the larger hills in this area consist, in part, of blocks of Cretaceous sandstone bedrock with bedding that was tilted, contorted, and faulted by the glacier. The high pore-water pressures that contributed to thrusting built up in zones within the bedrock.

Just a few examples of hill-hole pairs include Egg Lake Hill and Egg Lake southeast of Harvey in Wells County and Butte de Morale and Goose Lake north of Harvey; Grasshopper Hills and Medicine Lake north of Jamestown in Stutsman County; Rugh Lake and the adjacent hill in eastern Nelson County; Blue Mountain and the adjacent depression west of Stump Lake in Nelson County (fig. 5); and Devils Lake Mountain and the adjacent depression in southern Ramsey County. A large proportion of the equidimensional lakes between a half mile and three miles in diameter in North Dakota occupy thrust depressions.

Transverse, or Imbricate Ridge Forms

A second type of thrust mass consists of transverse ridges at overturned folds or at the ends of imbricate (stacked, or overlapping like shingles) thrust slabs. These features commonly consist of a composite ridge about a mile long ("length" is measured in the direction transverse to glacial flow, parallel to the ice margin). A composite ridge commonly contains 10 to 20 small ridges, each of which is about a hundred feet high and a few hundred feet long. In map view, the crests of the ridges are typically concave upglacier with a radius of curvature of one to six miles. Individual ridges (and the composite ridge as well) tend to be steepest on their downglacier sides. The depth of folding or thrusting of the transverse-ridge forms is not usually known, but individual thrust sheets are typically 100 to 300 feet thick, several hundred feet wide (measured in a direction parallel to the glacier flow), hundreds or thousands of feet long (measured parallel to the former glacier margin), and they typically dip upglacier at 30° to 60°.

Thrust masses are composed of sediment or rock that was beneath the glacier at the point where the thrusting occurred. Older glacial sediment is perhaps most common, but it normally lacks the bedding needed to reconstruct the structure of the mass. For this reason, it is likely that many thrust features composed of glacial sediment remain unrecognized. Many thrust masses are composed of lake or river sediment of Pleistocene age and several are known to be composed of Cretaceous or Paleocene materials. One example from central North Dakota, the Sibley Buttes in Kidder County, consists of a complex ridge system on which are superimposed about two dozen parallel, sharp-crested ridges consisting of Cretaceous Fox Hills Formation sandstone dipping upglacier at about 60°. The Sibley Buttes cover an area about 1.5 miles by 6 miles. Another example is the Antelope Hills in Pierce County, which consist of steeply dipping beds of Cretaceous sediment (which can be seen exposed in a railroad cut near Clifford). Dogden Butte, in northeastern McLean County, consists of at least 215 feet of the Paleocene Bullion Creek Formation sandstone, shale, and lignite that have been thrust over Pleistocene glacial sediment. All of these features are closely associated with buried aquifers.

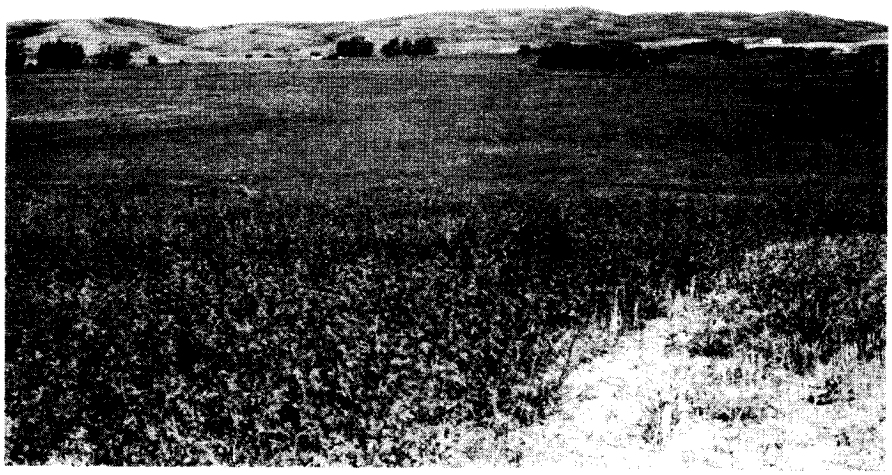


Figure 5. Blue Mountain in Nelson County. The level lake plain of the West Bay of Stump Lake is in the foreground. From Bluemle (1991).

Both glacial deposits and Cretaceous shale were involved in the extensive excavation of the Devils Lake basin, which is one of the largest and best-defined glacially excavated depressions found in the mid-continent region. The Devils Lake basin encompasses an area of approximately 300 square miles where the marine Cretaceous shale has been quarried at least 500 feet deep in places. The ice-thrust topography south of the basin covers another 200 square miles. Total relief between

the bottom of the Devils Lake basin and some of the adjacent, ice-thrust Cretaceous shale blocks, such as Sullys Hill, exceeds 650 feet. Much of the Sullys Hill-Devils Lake thrust complex is underlain by the Spiritwood Aquifer, one of the largest in North Dakota.

One of the best examples of a large, imbricate thrust and folded feature in North Dakota is the one known as the Prophets Mountains (fig. 6). The Prophets Mountains in western Sheridan County cover about eight square miles. They have local relief exceeding 300 feet, strong north-south linearity indicating imbricate thrusting from the east, and associated ice-contact river deposits along their western edge in McLean County. Much of the thrust feature is composed of glacial sediment, but a road cut on the south end of the Prophets Mountains exposes folded and contorted Cretaceous and Paleocene shale, sandstone, and coal beds. About 50 feet of Cretaceous sandstone and 40 feet of Paleocene sandstone and shale could be seen in the roadcut when it was fresh (it is now grown over with grass). The elevation of the roadcut is about 1,975 feet, whereas the subsurface contact between these two normally flat-lying formations is found in nearby test holes at an elevation of about 1,650 feet. The preglacial materials in the exposure are, therefore, interpreted as having been lifted, as a result of glacial thrusting, more than 300 feet above their original, in-place position. The Prophets Mountains directly overlie a large aquifer that is contained in a buried valley that served as a pre-modern route for the Missouri River.

Other examples of imbricate thrust masses include the "Streeter moraine" in eastern Logan and McIntosh Counties; McPhails Buttes, "Woodhouse Lake loop," "Lake Williams loop," "Crystal Springs loop," and "Lake George loop," all in Kidder County; "Alkabo moraine" in Divide County; "Binford Hills" and "Cooperstown moraine," in Griggs County; "Hawks Nest" in Wells County; and most other thrust masses on the Missouri Coteau and Turtle Mountains.

