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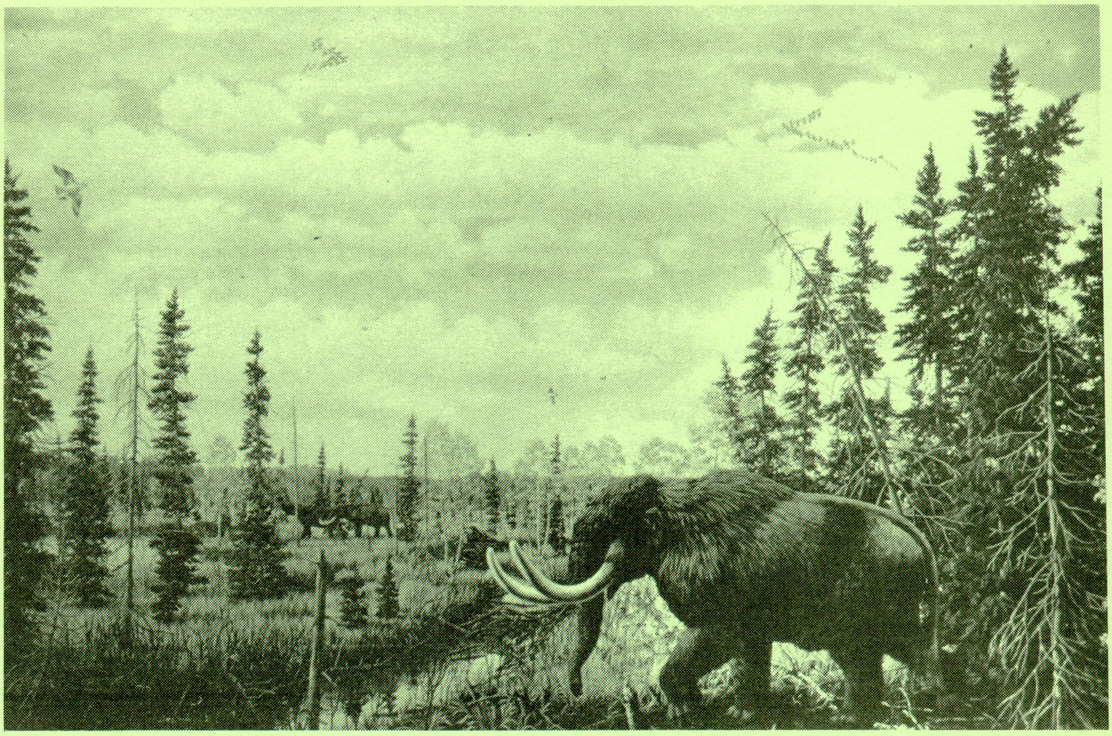

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CONTENTS

COVER PHOTO

About 12,000 years ago spruce forests similar to the one depicted here existed in parts of North Dakota. These wooded areas provided habitats for many kinds of animals that no longer live in North Dakota, such as mastodons-large beasts related to modern-day elephants. The Survey and State Historical Society are currently restoring a mastodon skeleton to be permanently exhibited in the North Dakota Heritage Center. (Painting by R. G. Larson, Illinois State Museum).

CURRENT SURVEY ACTIVITIES

--John Bluemle

When the legislature acted in 1989 to move the Geological Survey from Grand Forks to Bismarck, it was done with the idea that, by being closer to the center of State Government and closer to other state agencies, the Survey would be better able to accomplish its mission: to wisely manage our natural resources, protect our environment, promote economic development, and educate the public about North Dakota's natural heritage. As a result of the move, the Survey has embarked on a number of new directions that have resulted in many significant changes. Nearly all of these changes have been positive. Interaction between the Survey and other state agencies has increased dramatically. We are now working much more closely with agencies such as the Department of Health, Water Commission, Department of Agriculture, Land Department, Parks and Tourism, Historical Society, Attorney General's Office, Game and Fish, and others.

We can readily respond to concerns of government officials and legislators. In fact, our ability to deal with all mineral resources issues, particularly oil and gas, that result in significant revenue to the State, has been much improved. Similarly, our ability to deal with environmental problems is much better; we have daily contacts with people at the Health Department and Water Commission.

One of our more important recent initiatives, implementation of a large-scale Geographic Information System (GIS), could not have gone forward were it not for our new, centralized location. Our extensive work with the Heritage Center is another outstanding example of the kind of interaction that is possible now that we are in Bismarck (see article on the Highgate Mastodon in this newsletter).

I asked each of our geologists to give me a short summary of their current projects and I'll include their responses here.

Randy Burke presented a talk at the Williston Basin Symposium in Regina in October. The talk was titled "Mississippian Oil Production in Part of Burke, Mountrail, and Ward Counties, North Dakota." Randy also made a presentation at the symposium titled "A Detailed Gravity Survey Over a Known Devonian Winnipegosis Carbonate Buildup: the Shell golden Reef, Northwestern North Dakota." Randy was heavily involved with preparations for the symposium. He also supervised the installation of recently-acquired thin-sectioning equipment in our laboratory.

Tom Heck gave a talk on the history of horizontal drilling to the North Dakota Association of Oil & Gas Producing Counties in Watford City on November 14. In his well-received talk he compared the history of horizontal drilling in Saskatchewan and North Dakota and worldwide. Much of Tom's time recently has been spent doing land evaluations for the State Land Department. In January, Tom will be giving a talk at a Bureau of Land Management meeting in Reno, Nevada dealing with horizontal well drainage of the Bakken Formation in western North Dakota.

Tom was also involved in preparations for the Williston Basin Symposium, held in Regina in October. He has worked, most recently, on evaluations of the Elkhorn Ranch and Moraine Fields. He is also working on a project to evaluate the potential of horizontal drilling in the Madison Formation in North Dakota.

John Hoganson has now established an office and paleontology laboratory in the

Heritage Center. He has also moved the State Fossil Collection there and he has recently been working on restoration of the Highgate Mastodon. He has been assisted in this by Dr. George Lammers, who is a vertebrate paleontologist from the Manitoba Museum of Man and Nature. John hopes to have the mastodon ready for display by next May. The Fossils of North Dakota exhibit that went on display at the Heritage Center in February, 1991, continues to be very popular and will remain up for several more months.

John worked out an agreement with the Corps of Engineers this summer regarding management of North Dakota fossil resources. He has also been evaluating lands being offered in Oil and Gas Lease Sales to determine potential impact on paleontological sites. Most of John's field work this past summer dealt with the COGEOMAP program (the cooperative geologic mapping program we have with the United States Geological Survey).

John continues to give talks about North Dakota fossils, including at the Heritage Center Kid Nite (this was attended by over 500 children) and to the Lake Agassiz Rock Club in Fargo. He also gave a technical presentation in November at the Society of Vertebrate Paleontologist meeting in San Diego on fossil fish in North Dakota.

Julie LeFever is director of the core and sample library in Grand Forks. She is working on technical reports with people at the USGS and at the Manitoba and Saskatchewan geological surveys. Her studies involve work on the origin of the Bakken Formation sand, on the oil contained in the formation, and on the geology of the northern part of the Nesson Anticline. Julie presented two papers, on the Bakken Formation and Nesson Anticline, at the Williston Basin Symposium in Regina in October. She gave a talk at an International Horizontal Drilling Conference in Houston on horizontal drilling in Williston Basin on the Bakken Formation on November 14. She also spoke to the Lake Agassiz Rock Club in Fargo on October 2 on the geology of the Williston Basin. Our geologists probably average a couple of talks a month to service groups, groups of teachers or students, etc.

Mark Luther has recently been devoting most of his time to Geographic Information System (GIS) concerns. He coordinated a Symposium on November 21 and 22 that was attended by more than 200 people, most of them from other state agencies. The Symposium consisted of a series of talks by experts in GIS technology and applications as well as a number of exhibits by vendors of GIS hardware and software, shown at the Capitol on November 22. Through Mark's efforts, we have worked out agreements with the State Health Department and the Agriculture Department to do GIS work; we have also obtained a substantial amount of GIS hardware (workstations, printers, etc.) that will be used in this work. Mark also is coordinating our ESIC program and he oversees our map sales program.

Mark has also continued his studies of lithic resources (materials the Native Americans used to make tools). His work has led to better methods for recognizing distinct lithic sources in North Dakota. His field work on lithic resources also led to the discovery of an [apparent] mineral-bearing hydrothermal deposit. We cannot release the location at this time. We don't know yet whether this deposit has any commercial value, but even it doesn't, it is important because nothing at all like it has ever been found in North Dakota before (it's the kind of deposit that typically contains ores that produce various metallic resources). Initial analyses do indicate the presence of some anomalously high levels of certain economic metals including silver, chromium and some others. It is still quite premature to say whether the hydrothermal deposit may have any commercial value. We expect to do some additional field investigations of the site next summer.

Ed Murphy spent from a third to half of his time working on our COGEOMAP project, a cooperative geologic mapping program that is being partially funded by the U.S. Geological Survey. Much of this work centers on trying to learn about the transition from the Cretaceous (rich in fossil dinosaurs) rocks to the overlying Tertiary (no dinosaur fossils). These rocks are particularly well exposed in North Dakota. Ed has also been working on evaluating the geology of landfills (permit applications), and on the clean up of the salt plant in Williston, under our subsurface mineral and underground injection control programs (UIC Class III wells).

My own activities (**John Bluemle**) center mainly on administering the agency. I've attended a few meetings over the past six months: the 40th Anniversary of Oil in Williston, Rocky Mountain Section meeting of the American Association of Petroleum Geologists in Billings, the Williston Basin Symposium in Regina, and a couple of trips to Denver. I've been working at trying to hire some new geologists for the Survey. I've given a few talks on geology around the state. Right now I'm compiling materials for several lectures that I expect to give this winter.

NDGS HIRES TWO GEOLOGISTS

--John Bluemle

The Survey recently hired two new geologists to do environmental and surface mapping work. **Phillip Greer** came here from Laramie, Wyoming where he had been employed by the Wyoming Geological Survey. While there he mapped the geology of a number of 7.5 minute quadrangles and conducted subsurface studies, utilizing core, samples, and geophysical well logs. Phil was also involved in evaluating wastewater injection wells for the Wyoming Oil and Gas Commission. He served as assistant editor for a University of Wyoming technical journal, *Contributions to Geology*. Phil was also a geology instructor at the University of Wyoming and he has had considerable experience in the mineral industry, having held jobs with Allied Chemical Company, Gearhart Industries, and others. He has a M.S. degree in geology from the University of Wyoming and a B.A. from Macalester College.

Phil began working for the NDGS at the beginning of November. Over the next four years, he will be working with Jeff Olson, a hydrologist recently hired by the Water Commission, to evaluate all of the landfills in the state. Together, Phil and Jeff will examine the geology and hydrology of every landfill and report their findings to the Department of Health and Consolidated Laboratories, which will then determine what will be done in each case. Some of the landfills will likely close, others may be expanded, and methods of operating some may be changed. This is a project that the 1991 Legislature directed us to do.

Robert Biek will begin working for the Survey in January. He comes to us from Connecticut, where he was a Staff Geologist for Applied Earth Technologies, Inc. and also a consulting geologist for the Litchfield Hills Council of Elected Officials and for

Northwestern Connecticut Council of Governments. This involved consulting for public water supply watershed protection studies. Bob holds a B.A. degree in geology from the University of California, Berkeley and a M.S. in geology from Northern Illinois University. He will be involved in a variety of environmental studies and he will be involved in our geologic mapping program.

GIS SYMPOSIUM

--Mark Luther

On November 20-21, speakers from across the country, and an audience from the far-corners of North Dakota, converged on the State Capitol in Bismarck for a GIS Symposium. The symposium was initiated by the North Dakota GIS Technical Committee, with coordination provided by the NDGS, Information Services Division, and North Dakota State University.

Geographic Information Systems (GIS), in the strictest sense, are computer systems capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e., data identified according to their locations. GIS technology can be used for scientific investigations, resource management, and development planning, to name a few of many potential uses.

It is both, the speed with wich GIS technology can perform problem solving analyses, and the wide range of potential applications that were responsible for the high degree of interest shown at the symposium. Seventeen oral, and three poster presentations were given by industry and government personnel, dealing with a wide range of GIS applications.

One of the most well received features of the symposium was the vendor display. Several vendors had displays which included computer workstations, GIS software, and related peripheral equipment. Many of the displays were set up to allow "hands on" demonstrations of the products by symposium attendees.

Over 200 individuals attended the two day event; most from state agencies located in Bismarck, but there was a significant number of attendees from engineering firms, universities, and the larger cities. In general, attendees found the symposium to be very informative, and many expressed interest in making the GIS symposium an annual event.

NORTH DAKOTA SMAC FORMED

--Mark Luther

At a recent meeting of the North Dakota GIS Technical Committee (12/18/91), the NDGS proposed that the committee serve a dual role and act as a State Mapping Advisory Committee (SMAC). Attending members of the committee (which includes representatives from all state agencies) unanimously endorsed the idea, and will include SMAC related activities in future meetings of the GIS Technical Committee.

The U.S. Geological Survey's (USGS National Mapping Division (NMD) encourages the establishment of SMACs to consider and report Statewide interests and requirements for topographic maps, digital cartographic data, and other map products. The requirements of Federal map-using agencies are annually transmitted to the USGS in accordance with procedures established by the U.S. Office of Management and Budget Circular A-16. To insure that State interests are appropriately represented, the establishment of a central group, such as a SMAC, to coordinate State requirements for mapping, and to communicate those requirements in a consolidated report to the USGS through the A-16 mechanism, is essential to the annual planning of the National Mapping Program.

The North Dakota SMAC will be composed of representatives of State agencies and public institutions with Statewide interests. Input by representatives of county or municipal organizations, State chapters of professional societies, and the general public will also be encouraged. The widest possible representation will assure a better consensus of Statewide mapping requirements and provide a forum through which State agencies can coordinate and transmit mapping and spatial data priorities to the USGS. Federal agencies will not be represented on the SMAC, since their requirements are routed through their agency headquarters under the A-16 process. However, local Federal and private organization representatives may provide valuable advice or background information and will be invited to attend SMAC meetings in an advisory role.

Some objectives of the SMAC include:

1) To consolidate Statewide mapping requirements into a single annual report to the USGS.

2) To inform map users about the status of the USGS mapping program, the availability of map materials, digital data and related products, and to share information about other NMD cartographic activities and technological developments.

3) To develop jointly-funded, multi-year map revision plans for the State.

4) To provide a forum for discussion and communication of mapping knowledge and activities within the State, and for seminars on mapping, remote sensing, and digital applications.