Complex Thrust Forms

A third type of glacial thrust mass, which is gradational with hill-hole pairs and transverse or imbricate ridge forms, consists of disordered terrain with irregularly distributed, closely spaced hills, ridges, and depressions. Variations in local relief are great. The hills can rarely be

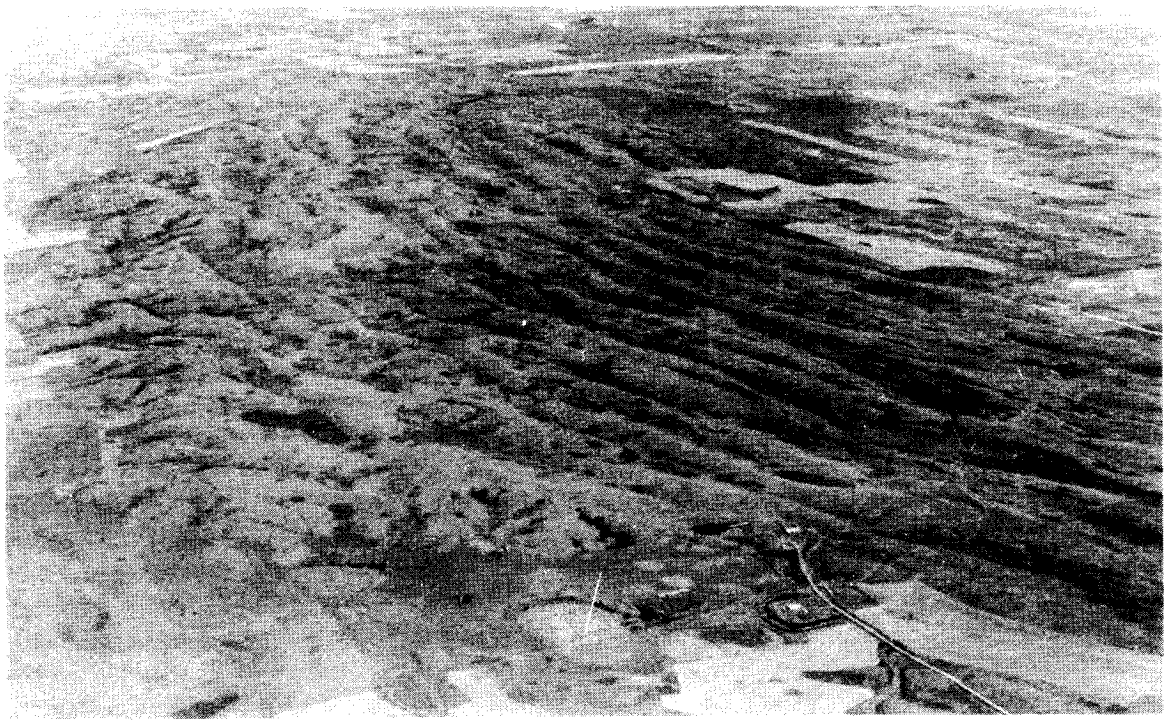


Figure 6. Prophets Mountains in western Sheridan County. A series of imbricate ridges, described in the text, were thrust by the west-flowing glacier, which came from the right (the view on this photo is to the northeast). The Prophets Mountains directly overlie a large aquifer that is contained in a buried river valley. The route of the interglacial Missouri River was to the east, directly beneath the location of the Prophets Mountains. From Bluemle (1991).

related to specific depressions. Some of the irregular forms are recognized by the presence of displaced or deformed Pleistocene river or lake sediment or Paleocene or Cretaceous rock or sediment in outcrop or in drill holes; thus, for example, if Cretaceous shale overlies glacial till in a drill hole, a thrust is inferred. Most of the features, however, were first identified on airphotos. It is likely that many of these features formed during a time when the glacier was generally advancing. Continued advance of the ice tended to smooth out the thrust features and fill in the depressions that might have formed at the time of initial thrusting.

A few examples of irregular thrust-mass forms include the Whitestone Hills area north of Gwinner in Sargent County; Standing Rock Hill on the Barnes-Ransom county line, where a large block of Cretaceous Niobrara Formation shale has been thrust over glacial sediment and Pierre Formation shale (the block was raised at least 180 feet in the process); the range of hills near Denhoff in Sheridan County; and extensive areas of rugged glacial topography in northern Pierce County, northwestern Benson County, eastern Eddy County, and northwestern Griggs County.

Discussion

Why are there so many ice-thrust features in North Dakota? Regional drainage in the area was generally to the north, opposite to the direction in which the glaciers flowed. This probably contributed to the build-up of groundwater pressures. In any situation in which the groundwater could not easily escape pressures tended to build up. If the surface ahead of an advancing glacier was frozen, this contributed to this tendency. In other instances, water probably simply became trapped in the bedrock or glacial sediments beneath the ice, thereby increasing the likelihood of thrusting. The same situation occurred in northern Europe, where glaciers advanced southward against the regional flow systems. Extensive thrusting took place there too. On the other hand, in areas where the glaciers advanced in the same direction as the regional flow systems, very little thrusting occurred. The groundwater was able to escape ahead of the advancing ice.

Certainly it was not absolutely necessary for aquifers to be present for high pore-water pressures to build up. In any situation where water could not readily drain from the sediments, high pore-water pressures tended to develop and the possibility of thrusting was greatly enhanced. On the other hand, there is an obvious correlation between the presence of aquifers and areas of ice-thrust topography. Apparently overpressured water in the aquifers contributed to the possibility of thrusting.

Pertinent References

Aber, J. S., and Bluemle, J. P., 1991, Great Plains glaciotectonics: North Dakota Geological Survey Miscellaneous Map 31.

Bluemle, J. P., 1966, Ice-thrust bedrock in northwest Cavalier County, North Dakota: North Dakota Academy of Science Proceedings, v. 20, p. 112-118.

_____, 1970, Anomalous hills and associated depressions in central North Dakota: Geological Society of America Program Abstracts, Rocky Mountain Section, p. 325.

_____, 1991, The face of North Dakota, revised edition: North Dakota Geological Survey Educational Series 21, p. 36-43.

_____, and Clayton, Lee, 1984: Large-scale glacial thrusting and related processes in North Dakota. Boreas Vol. 13, pp 279-299.

Croot, D. G. (editor), 1988, Glaciotectonics, forms and processes: A. A. Balkema, Rotterdam, 212 p.

PRODUCTION IN PERSPECTIVE

by Julie LeFever

Since oil was discovered in North Dakota in 1951, the oil and gas industry has contributed significantly towards the economy of the state. A portion of this contribution comes in the form of jobs. These jobs are related to exploration, refining, and marketing of petroleum and petroleum products. It also comes in the form of oil and gas severance taxes, which play a major role in the state's budget. These taxes comprise approximately 11% of the general fund money for the current biennium. Additional revenue to the state comes from oil leases, bonuses, royalties, and gasoline and special fuel taxes.

The following facts attempt to place the oil and gas industry of North Dakota in perspective with the United States and the world.

NORTH DAKOTA

* North Dakota is ranked 9th in total crude oil production in the United States. North Dakota produced 35.9 million barrels of oil in 1991. The average daily production rate was 98,321 barrels. This average daily production is enough to fill a silo 30 feet in diameter and 195 feet high.

* A total of 3,447 wells were producing in North Dakota at the end of 1991. The average well produced 29 barrels of oil per day (BOPD) (1,218 gallons) in 1991.

* The drilling rig count averaged 13 rigs in 1991, down from the record high average of 119 in 1980.