5) To share and disseminate information on geographic information systems (GIS) technology and activities through which NMD can asses in coordinating and promoting mutually beneficial digital activities.

6) To supply information to NMD concerning the cartographic programs, activities, and products within the State.

The Federal mapping program for each fiscal year must consider Federal as well as State map requirements, and the total amount of mapping that can be scheduled, based on production capacity and available funds. NMD sets priorities, based in large part, on coincidence of Federal and State needs. It is advantageous for State and local Federal agencies to coordinate to the greatest extent possible their requirements for map, digital, and image products. As far as capacity permits, the USGS will accommodate the highest priority requests of each SMAC.

Transmittal to NMD of map (and

related) priorities determined by the SMAC will be through the NDGS' Earth Science Information Center (ESIC) office, which has previously handled this process. Distribution of USGS materials to the SMAC will also be handled by the NDGS' ESIC office.

Combining the activities of the SMAC and GIS Technical Committee under one group will provide a two-fold benefit to the State. First, potential transportation and per diem expenses will be reduced by 50 percent, and second, formation of the SMAC will result in the production of maps, digital products, and imagery that more fully meets the anticipated needs of the State. This is another example of State agencies working together to provide maximum benefits to the residents of the State, at the lowest possible cost. An idea whose time has come.

THE CRETACEOUS/TERTIARY BOUNDARY COGEOMAP PROJECT --Ed Murphy

This past summer, Doug Nichols (USGS), Nels Forsman (UND Geology Dept.), John Hoganson (NDGS), and myself, measured 24 stratigraphic sections throughout a five-county area in south-central North Dakota (Emmons, Burleigh, Morton, Grant, and Sioux). The work was done under a cooperative mapping project (COGEOMAP) between the North Dakota Geological Survey and the US Geological Survey. The focus of the study is to determine the relationship between the Cretaceous/Tertiary boundary timeline and the contact between the Hell Creek and Ludlow Formations (ie., the relationship between the rock-stratigraphic and the time-stratigraphic units). We are hoping to shed additional light on the events that took place at the end of the Cretaceous Period, events that apparently resulted in the extinction of the last of the dinosaurs along with many other organisms. The contact between the Hell Creek and Ludlow Formations was plotted on 7.5 minute quadrangle maps. In addition, the surface geology was completed for two 7.5 minute quadrangle maps in Grant and Sioux Counties.

A total of 70 lithologic samples were collected for palynomorph (fossil pollen and spores) analysis. Doug Nichols (USGS palynologist-a palynologist is a paleontologist who specializes in the study of fossil pollen and other spores) is able to determine the position of the Cretaceous/Tertiary boundary based on the presence or absence of certain palynomorphs that are found in the sedimentary rocks. Palynomorphs are best preserved in organic-rich claystones and coals. Therefore, we generally sampled these units when we were collecting rock samples for analysis (fig. 1). We took at least three lithologic samples from each stratigraphic section, ie., one from rocks that we believed were Cretaceous in age, one from rocks that were believed to be Tertiary in age, and one from rocks that we believed were at the Cretaceous/Tertairy contact. Our intention was to bracket the contact with our sampling points. At most of the sites, we took 6 to 8 lithologic samples. This should enable us to determine the horizon within which the Cretaceous/Tertiary contact occurs (fig. 2).

Palynomorphs appear to be good indicators of the position of the Cretaceous/Tertiary boundary. They have been successfully used throughout the Rocky Mountain Region of the United States and Canada to pinpoint this horizon. The Cretaceous/Tertiary boundary is often marked

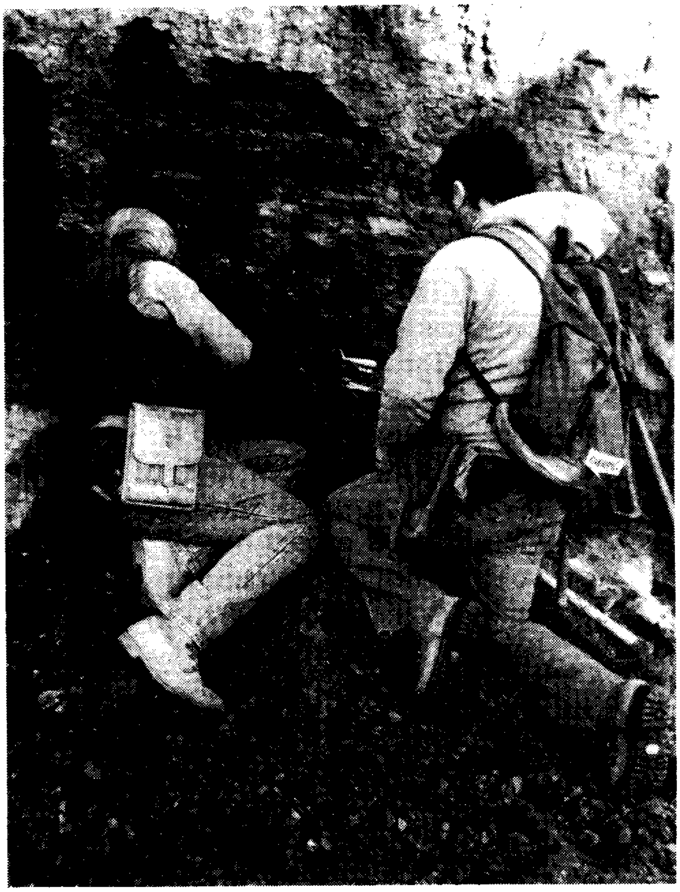


Figure 1. Doug Nichols (USGS) and John Hoganson (NDGS) obtaining samples for palynologic analyses at a site in Morton County.

Figure 2. A trail near Barren Butte in Sioux County. Many of the outcrops are difficult to reach due to the limited amount of roads and trails in this area.

by a sudden increase in the abundance of fern pollen, generally referred to in the literature as a fern spike. There is some speculation that this fern spike is a result of the ferns being one of the first plants to proliferate after a major extinction event created, perhaps, by a single or multiple bollide (asteroid) impact(s).

Once we have the Cretaceous/Tertiary boundary located as precisely as possible with palynomorph analysis, we plan to search for additional indicators of the Cretaceous/Tertiary boundary such as iridium (a platinum group element that is rare on earth but occurs in elevated concentrations in extraterrestrial material) and shocked quartz (quartz grains which, in thin section, exhibit unique stress features thought to have resulted from extremely high energy events such as a bollide impact). In addition, we are mapping the occurrence of vertebate fossils (including dinosaur remains) when we measure sections so that we can relate the position of the last dinosaur fossils (and other vertebrates occurrences) to the palynomorph-defined Cretaceous/Tertiary boundary.

Some of the same features that facilitated our work with the field mapping of the Hell Creek and Ludlow Formations made it more difficult to measure stratigraphic sections. For instance, the Hell Creek Formation is often largely devoid of vegetation, whereas the Ludlow Formation is generally moderately to well vegetated. The vegetative cover often makes it easier to identify and map the contact between these two formations, but makes it difficult to measure a stratigraphic section within the Ludlow Formation (fig. 3 & 4). The contact quite often is marked by a coal bed or a carbonaceous mudstone (generally a coal in the west and a carbonaceous mudstone in the south-central portion of the state). Whether the contact is a lignite or a mudstone, there is often a break in slope at this horizon due to these beds being less resistant to erosion than the surrounding beds. At many of the sites, the Hell Creek/Ludlow contact is marked by a game or cattle trail, etc. The break in slope makes the contact easier to map but, in turn, makes it more difficult to measure a section through this interval.

The Hell Creek Formation contains numerous beds of swelling or "popcorn" clays. These beds are referred to as popcorn clays because their rough surface resembles numerous grains of popcorn. The surface texture is the result of repeated wetting and drying events, which have alternately caused the surface to expand up to 16 times its dry volume when it is hydrated and to contract the same amount when it is dehydrated. This behavior makes it difficult for vegetation to establish itself on these units and, as a result, the Hell Creek is generally void of vegetation on outcrop.

Most of the Upper Cretaceous and Tertiary sedimentary rocks are susceptible to an erosional phenomenon called piping (fig. 5). This is because the beds are generally poorly to moderately cemented or indurated and therefore are easily eroded. Surface water runoff along the sides of buttes and valleys often is funneled or focused into small gullies or ravines . This runoff downcuts through the exposed rocks and often flows through small cracks in the sedimentary rocks beneath the surface. Over time, as water intermittently flows through these rocks, it erodes a larger and larger hole. After a time, these holes, or pipes as they are called, can become very long and deep. On some hillsides piping has progressed to the point that only a small portion of the runoff flows above the ground surface and most of it flows under the surface through an elaborate system of pipes. These pipes may reach 6 feet or more in diameter and many contain unstable roofs consisting of only inches of sedimentary rock. As a result,

Figure 3. The contact between the Hell Creek and Ludlow Formations in Sioux County. Note the absence of vegetation on the outcrop below the contact relative to that above the contact.

Figure 4. Vegetation is more prevalent above the Hell Creek/Ludlow contact in this outcrop below the University of Mary in Burleigh County. The visible lignite bed marks the top of the Ludlow Formation and the base of the Cannonball Formation at this site. The Ludlow Formation is only 32 feet thick at this site.

the pipes pose a significant danger to a geologist or anyone else climbing along the sides of the buttes. Because they remain cool during the summer, they are commonly inhabited by rattlesnakes, an added danger to anyone who might break through the overlying crust and fall into one of these pipes. When climbing along hill sides in badland topography it is a good idea to avoid walking over areas where piping is evident.

Figure 5. Doug Nichols (USGS) stands adjacent to the opening of a large erosional pipe on Rattlesnake Butte in Grant County.

STANDING ROCK COMMUNITY COLLEGE GEOLOGY CLASS VISITS THE NORTH DAKOTA GEOLOGICAL SURVEY **--Ed Murphy**

On October 10, 1991, Ms. Charmaine Wisecarver's geology class from Standing Rock Community College visited the North Dakota Geological Survey. Ms. Wisecarver's class was studying environmental geology and came to Bismarck to observe firsthand the environmental work being done by state and federal agencies in North Dakota. I gave the group a slide presentation on the general geology of the state and the methods that are used by our agency during investigative studies. The group also toured the fossil display at the Heritage Center.

In addition, Steve Cates (U.S. Geological Survey) presented his work on delineating buried channel aquifers on the Fort Berthold Reservation, Dave Glatt (Department of Health and Consolidated Laboratories) presented two case histories of leaking underground storage facilities in North Dakota, and Linda Weispfenning and Bill Scharf (State Water Commission) presented the group with information on the responsibilities of the State Water Commission and the WET program.

Figure 1. Pictured are Charmaine Wisecarver (second from right) and the students in her geology class from the Standing Rock Community College in Ft Yates. The photo was taken in the parking lot of the Manhattan Building which houses the Geological Survey and the Oil and Gas Division.

HORIZONTAL DRILLING IN SASKATCHEWAN AND ITS IMPLICATION IN NORTH DAKOTA

--Tom Heck

This paper is a condensation of a talk I gave to the North Dakota Association of Oil & Gas Producing Counties in Watford City in November. In that talk, I reviewed the history of horizontal drilling, both worldwide and in Saskatchewan; I compared the stratigraphy in North Dakota and Saskatchewan, showed the fields in which horizontal wells have been drilled in Saskatchewan, reviewed oil production from several fields, and drew some general conclusions about what Saskatchewan's horizontal drilling play means to North Dakota.

One of the basic questions that needs to be answered is: Why drill sideways? There are several answers. Fewer wells are required to drain a reservoir; the risk of drilling a dry hole is reduced; oil is recovered faster and more of it may be recovered; and, finally, horizontal wells can reduce some engineering problems such as coning water. All of these reasons impact the economics of an oil well, an essential consideration in any horizontal drilling program.

Summarizing from Joshi (1990), the first known horizontal wells were drilled during the 1930's when the first horizontal wells were drilled from a tunnel in Yarega Field in the Soviet Union. Relatively few horizontal wells had been drilled when, in 1942, a major advance in horizontal drilling technology was made with the first use of flexible drill-pipe and downhole motors to drill a deviated well-bore in California. Today's technologies are improvements upon the equipment used then. Since the first milestone, only sporadic activity took place world-wide until quite recently when the North Dakota Bakken Formation, the Austin Chalk in Texas, and the Madison in Saskatchewan became horizontal targets. Hundreds of horizontal wells have been drilled worldwide since 1987 and I believe that this technology is here to stay.

Stratigraphy. Many of the differences in stratigraphy between Saskatchewan and North Dakota can be stated in one word--terminology. By that, I mean a certain layer of rocks in North Dakota may actually be identical to rock layers in Saskatchewan but each may have a different name (figure 1). Even though the rocks themselves are identical, different nomenclature systems have evolved. This is a common problem within a basin or even within a state. Knowing the different stratigraphy, or producing zones, is important because horizontal well-bores are not completely horizontal--they tend to wander vertically within the rock section. Since this wandering can be either accidental or deliberate, it is difficult to know exactly what zones are producing in a horizontal well. This fact obscures selection of those fields that are the most attractive candidates for horizontal drilling in North Dakota. Figure 1 shows only major geologic intervals and does not investigate the detailed stratigraphy.

Recent Saskatchewan Activity. In the 1980's, horizontal drilling came into its own world-wide. In 1987, horizontal drilling began in both North Dakota and Saskatchewan. The objectives, however, were different. In North Dakota the target was the Bakken Formation whereas in Saskatchewan the first targets were heavy oil reservoirs.

Saskatchewan can be divided into several producing areas. Areas 1 and 2 lie in western and west-central Saskatchewan and contain many of the heavy oil reservoirs; area 3 covers the Swift Current Arch; and Areas 4 and 5 cover the Madison play in southeastern

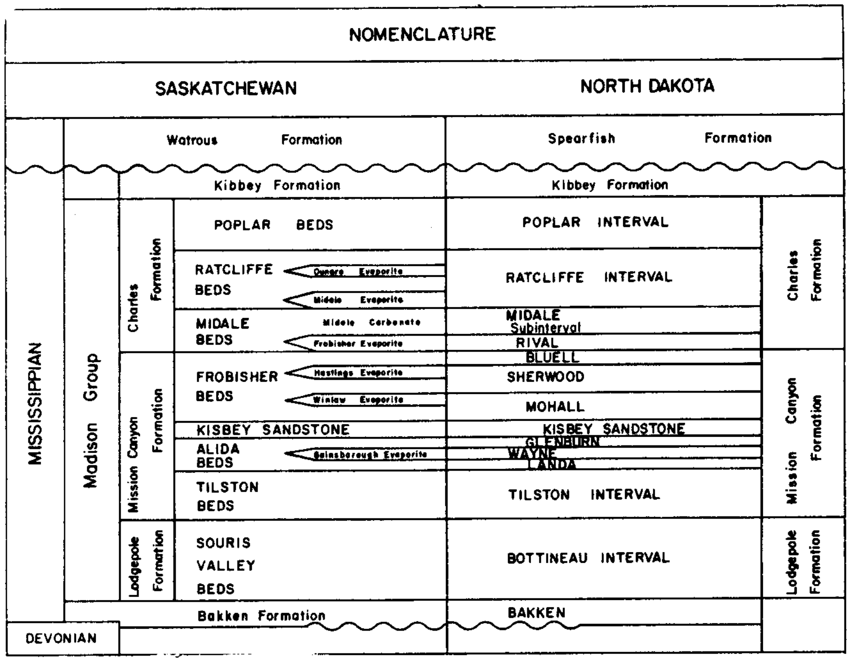


Figure 1.