* The value of North Dakota crude oil produced in 1991 was approximately $704 million. Total estimated value for production to date is in excess of $16.2 billion.

* Total crude oil production in North Dakota amounts to more than 1.1 billion barrels with remaining reserves estimated to be in excess of one billion barrels. The remaining reserves assume production obtained from secondary and tertiary recovery techniques.

* An estimated 54.8 billion cubic feet of natural gas was processed in North Dakota during 1991 (valued at more than $68.5 million).

UNITED STATES

* Ranking of States in the U.S. by crude oil production:

1. Texas	6. Wyoming
2. Alaska	7. New Mexico
3. Louisiana	8. Kansas
4. California	9. North Dakota
5. Oklahoma	10. Colorado

* The average well in the United States produces 12.5 BOPD ($250 @ $20/barrel) compared to the average well in Saudi Arabia that produces 8,314 BOPD ($166,280 @ $20/barrel). 1 out of every 5 wells in the United States is marginal. Stripper wells produced 383,196,892 barrels of oil in 1991. Nationwide, 17,235 stripper wells were abandoned in 1991.

* Over 10.4% of the oil produced in the United States comes from Enhanced Oil Recovery (EOR) projects. This percentage results from an overall increase in EOR projects and a decrease in domestic oil production.

WORLD

* Ranking of Countries by Average Monthly Crude Oil Production (barrels/day):

1. USSR	10,300,000
(CIS - Commonwealth of Independent States)	
2. Saudi Arabia	8,158,000
3. United States	7,372,000
4. Iran	3,358,000
5. China	2,800,000

* EOR projects throughout the world produced a total of 1.9 million BOPD (equals 3.2% of the average daily total of 59.96 million BOPD in 1991).

* OPEC crude production rose 0.6% (averaging 23.425 million BOPD; non-OPEC production fell 1.9% (averaging 36.539 million BOPD).

* World demand is up 200,000 BOPD (1991), to a total of 66.4 million BOPD.

* World crude oil prices average $17.82 per barrel (down 16.5% from 1990).

RADIOMETRICS AND FREE GAS MEASUREMENTS APPLIED TO OIL EXPLORATION IN NORTH DAKOTA

by Randy Burke

During a period when major oil companies are downsizing and exploring abroad, smaller companies and independents take over domestic exploration and field development. Small geologic staffs and budgets require exploration reconnaissance techniques that are economical and rapid in order to focus both labor intensive geologic research and the spending of limited seismic exploration budgets. These conditions encourage the use of less conventional exploration methods and ideas. One such idea is that oil reservoirs will cause various vertical anomalies above the reservoir that are detectable at the earth's surface.

Oil reservoirs are anomalies in the earth's crust where different phases and compositions of hydrocarbons are concentrated. Accumulations of oil and gas alter the passage of many of the products normally emitted from the earth's crust. The earth is continuously liberating and transmitting a variety of gases, fluids and radiation as part of the normal evolutionary processes of the planet. These emissions are measurable and provide a background from which to detect anomalies. The occurrence of any large concentration of elements or compounds, such as oil, will alter the type, rate and distribution of these emissions. Common examples of this phenomenon are concentrations of iron that will alter the geophysical environment by having increased gravity and magnetic intensity, uranium rich beds that have increased radiation levels, and oil by seeps that have increased hydrocarbon gases.

Much of the theory upon which most direct detection geophysical and geochemical exploration techniques are based is premised on the assumption that the rocks confining petroleum reservoirs are leaky, and hydrocarbons will migrate vertically and imprint anomalous conditions in the overlying rocks, soil, vegetation and atmosphere. A variety of geochemical and geophysical survey techniques can detect these anomalies and can be used economically and quickly to evaluate large areas for their hydrocarbon potential. Radiometrics and gas measurements (sniffing) are two such techniques.

Radiometrics

Radiometrics in this instance is the measurement of radiation that is naturally emitted by earth materials, specifically gamma radiation. The common terrestrial gamma radiation sources include bismuth 214, from the decay of uranium 238; thallium 208, from the decay of thorium 232; and potassium 40 found in illite and mixed-layered clays. The radiometer is a device that consists principally of a large crystal sensor and electronic filters to record specific wavelengths of radiation. Crystal size and quality determine the quality of the results. Crystal composition ranges from natural sodium iodide to synthetic plastic. A minimum size is around 256 cubic inches although some up to 1,000 cubic inches are used. The larger the crystal the better the response because radiation detection is from a larger area. Large natural crystals of sodium iodide cost up to $250,000. The radiation sensor can be hooked up to the same strip chart recorder that records hydrocarbons so that concurrent sampling occurs and the coincidence of radiation and gas anomalies is readily observable. Radiometric surveys range in price from $40-$50/mile (Schumacher and Weissenberger, 1992). This technique is considered an indirect geochemical method of detecting subsurface accumulations of hydrocarbons because it measures the effect of the presence of hydrocarbons without actually measuring hydrocarbons.

Petroleum explorationists look for radiation levels above or below normal background levels, therefore anomalous levels, of radiation. Anomalies occur because petroleum reservoirs serve both as a filter and a barrier to naturally occurring emissions from the earth. The passage of different compounds and their phases as they migrate outward from the earth will be altered as they encounter large accumulations of hydrocarbons. Oil reservoirs thus act as a barrier to the transmission of radiation because radiation adsorbs to hydrocarbons and precludes the accumulation of radiation emitting minerals immediately above the hydrocarbon reservoir. This creates a lowering of the background emissions of radiation over the top of an oil reservoir (Figure 1). Radiation levels are increased