Saskatchewan. As of August 31, 1991, a total of 114 horizontal wells had been completed in Area 1, eleven in Area 2, two in Area 3, and 51 in Areas 4 and 5. Looking more closely at Areas 4 and 5, the distribution of the 51 wells is shown in figure 2. The distribution of wells that were still in the permitting process on August 31 is shown on Figure 3.

Manitoba also has a completed horizontal well. It was completed this year in the Lodgepole Formation (Souris Valley Beds in Manitoba) in Daly Field. I am unaware of any pending drilling there.

No horizontal Madison wells have yet been drilled in the north-central North Dakota, the area closest to Saskatchewan. However, a couple of wells are slated to be drilled there in the near future. Two locations have been spaced in North Haas Field, but neither has yet been permitted. The drilling of either of these ventures will provide valuable information to others who are interested in the play.

Two horizontal Madison wells have been drilled in North Dakota, one in Mondak Field and the other in Pierre Creek Field. The first well was drilled in 1987 by McCormick Resources. It was a poor well that was plugged in 1990. The other well, drilled by Meridian Oil Inc., produces oil and a lot of water. The results from these two wells will probably delay further horizontal drilling in southwestern North Dakota, but I am certain more drilling will eventually occur there.

Production. Let's turn our attention to the main issue, oil production. Generally, horizontal wells are projected (by some experts) to recover more oil and to recover it much faster than would vertical wells in the same spacing unit. Both the rate of production and the ultimate recovery have a profound effect on a company's cash flow and hence the overall economics of a play.

HORIZONTAL DRILLING DISTRIBUTION

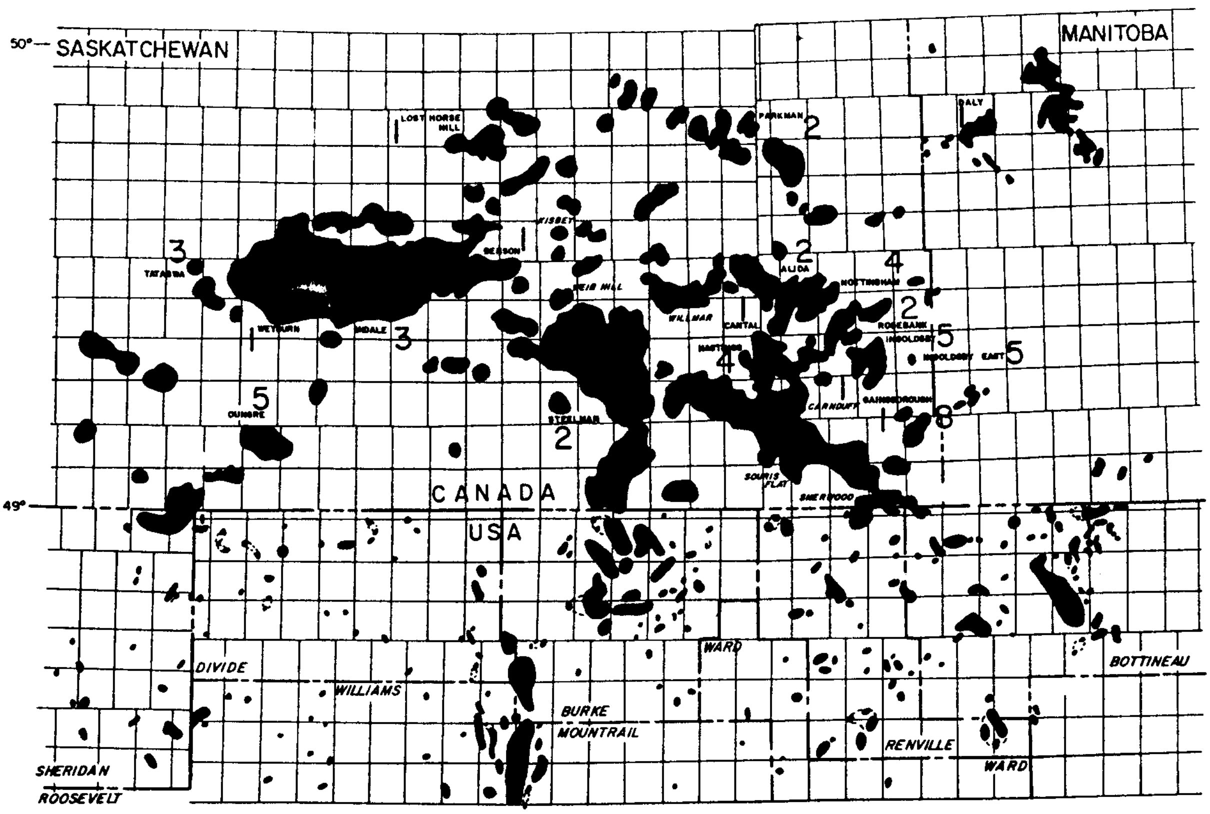


Figure 2.

Figures 4 and 5 compare the number of vertical and horizontal wells and production in a number of saskatchewan oil fields through the first third of 1991. The discovery year for each field is also shown. The number of horizontal wells is generally a small percentage of the total number of wells in most of the fields (figure 4), but the percentage of total production contributed by these horizontal wells (during the first four months of 1991) was higher than the percentage of horizontal wells in the field (figure 5) indicating a disproportionate percentage of the oil is produced by the horizontal wells. Let's look more closely at the production from several fields.

First is Hastings Field, which produces from the Frobisher beds. The Frobisher beds are equivalent to the Bluell, Sherwood, and Mohall intervals in North Dakota (figure 6). A total of 91 vertical and 4 horizontal wells have been completed in Hastings Field with the first horizontal production beginning in August of 1990. The field was producing just under 40,000 barrels a month before the first horizontal completion, but production jumped to approximately 43,000 barrels a month in the first month after its completion. Two additional horizontal wells were completed in late 1990 and a fourth in early 1991 and the pool production total rose to 55,000 barrels per month. The contribution from the hori-