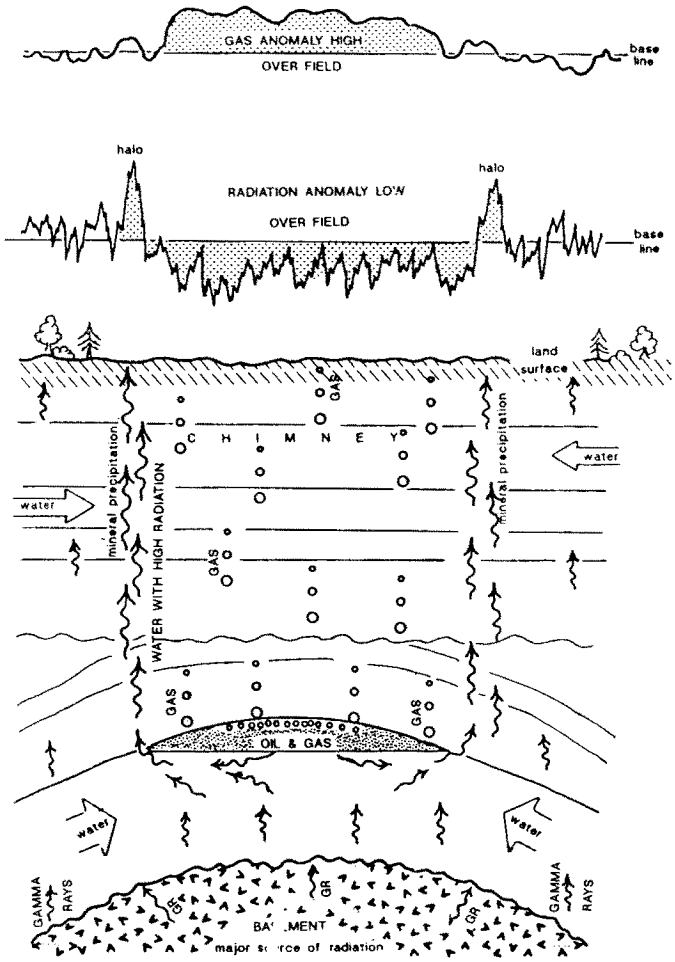


Figure 1. Schematic cross-section showing source and path of gamma radiation and hydrocarbon gases. Note how the oil and gas reservoir produces a gas anomaly high over the top of the reservoir, and how the reservoir acts as a barrier to emanating gamma radiation. The barrier produces a radiation anomaly low over the top of the reservoir and is bordered by increased radiation levels. When mapped, these increased radiation levels form a ring, or "halo", that approximates the perimeter of the hydrocarbon reservoir. Modified from Weart and Heimberg (1981).

around the edges of an oil reservoir and are recorded by a peak in the radiometric signal (Figures 1 and 2). When the increased radiation levels are mapped, they appear as a ring, or "halo", that approximates the perimeter of the hydrocarbon reservoir.

There are at least two theories to explain the high levels of radiation around a hydrocarbon reservoir. Weart and Heimberg (1981) interpreted the raised radiation levels to result from the vertical movement of ground water around the reservoir (Figure 1). Formation waters already containing background concentrations of radiation will gain radiation from that adsorbed to the hydrocarbons when they encounter an oil reservoir. Water moving out around the edges of the oil barrier will have higher than background concentrations of radiation. This creates an emission of radiation around the perimeter of the reservoir higher than background levels. This halo of intense radiation can define the limits of a reservoir.

Tompkins (1990) explained the radiation halo as part of a "unified theory" to explain the wide range of geochemical and mineralogic anomalies found over oil reservoirs. Simply, the theory suggests that a large redox cell is established over the top (chimney) of the hydrocarbon reservoir. It is the concentration of radioactive minerals along the walls of the chimney that cause the increased radioactive response. Radioactive minerals are concentrated around the perimeter of the reservoir by the reaction of horizontally moving ground waters encountering the redox cell. This reaction results in the precipitation of radioactive minerals.

Free Gas Measurements

Free gas measurement in this case is simply the direct measurement of ambient gaseous hydrocarbons in the atmosphere from an actively seeping reservoir. Leaking oil pools can cause anomalous high gas concentrations in the air above the reservoir (Figure 1). Some people have suggested that all reservoirs are leaky only at various rates to different hydrocarbon molecules (Tompkins, 1990; and Kontorovich, A.E., 1984). There is a wide chemical spectrum of gases emitted by oil reservoirs, but methane is one common form detected with gas sensors. Small quantities of gas can be easily detected during continuous recording while travelling over areas with increased hydrocarbon concentrations. Measurement of gas emission is considered a direct detection technique.

Many areas have high levels of biogenic methane, so characterization of the source and type of hydrocarbon gases is necessary. This type of sampling and analysis might cost as much as $60-$100/sample and the area sampled should be on a grid every 2 to 10 miles depending on the size of the anomaly being tested (Schumacher and Weissenberger, 1992).

One advantage of free atmospheric gas and radiometrics surveys is that they can be run simultaneously. Both instruments are mounted on a truck that is driven

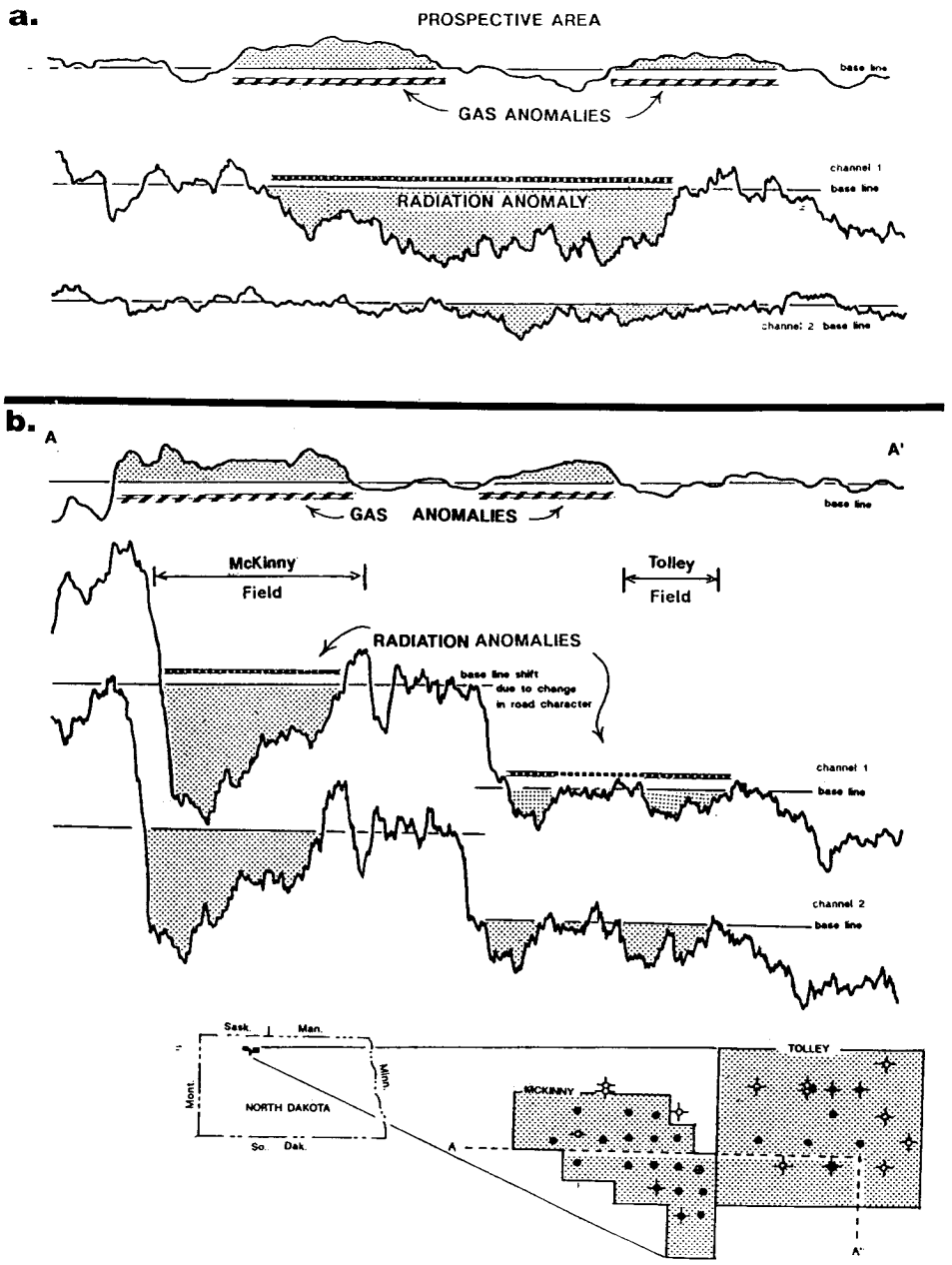


Figure 2. ***a.*** *Radiation and gas profiles over prospective wildcat areas in the southern Williston Basin.* ***b.*** *Radiometric and free gas reconnaissance transect over the McKinny and Tolley fields of north-central North Dakota. Note the location of the two fields with respect to radiation low and gas high, and radiometric baseline shift due to change in road character. Source: Personal communication - Dr. Richard Inden, LSSI, 1992.*

over all types of passable surfaces. The gas sniffer can be mounted on the front bumper, intake down about six inches off the ground. It consists of a gas detector and a fan that pulls air toward the sensor while driving. The sensor is hooked up to either a strip chart or digital recording device that continuously records readings while driving. It is important to maintain a constant rate of travel to insure a uniform rate of sampling.