WELLS LICENSED, APPROVED WELLS AND PENDING APPROVAL

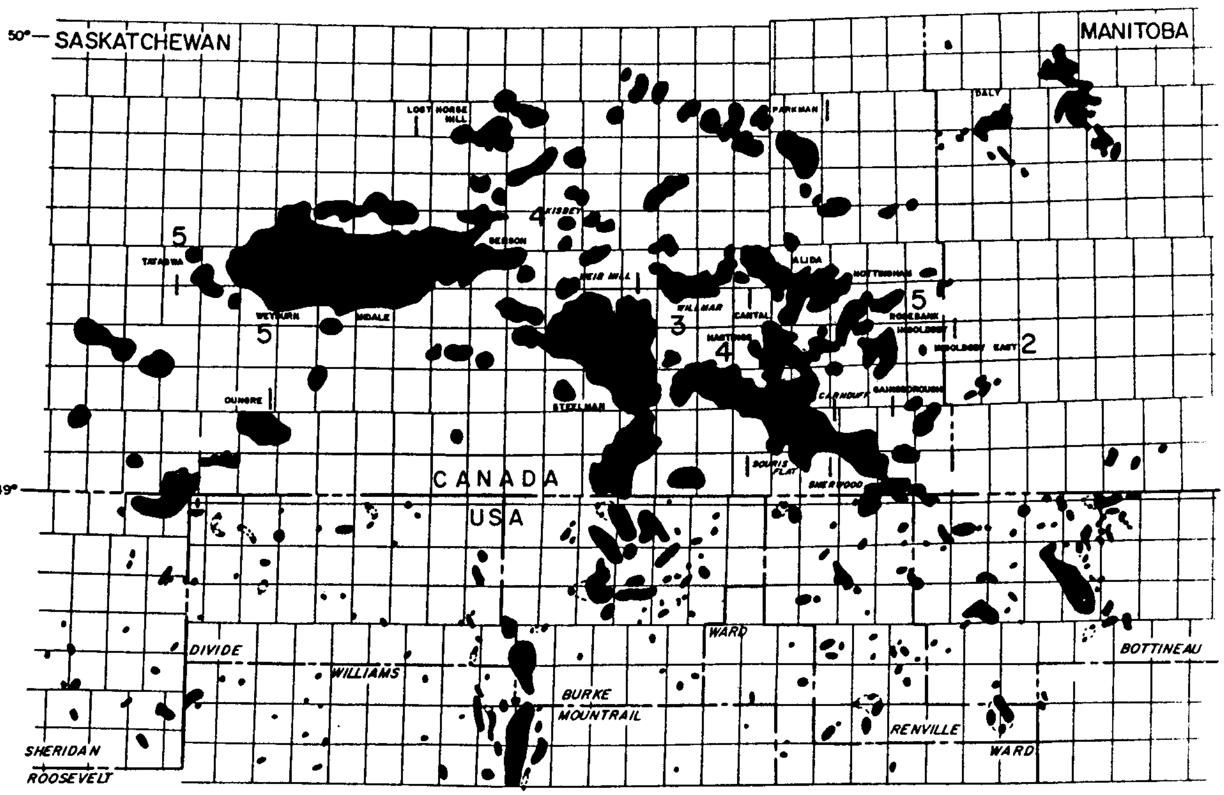


Figure 3.

zontal wells in the first 4 months of 1991 was 19% of the fields total production from 3% of the producing wells. This is a significant increase but, during the last few months, a decrease in horizontal production has occurred.

Next is Cantal South Field, an Alida producer. The Alida beds are equivalent to the Glenburn, Wayne, and Landa intervals in North Dakota. Cantal South Field contains 17 producing vertical wells and only one horizontal well. However, production jumped from 4,000 barrels a month to nearly 11,000 barrels and then gradually declined to 6,000 barrels a month over the next seven months, still a respectable 50% increase.

It would be wise to be cautious about how well the horizontal Madison play will do because the production histories for horizontal wells are still short. In at least some cases, significant production declines have occurred in a matter of months. Too rapid a decline could adversely alter the economics and kill the play.

Shell Canada drilled three horizontal wells in Midale Field; of these, two are still producing. At the October Williston Basin Symposium in Regina, Charbonneau and Spitzer (1991) reported that an incremental 9% of the original oil in place (OOIP) for the individual spacing patterns is expected to be recovered. We can calculate approximately

PERCENT HORIZONTAL WELLS
BY FIELD

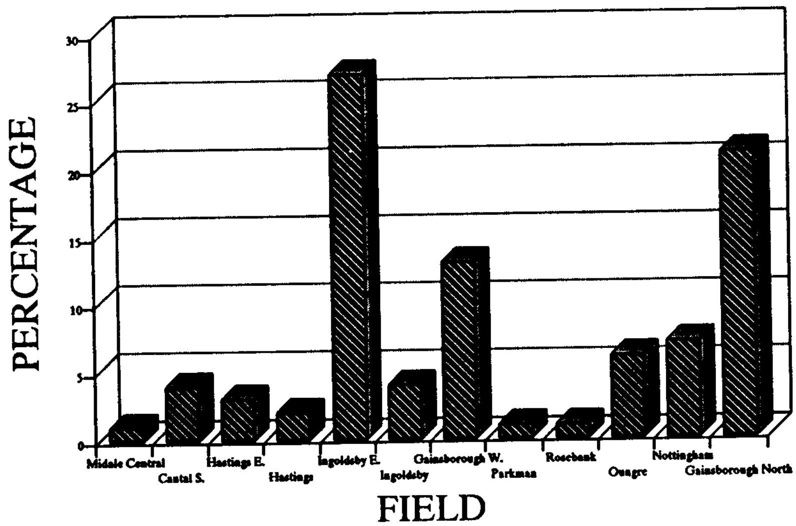


Figure 4.

PERCENT HORIZONTAL PRODUCTION
JANUARY 1 TO APRIL 30, 1991

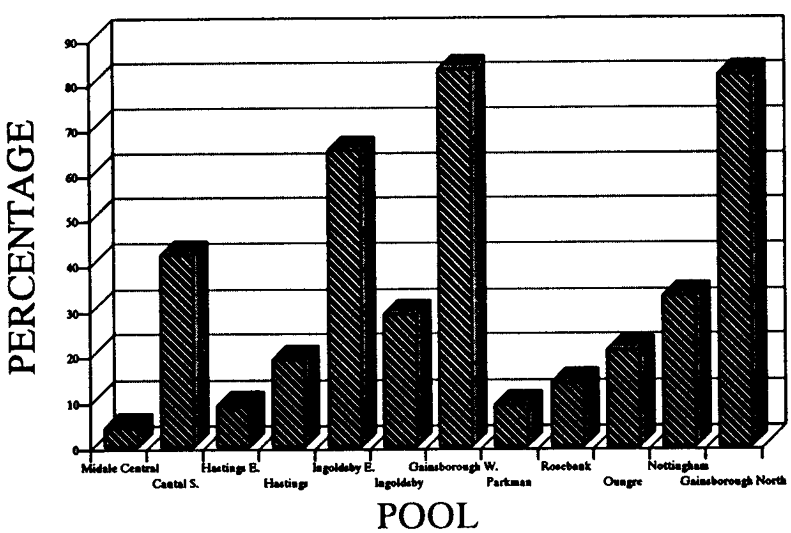


Figure 5.