Some Constraints

There are a number of factors that have to be accounted for when making both radiometric and gas surveys. Two factors of particular concern in evaluating radiometric measurements in North Dakota are the influx of glacial debris from the Canadian shield in the northern portion of the state and high levels of uranium in the southwestern portion of the state. Igneous and metamorphic rocks common to the Canadian Shield are similar to the basement rocks and contain a variety of minerals with radioactive potential. Additional factors affecting radiometric readings that must be recorded during surveys are changes in soil types and occurrences of moisture. When utilizing established roads and tracks, the character of the

road should be noted. Significant variability in the intensity of the signal can occur depending on the composition of the road (gravel, asphalt, or earthen track; Figure 2b, see base line shift). There will be a change of intensity in the radiometric signal as one passes from one road surface to another. Standing bodies of water and moist soil will significantly depress the intensity of the signal because water absorbs radiation. Qualitative adjustments are made by readjusting the baseline when conditions change. This can be seen in Figure 2b. The qualitative adjustments make some people skeptical of the technique, but one must remember that background levels are subject to natural variations and it is the presence of an unexplained anomaly that is the indicator of oil and gas, especially when it is combined with other geological and geophysical data.

Gas detectors (sniffers) are subject to a wide range of external factors influencing measurements as well. Significantly high readings are caused by paved roads, freshness of the asphalt, or by passing vehicles. Likewise, wetlands and active pasture land or livestock feed lots will give high positive anomalies. This tool is also sensitive to soil type and to soil moisture. In the glaciated terrain north of the Missouri River, buried glacial lake deposits produce large volumes of methane. The high organic content of the Pleistocene lake sediments has produced sufficient quantities of natural gas to be used locally for domestic purposes.

The large number of nonhydrocarbon variables that can contribute to reducing or enhancing these signals are reason for concern. Statistical techniques are available for more precise testing for the significance of anomalies. Some statistical tests applied to this type of geochemical data are clearly and concisely discussed by Weissenberger (Schumacher and Weissenberger, 1992).

The reliability of a variety of geochemical and geophysical techniques, including these, were tested as part of a larger geochemical study that evaluated 12 different geochemical methods (Calhoun, 1991). The purpose of the experiment was to evaluate surface geochemical exploration methods that are effective in finding oil. The experiment design required that the techniques be tested over well locations that met two criteria; 1) companies were committed to drill, and 2) locations had been selected using conventional exploration techniques. The windowed radiometrics accurately predicted oil in 15 of 18 wells drilled for an 88% success rate (Calhoun, 1991). One of the conclusions of GERT (Geochemical Evaluation Research Team) was that there is no single best geochemical tool because they measure different things and most geologic settings differ. Therefore a minimum of three geochemical techniques must be applied to fairly evaluate a prospect with geochemical tools. One of the techniques recommended was some type of direct detection in order to recognize live seeps. The direct detection technique with the greatest success (73%) was fluorescence-microbial analysis of soil samples.

Case Studies

Recently, Dr. Richard Inden of LSSI (Lithologic and Stratigraphic Solutions), Denver, Colorado, was in North Dakota and South Dakota conducting a radiometric and free gas survey. Hired by an independent company, the objective of the survey was reconnaissance exploration for oil and gas in under-explored wildcat areas. This reconnaissance survey included a test transect over both McKinny and Tolley fields (Figure 2b). The predicted response of coincident radiometric low readings with high gas readings were found over those oil fields in addition to being found over the prospective wildcat areas (Figure 2a). The intent is to resurvey areas that have coincident low radiation and high gas anomalies with more detailed soil gas surveys. The soil gas surveys take shallow (less that 1 foot to 10 feet) samples of gas from the soil and analyze them for specific types of hydrocarbon gases.

A number of geochemical and geophysical surveys have been run in the Williston Basin and North Dakota. Some results from these types of surveys in Bowman and Ward Counties are reported in Weart and Heimberg (1981); in Saskatchewan and Montana in Schumacher and Weissenberger (1992); and for Pratt and Glenburn fields, North Dakota, in Pirson (1969).

Summary

The discovery of a radiometric or free gas surface anomaly does not prove the occurrence of economic quantities of hydrocarbons, however, it does establish the presence of hydrocarbons. If the geology indicates potential structures or other traps, this additional information allows one to high-grade prospects or help guide development programs.

These tools and other direct and indirect geochemical tests serve as a complement to more traditional geologic and geophysical exploration techniques. Results from these techniques should be integrated with information from more traditional techniques. "Properly applied, the combination of surface and subsurface exploration methods has the potential to greatly reduce exploration and

development costs, while improving success rates and shortening development time" (p. 5, Schumacher and Weissenberger, 1992).

References and suggestions for further reading

Calhoun C.G., 1991, How 12 geochemical methods fared in GERT project in Permian Basin. Oil and Gas Journal, p. 68.

Curry III, W.H., 1984, Evaluation of Surface Gamma Radiation Surveys for Petroleum Exploration in the Deep Powder River Basin, Wyoming. In, Davidson, M.J., Gottlieb, B.M. eds., Unconventional Methods in Exploration for Petroleum and Natural Gas III; A symposium under the auspices of the Institute for the Study of Earth and Man, Southern Methodist University Press, Dallas, Texas, p. 25-39.

Groth, P.K.H., 1988, Bibliography for Near Surface Prospecting Methods. Special Publication No. 2, Association of Petroleum Geochemical Explorationists, Denver, Co.; pp. 244.

Foote, R.S., 1969, Review of Radiometric Techniques in Petroleum Exploration. In, Heroy, W.B., ed., Unconventional Methods in Exploration for Petroleum and Natural Gas; A symposium under the auspices of the Institute for the Study of Earth and Man, Southern Methodist University Press, Dallas, Texas, p.43-55.

Jones, V.T., and Drozd, R.J., 1983, Predictions of Oil or Gas Potential by Near-Surface Geochemistry. American Association of Petroleum Geologists 67 (6):932-952.