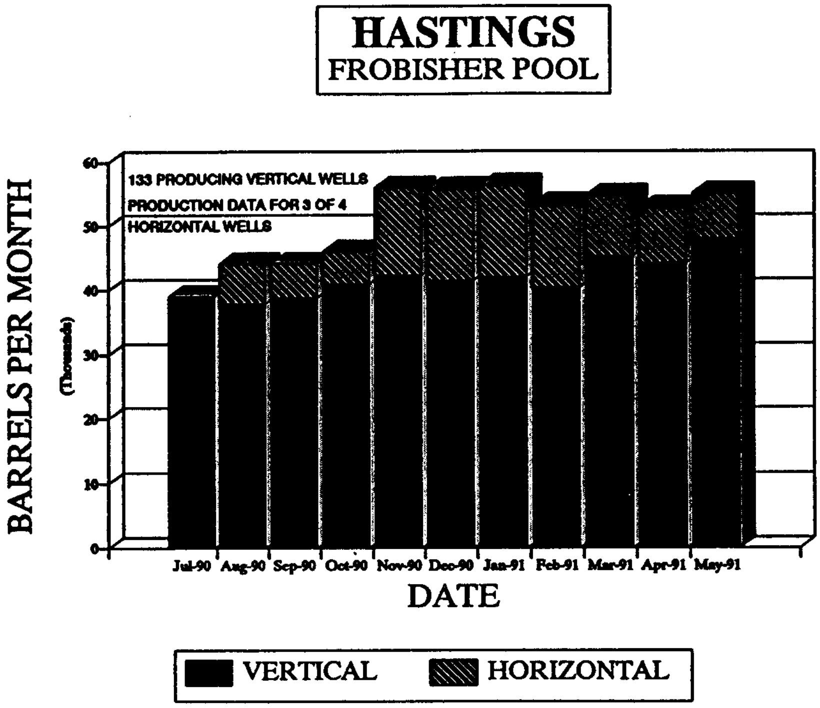


Figure 6.

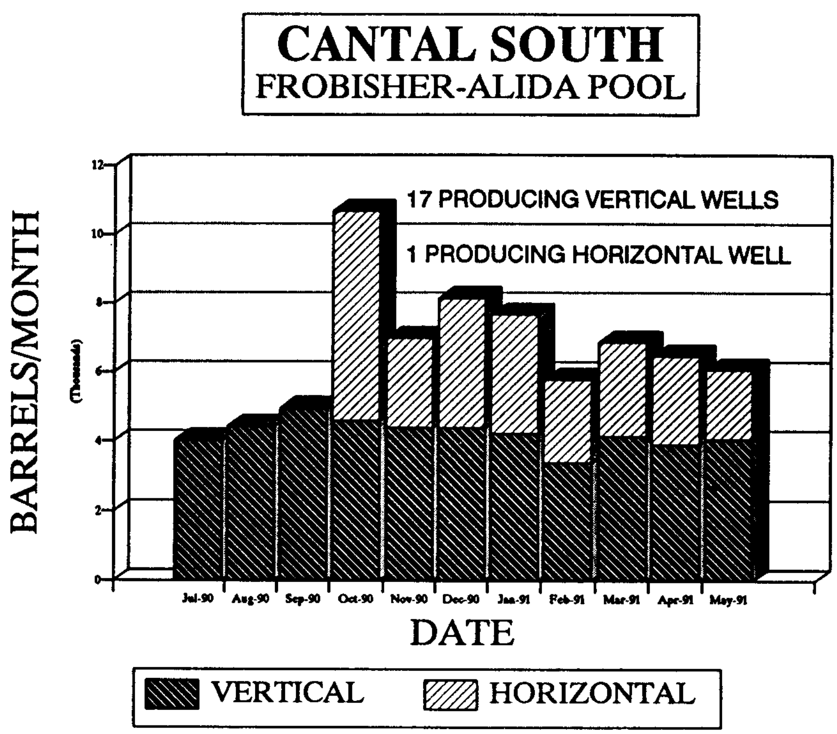


Figure 7.

what this means in terms of barrels recovered. The field is reported to have approximately 350,000,000 barrels of oil in place. More than 500 wells have been completed in the field so, if the spacing patterns are the same, the average well had approximately 700,000 barrels of oil in place. 9% of 700,000 barrels is an additional 63,000 barrels of oil recovered for the "average" Midale Field spacing. Not bad for an infill well drilled in a field that has produced more than 100,000,000 barrels since its discovery in 1953.

Finally, we'll look at Gainsborough North Field, a Frobisher-Alida producer discovered in 1988. Initial production, from only vertical wells, averaged about 10,000 barrels a month until, in November, 1990, the first horizontal well was completed. Since then, a total of seven horizontal wells were completed and production from the horizontal wells alone rose to nearly 200,000 barrels a month, a 10-fold increase. During the first 4 months of 1991 7 horizontal wells produced 82% of the oil. From discovery through April, 1991, horizontal wells have produced nearly 68% of the total, or just over 2,000,000 barrels. At the end of April, 1991, the 7 horizontal wells were 23% of the 30 total producing wells. Production from horizontal wells is declining fairly rapidly, but remains at significant levels. The use of horizontal wells in fields still under development appears to be a promising technique because of the significant gains in production when it was employed in Gainsborough North Field.

Conclusions. For a number of reasons, it is too early to accurately forecast the potential for horizontal drilling in North Dakota. First, only a short history exists for the Saskatchewan drilling program and it is too early to accurately extrapolate it into the North Dakota. Second, I do not believe that the applicability of horizontal wells in any par-

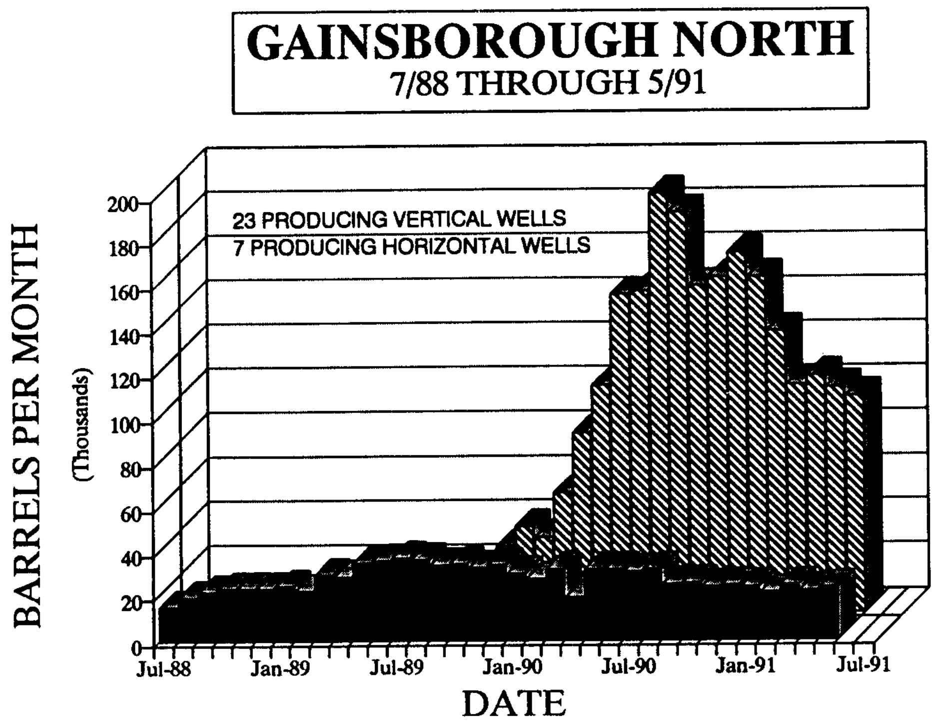


Figure 8.

ticular reservoir type has been categorically ruled out. Certainly, some suggestive evidence exists (the decline rates in many of Saskatchewan's wells and the two early Madison attempts in south-western North Dakota) that some fields may be unsuitable for horizontal drilling, but even so, the possibilities are not completely ruled out. Only experience will tell us for certain where horizontal drilling technology is most applicable in North Dakota.