Kontorovich, A.E., 1984, Geochemical Methods for the Quantitative Evaluation of the Petroleum Potential of Sedimentary Basins. In, G. Demaison and R. J. Morris, eds., Petroleum Geochemistry and Basin Evaluation; AAPG Memoir 35, Tulsa, Oklahoma, p. 79-109.

MacElvain, R.C., 1969, Mechanics of Gaseous Ascension Through A Sedimentary Column. In, Heroy, W.B., ed., Unconventional Methods in Exploration for Petroleum and Natural Gas; A symposium under the auspices of the Institute for the Study of Earth and Man, Southern Methodist University Press, Dallas, Texas, p. 15-28.

Pirson, S.J., 1969, Geological, Geophysical and Chemical Modifications of Sediments in the Environment of Oil Fields. In, Heroy, W.B., ed., Unconventional Methods in Exploration for Petroleum and Natural Gas; A symposium under the auspices of the Institute for the Study of Earth and Man, Southern Methodist University Press, Dallas, Texas, p. 159-186.

Saunders, D.F., Burson, K.R., and Thompson, C.K., 1991, Observed Relation of Soil Magnetic Susceptibility and Soil Gas Hydrocarbon Analyses to Subsurface Hydrocarbon Accumulations. American Association of Petroleum Geologists 75(3):389-408.

Schumacher, D., and Weissenberger, K., 1992, Surface Exploration for Oil and Gas Advances of the Eighties, Application for the Nineties. Short Course Notes Canadian Society of Petroleum Geologists for 1992 AAPG Annual Convention, Calgary, Alberta, Canada; pp. 133.

Tompkins, Reed, 1990, Direct location technologies: a unified theory. Oil and Gas Journal, p. 126-134.

Weart, R.C., and Heimberg, G., 1981, Exploration Radiometrics: Postsurvey Drilling Results. In, B.M. Gottlieb, ed., Unconventional Methods in Exploration for Petroleum and Natural Gas II; A symposium under the auspices of the Institute for the Study of Earth and Man, Southern Methodist University Press, Dallas, Texas, p. 116-123.

CURRENT STAFF ACTIVITIES

Bob Biek has continued detailed geologic mapping in the Jamestown area. He is also working to develop a contract mapping program wherein qualified geologists and geology graduate students can map a 7.5' quadrangle in exchange for certain NDGS support.

Bob has spent a considerable amount of time with the State's Geothermal Regulatory Program. He revised the regulations (see article on page 2), coordinated review of two new heat transfer fluids, and worked to get existing systems permitted. He also presented a poster summarizing North Dakota's industrial mineral production, potential, and regulation at an industrial minerals workshop (see article page 3). He was co-editor of the "Program with Abstracts" for that workshop. He also worked on an educational publication about the building stones used on the North Dakota Capitol Grounds, which should be completed this winter.

Bob also compiled an introductory brochure about the Survey. He participated in the Central Dakota Gem and Mineral Society annual show and organized the Survey's display for State Employees Appreciation Week in Bismarck.

John Bluemle, despite daily administrative duties, has completed a manuscript on the long drumlins in McHenry County ("Exceptionally long, narrow drumlins formed in subglacial cavities, North Dakota"), which will be published in the January issue of *Boreas*, an international journal of geology published in Sweden. The paper was co-authored by Mark Lord and Nathan Hunke. John is working on a report with Dr. James S. Aber (Emporia State University) on the distribution and occurrence of glaciotectonic features of the northern plains. That report will be published in a symposium volume of INQUA (see meeting announcement on page 15). He is also involved with Dr. Aber in a study of glacial and environmental geology using Landsat images of the Devils Lake region. John co-authored a report on the geology and hydrogeology of the Devils Lake wastewater impoundments (reviewed on page 32).

John attended the annual meeting of the Association of American State Geologists in Tuscaloosa and the national meeting of the American Association of Petroleum Geologists in Calgary (both in June), and the annual meeting of the Rocky Mountain Section of the American Association of Petroleum Geologists in September. He participated in the Central Dakota Gem and Mineral Society annual show and helped staff the Survey's display at the State Employee's Appreciation Week show in Bismarck. John also gave several talks at service organizations, mainly on topics relating to the geology of North Dakota; all of these were in Bismarck.

Randy Burke has nearly completed his study of the Lucky Mound Field. He has examined all the available cores and is now working on the report, which should be completed around the first of the year.

This past summer, Randy became involved with a radiometric and free gas survey in north central North Dakota. This led him to become better informed on the wide array of direct and indirect geochemical and geophysical tools that are currently being used and tested in exploration for hydrocarbons. With the down-sizing of the domestic oil industry these economical exploration techniques are becoming more attractive.

Randy's project on the Devonian Winnipegosis reefs continues but at a slowed pace. Delayed by acquisition of additional seismic data, he looks forward to interpreting that data for comparison with gravity maps. Once the interpretation of the seismic data is complete and the gravity maps are revised, the project should progress quickly.

During June, Randy attended the AAPG National Convention in Calgary. While there, he participated in an AAPG short course entitled "Sedimentology and Sequence Stratigraphy of Reefs and Carbonate Platforms," earning 1.5 continuing education units.

Phil Greer is continuing work on landfill site evaluations as part of a cooperative program with the State Water Commission. This study began in early 1992 and is scheduled to be completed on July 1, 1995. The objectives are to determine the types of rock and soil beneath each landfill, the depth to the water table, and the direction of groundwater flow. Water samples are taken at each landfill to test for possible groundwater contamination.

During the 1992 drilling season field work was completed at 19 landfills across the state. Sites completed include: Mandan, Glen Ullin, New Salem, Hebron, Hazen, Beulah, Jamestown, Valley City, Bismarck, Mayville, Casselton, Devils Lake, Nelson County, Bauer Sanitation near Wilton, Huschka Sanitation near Underwood, Gahner Sanitation near Kulm, Jahner Sanitation near Wishek, USA Waste near Gwinner, and Lloyd Sanitation near Fessenden.

Reports on the first 19 landfills should be completed this winter. Approximately 15 additional landfills will be studied during the 1993 field season. Phil also participated in the Central Dakota Gem and Mineral Society annual show.

Tom Heck recently completed the 1990-1991 oil and gas update for the North Dakota portion of the Williston Basin (reviewed on page 31). He currently has two projects underway. For the biennial report published by the Potential Gas Committee, he is estimating the undiscovered gas resources in the North Dakota portion of the Williston Basin. That report should be available in May, 1993.

With Dr. Richard LeFever (UND), Tom has estimated the ultimate recovery, producing area, and number of wells for all producing oil and gas fields and pools in North Dakota. From this information, and the discovery history of the fields, they will estimate the amount of oil and gas that remains to be found in North Dakota. The study may be extended, in cooperation with the State of Montana and the Geological Survey of Canada, to include an estimate of remaining reserves for the entire Williston Basin.

John Hoganson published a paper entitled "Vertebrate fossil record, age, and paleoenvironmental setting of the Brule Formation (Oligocene) in North Dakota" and co-edited the volume in which it appears (reviewed on page 31). He was an invited speaker at the "Northern Plains Governors' Conference: Fossils for the Future" where he gave a presentation on the North Dakota Fossil Resource Management Program. John also attended the North American Paleontological Convention in Chicago where he participated in a round table discussion concerning fossil resources on public lands.

With Ed Murphy and Nels Forsman of UND, John continues to work on a COGEOMAP project of the stratigraphy and paleontology of Oligocene and Miocene rocks of western North Dakota buttes. Also with these two co-researchers and Doug Nichols (USGS), he is continuing work on the Cretaceous/Tertiary boundary in North Dakota. Other projects that John is now working on include studies of vertebrate fossils from Cretaceous formations in North Dakota and Manitoba. With Ed Murphy and Donald Schwert (NDSU), John will soon begin work on Roadside Geology of North Dakota, one in the nationally acclaimed series published by Mountain Press.

John acts as an advisor to the North Dakota Land Department, evaluating Oil and Gas Lease Sale land for potential impact on paleontological resources; he is also responsible for the State's Paleontological Resource Protection Regulations. John gave 8 public service presentations about paleontology and North Dakota fossils to a variety of service groups and organizations, and participated in a KX12 TV program regarding North Dakota dinosaurs and their extinction. He also participated in the Central Dakota Gem and Mineral Society annual show, a Girl Scout Camp on Lake Sakakawea, and in the grand opening of the Heritage Center's Prehistory exhibit.

Julie LeFever is continuing work on two projects dealing with the Bakken Formation. One is a joint project with Leigh Price of the USGS in which they are focusing on correlation of source rocks to produced oil in an attempt to define the amount of lateral and vertical migration of Bakken-sourced oil. In addition, she continues with her own study of the Bakken Formation, mapping lithofacies of the Bakken and the lower portion of the overlying Lodgepole Formation ("false Bakken"). The main emphasis of that project is to evaluate the petroleum potential of the middle member of the Bakken Formation throughout the state.

In addition to her research, Julie is the Director of the Wilson M. Laird Core and Sample Library in Grand Forks. She is currently working on a full-scale inventory of the library. Julie also gave a presentation on the Bakken at the Rocky Mountain AAPG meeting in Casper, Wyoming, a similar presentation to the North Dakota Geological Society in Bismarck, and a presentation on geology to the Lake Agassiz School fourth grade class.

Mark Luther is still devoting at least half of his time to getting the Survey's GIS lab fully equipped and operational. Mark is coordinating several GIS/CAD

projects now underway (see article on page 2.)

Mark is working on a GIS prototype project in Grand Forks County designed to test the integration potential of digital spatial data produced by a number of natural resource agencies operating in North Dakota. The project should reduce the likelihood of duplication of effort or the need for extensive revision of coverages. The NDGS and the USGS Water Resources Division are the lead agencies working with several other state and federal agencies on this prototype project. Ken Harris (formerly with the NDGS and now with the Minnesota Geological Survey) has helped Mark with the conversion of geologic mapping from both the County Bulletins and Atlas Series of maps onto a 1:24,000 scale base map.

On behalf of the State GIS Technical Committee, Mark once again coordinated the State GIS Symposium, held November 17 and 18, 1992. There were displays of GIS hardware and software by over 10 vendors, and 1 1/2 days of presentations by experts in the field of GIS. More than 200 people attended the symposium.

Mark has also spent a great deal of time on our map sales and ESIC program. He has given talks on map types, and topographic map and compass use, to several groups including the Girl Scouts, sportsman groups, and the State Teachers Convention. Along with Bob Christensen (NDDOT), Mark gave a demonstration on UV fluorescence to more than 200 children at the Heritage Center's Kid's Night. He continues to be active on issues involving nonpoint source pollution.

Bill McClellan continues his work on the regional distribution of the Sherwood interval of the Mission Canyon Formation (the study is an extension of the play that includes the recently discovered Lucky Mound Field). Bill also supervised the set-up of our new lab and storage facilities, and has worked to improve core handling procedures (see article on page 6).

Bill attended several meetings, including the Interstate Oil and Gas Commerce Commission (IOGCC) semi-annual meeting last June in Wichita, Kansas. In August he attended the "Northern Plains Governors' Conference: Fossils for the Future" in Rapid City, South Dakota; in September, a USGS cluster meeting with central region State Geologists; and in October, a one-day workshop entitled "Doing Business with the DOE" where he learned more about federal funding available to state agencies for oil and gas programs.

Ed Murphy has recently completed or is nearing completion of several reports. With Steve Pusc (State Water Commission) and John Bluemle, he published a geologic and hydrogeologic investigation of the Devils Lake wastewater impoundments (reviewed on page 32). He also completed an important comparative study of six landfills in North Dakota (reviewed on page 32), and by the time this issue goes to press, will have completed an investigation of Tordon and 2,4-D in groundwater in the Denbigh Sand Hills of McHenry County. In addition, with co-investigators John Hoganson and Nels Forsman (UND), Ed is nearing completion of a COGEOMAP study of the stratigraphy and paleontology of Oligocene and Miocene rocks of western North Dakota buttes. Ed is also working with John Hoganson on the Cretaceous/Tertiary COGEOMAP project mentioned above. With John Hoganson and Donald Schwert (NDSU), Ed will soon begin work on Roadside Geology of North Dakota, part of the nationally acclaimed series published by Mountain Press.

This past summer, Ed began assisting Kris Roberts (State Department of Health) with his project on the occurrence of uranium in groundwater of western North Dakota. Ed continues to oversee regulatory programs for coal exploration, subsurface minerals, and underground injection control, and has reviewed several landfill permits. Ed also participated in the Central Dakota Gem and Mineral Society annual show.

NEW NDGS PUBLICATIONS

Oil Exploration and Development in the North Dakota Williston Basin: 1990 - 1991 Update, by Thomas J. Heck, NDGS Miscellaneous Series 77, (1992), 26 pages, $6.00.

This, the most recent in a series of biennial oil and gas updates, summarizes petroleum development and exploration in North Dakota in the 1980s and focuses on the events and changes of 1990 and 1991. The report presents a detailed analysis of drilling activity in 1990 and 1991. Each field or productive horizon is discussed, with particular attention given to the Bakken play and the Sherwood shoreline play, the centers of industry interest during this time.

The report contains numerous bar and line graphs that clearly illustrate trends in tax revenues, number of wells drilled each year, number of new pools discovered, annual crude oil production, and other factors. Also included are three maps that show the locations of all known oil fields in North Dakota (including those fields discovered in 1990 and 1991) and a list of new field/pool discoveries.

Proceedings of the F. D. Holland, Jr., Geological Symposium, edited by J. Mark Erickson and John W. Hoganson, NDGS Miscellaneous Series 76, (1992), 318 pages, $15.00.

This Proceedings contains 16 technical papers, listed below, 14 of which were presented at the April 14, 1989 F. D. Holland, Jr., Geological Symposium. Abstracts of papers presented at the symposium, the program itself, and a dedication to F. D. "Bud" Holland are also included. The symposium was organized in honor of Dr. Holland, who taught paleontology and geology at the University of North Dakota for 35 years. The diversity of the papers reflects not only the diversity of interest of his former students, but that of Dr. Holland himself.

"A Dedication to F.D. Holland, Jr., Praire Paleontologist, from Former Students and Colleagues," by J. Mark Erickson;

"Ordovician Coals of the Red River - Stony Mountain Province," by Frank P. Caramanica;

"Arthrostylidae (Bryozoa: Cryptostomata) from the Gunn Member, Stoney Mountain Formation (Upper Ordovician), North Dakota and Manitoba," by Frederick K. Lobdell;

"Cyanobacterial Filaments and Algae in the Winnipegosis Formation (Middle Devonian), Williston Basin, North Dakota," by Nancy A. Perrin;

"The Paleoecology of *Echinocaris randallii* Beeceher from Drake Well, Titusville, Pennsylvannia," by Rodney M. Feldmann, Joseph T. Hannibal, Douglas J. Mullet, Barbara A. Schwimmer, Dale Tshudy, Annette B. Tucker, and Robert W. Wieder;

"Petroleum Source Rocks and Stratigraphy of the Bakken Formation in North Dakota," by Rick L. Webster;

"Brachipods as a Biostratigraphic Tool for Correlating Devonian-Mississippian Rock Sequences," by Lawrence C. Thrasher;

"*Tylerocaris hollandi* n. gen., n. sp., (Malacostraca: Tealliocarididae) from the Tyler Formation (Pennsylvannian) of North Dakota," by James C. Grenda;

"Subsurface Stratigraphy, Lithofacies and Paleoenvironments of the Fox Hills Formation (Maastrichtian: Late Cretaceous) Adjacent to the Type Area, North Dakota and South Dakota - Toward a More Holistic View," by J. Mark Erickson;

"Vertebrate Fossil Record, Age, and Depositional Environments of the Brule Formation (Oligocene) in North Dakota," by John W. Hoganson and George E. Lammers;

"The Johns Lake Site: A Late Quaternary Fossil Beetle (Coleoptera) Assembalge from the Missouri Coteau, North Dakota," by Allan C. Ashworth and Donald P. Schwert;

"Tuffs in North Dakota," by Nels F. Forsman;

"Zoned Crystals," by Gordon L. Bell;

"Oil Development in North Dakota: A Historical and Stratigraphic Review," by Clarence G. Carlson;

"Stratigraphic Controls on Gold Mineralization, Carlin Trend, Nevada," by Odin D. Christensen;

"Characterization of Liquid-Water Percolation in Tuffs in the Unsaturated Zone, Yucca Mountain, Nye County, Nevada," By Jack Kume and Joseph P. Rousseau; and

"The Impact of F. D. Holland, Jr., on Geological Literature," by Mary W. Scott and Joanne Lerud.

Organic and Inorganic Contaminants in Shallow Groundwater at Six Municipal Landfills in North Dakota, by Edward C. Murphy, NDGS Report of Investigation No. 94, (1992), 144 pages, $15.00.

This report is a culmination of a three year study of six North Dakota landfills by the NDGS and the North Dakota Department of Health and Consolidated Laboratories. The six sites (Williston, Wishek, Linton, Harvey, Hillsboro, and Devils Lake) were choosen as representative of North Dakota landfills because of their geologic setting, size, and age. A total of 83 monitoring wells were installed at these sites. Monthly water levels were taken from these wells whenever possible and water samples for organic and inorganic analyses were obtained on three separate occassions. Selected samples were tested for volatile organic compounds and 16 pesticides.

The results of the study indicate that leachate is being produced at each of these landfills. Since these sites are indicative of other landfills in North Dakota, there is a strong possibility that leachate is being produced at all North Dakota landfills. The landfill leachate was found to be characterized by low to moderate increases in major ion concentration, little or no increases in selected trace metal concentrations, and moderate to high increases in the organic carbon content. The chloride ion and total organic carbon content were found to be the best indicators of landfill leachate. Leachate was generally found within a few hundred feet of the landfill boundaries.

The report recommends that more attention be paid to the geologic suitability of a site before it is choosen for a landfill in order to minimize the long-term impacts of waste disposal.

The Geologic and Hydrogeologic Conditions in the Area Adjacent to the Devils Lake Wastewater Impoundments, by Edward C. Murphy, Steve W. Pusc, and John P. Bluemle, NDGS Report of Investigation No. 93, (1992), 93 pages, $5.00.

This study of the geology and hydrogeology of the area adjacent to the Devils Lake wastewater impoundments was initiated in 1988 in response to local concerns that the impoundments may be contaminating local groundwater supplies. Thirty-eight monitoring wells were installed within a three-mile radius of the impoundments. From this drilling program, it was determined that the impoundments are situated approximately one mile from the edge of the Spiritwood Aquifer. Groundwater samples from these wells were obtained for general chemical and bacterial analyses; select wells were also sampled for trace metals and nutrients.

Due to the highly variable nature of the groundwater chemistry in the Devils Lake Basin, this study was not able to determine, unequivocally, the impact the wastewater impoundments were having on the surrounding area. Additional groundwater analyses, and additional monitoring wells, would be required to further define that relationship.

The study did, however, discover buried sand and gravel deposits east and south of the impoundments that may be tributary channels to the much larger Spiritwood Aquifer. A shallow seismic or gravity survey is recommended to further evaluate these channels.

An Introduction: North Dakota Geological Survey, compiled by Robert F. Biek, (September, 1992), 16 pages, free on request.

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

Earth Scientists + Students + Teachers = Partners for Excellence

Partners for Excellence - developed under the Geological Society of America's SAGE (Science Awareness through Geoscience Education) initiative - seeks to bring together teachers, students, and earth scientists and help them form cooperative educational partnerships. SAGE partnerships offer teachers and students the opportunity to gain relevant, up-to-date knowledge about a wide variety of earth science topics, while at the same time they give earth scientists opportunities to contribute to and learn about the pre-college science education system. The Geological Society of America supports all Partners for Excellence by providing them with training, materials, and follow-up support.

Partnering activities are limited only by the imagination of the two partners. The earth scientist and teacher jointly decide what type of activities and what level of involvement will work best for them. This may include classroom presentations, laboratory demonstrations, field trips, mentoring, or other assistance. Partnering may involve groups of scientists, teachers, and students working together, or one-on-one sessions between scientists and teachers or between scientists and students.

Partners for Excellence is a relatively new program. It needs the support of science teachers and earth scientists throughout North Dakota. To learn more about GSA's Partners for Excellence program, contact:

SAGE Program Director
3300 Penrose Place
P.O. Box 9140
Boulder, CO 80301-9140
(Tel. 303-447-2020 or
800-824-SAGE)

NDGS publications and USGS topographic maps are available at our sales office (1022 E. Divide Ave, Bismarck), by telephone (701-224-4109), by FAX (701-224-3682), 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.

ORDER FORM

Send to: Publications Clerk, NDGS Publications, 600 E. Boulevard Avenue, Bismarck, ND 58505-0840

Quantity	Series & No. Map & Scale	Title	Price	Total
Your Name and Address			Subtotal	
			Shipping	
			TOTAL	