Some general conclusions can be drawn. Because of the similarities in stratigraphy between Saskatchewan and North Dakota, similar producing characteristics can be expected. The North Dakota fields that are most similar to the Saskatchewan fields probably are the ones that will be drilled first. I think too, that horizontal drilling will be used as an integral part of the development programs in newly discovered fields with results similar to that in Gainsborough North Field. Based on the production seen in Saskatchewan to date, I am optimistic about the future of horizontal drilling in North Dakota.

References

Charbonneau, S., and Spitzer, R., 1991, Horizontal drilling in a fractured carbonate reservoir, Midale Unit, Saskatchewan, abstract of poster, Sixth International Williston Basin Symposium, Regina, Saskatchewan.

Joshi, S. ,1990, Horizontal drilling technology, PennWell Publishing, Tulsa, OK, 535 p.

NONFUEL MINERAL INDUSTRY STATISTICS

--John Bluemle

Table 1.--Nonfuel mineral production in North Dakota1/

Mineral	1988 Quantity	1988 Value (thousands)	1989 Quantity	1989 Value (thousands)	1990 Quantity	1990 Value (thousands)
Clays ———— metric tons --	76,918	$147	47,903	W	50,485	W
Gem stones ————————	NA	2	NA	$10	NA	$10
Lime —— thousand short tons --	108	7,094	107	5,439	82	4,623
Sand and gravel (construction) -- do.--	3,772	8,079	e/3,600	e/8,100	7,644	17,219
Stone (crushed) —— short tons --	W	W	--	--	e/1,000	e/4,600
Combined value of other industrial minerals and values indicated by symbol W ———	XX	3,485	XX	111	XX	116
Total ———————	XX	18,807	XX	13,660	XX	26,568

e/Estimated. NA not available. W withheld to avoid disclosing company proprietary data; value included with "Combined value" figure. XX not applicable. 1/Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

The U. S. Bureau of Mines recently released their tabulations for 1990 nonfuel mineral production for North Dakota. The value of North Dakota's nonfuel mineral production in 1990 nearly doubled from that reported for 1989. Total value in 1990 was $26,568,000 (see Table 1 on previous page). Construction sand and gravel contributed the greatest amount to the State's nonfuel mineral value and accounted for much of the increase over 1989. Other commodities produced included clays, gem stones, lime, peat, sulfur, and crushed stone.

THIRD INTERNATIONAL CONFERENCE ON HORIZONTAL WELL TECHNOLOGY

--Julie LeFever

The 3rd International Conference on Horizontal Well Technology was held in Houston, Texas from November 12-14, 1991. The conference was sponsored by World Oil Magazine and attracted attendees from all over the world. The conference was split into two segments. The first segment dealt with the engineering aspects of horizontal drilling and the new technology that is available. Topics included such items as bit selection, coring, new wireline logging techniques, methods of fracture stimulation, and drilling with coiled tubing. Several companies discussed different methods using multiple laterals and coiled tubing to solve specific problems or drain a larger portion of the reservoir. The second segment of the conference dealt with case studies. The case studies showed the application of horizontal drilling to solve special problems (geologic or engineering), the application of horizontal drilling to fractured and convential reservoirs, and the use of horizontal drilling instead of infill drilling in old, well-established fields.

Approximately half of the registrants were International. Two points were made several times throughout the course of the meeting relating to the International group. First, it was apparent that the American group is not using horizontal drilling to its full capacity. Horizontal applications have focused primarily on fractured reservoirs, such as the Austin Chalk in Texas and the Bakken Formation in North Dakota. In contrast, horizontal drilling on the International front has been concerned with applying the technology toward more convential reservoirs. Secondly, the International group was very concerned with reservoir management throughout the entire course of exploration and development. The ultimate goal in the development of an oilfield is to recover as much of the original oil in place as possible. Starting with the initial discovery, an attempt is made to thoroughly understand all of the geologic and engineering aspects of that field. The reservoir is then managed based on this information.

Case studies presented at this conference showed that many of the older, well-developed fields could greatly benefit from horizontal drilling by recovering more of the original oil in place. The technology exists and, when used in a creative way, is beneficial.

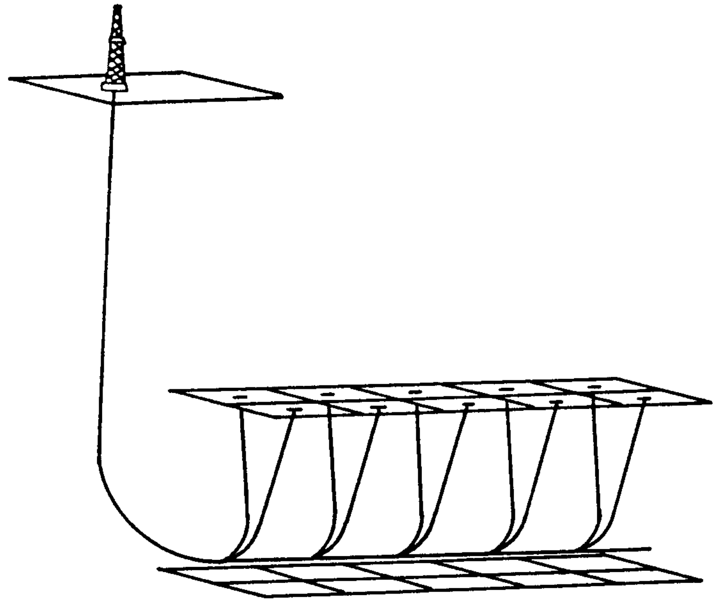


Figure 1. Advanced technology allows an operator to design a horizontal well system to suit any geological problem or engineering need. An example of this is shown by the Gardes Directional Drilling System where radial technology provides for multiple wellbores, as many as 100, to be drilled from a single horizontal section.

FIELD SUMMARY FOR LUCKY MOUND FIELD

--Randy Burke

Editor's Note: The field summary for Lucky Mound Field, on the following three pages, is a compilation of available data relating to the field, as well as a structure cross-section, structure and porosity map, and production history for the field. This is the first such field summary we have included in our newsletter and we will be interested in hearing your reaction to articles of this type.

Lucky Mound Field is one of the most recent discoveries that extends the Madison "shoreline" play along the eastern margin of the Williston Basin. The "shoreline" play is defined primarily on a change updip in lithology from porous carbonates to nonporous anhydrite and anhydrite cemented carbonates. The extension of this play brought the first oil production to McLean County. The only other production in McLean County is from Centennial Field.

LUCKY MOUND FIELD

T. 150 N., R. 89 W.
Mc Lean County, North Dakota
(Current to 11/7/91)

GENERAL FIELD DATA

GEOLOGIC SETTING:
eastern margin Williston Basin
PALEOSETTING:
sabkha shoreline of epicontinental sea
TRAP TYPE:
stratigraphic; updip facies change from carbonate to anhydrite
OLDEST HORIZON PENETRATED:
Glenburn subinterval, Mission Canyon Fm., Madison Group, Mississippian
OTHER HORIZONS WITH OIL/GAS SHOWS: none
NUMBER AND STATUS OF WELLS:
Producing: 22
Abandoned: 1
Shut In or Temporarily Abandoned: 0
Disposal/Injection: 1
Permitted: 6
Confidential: 8
MAJOR OPERATORS:
Balcron Oil Co. and Duncan Energy Co.
MARKET:
Murphy Oil Co. and Koch Oil Co.

DISCOVERY WELL

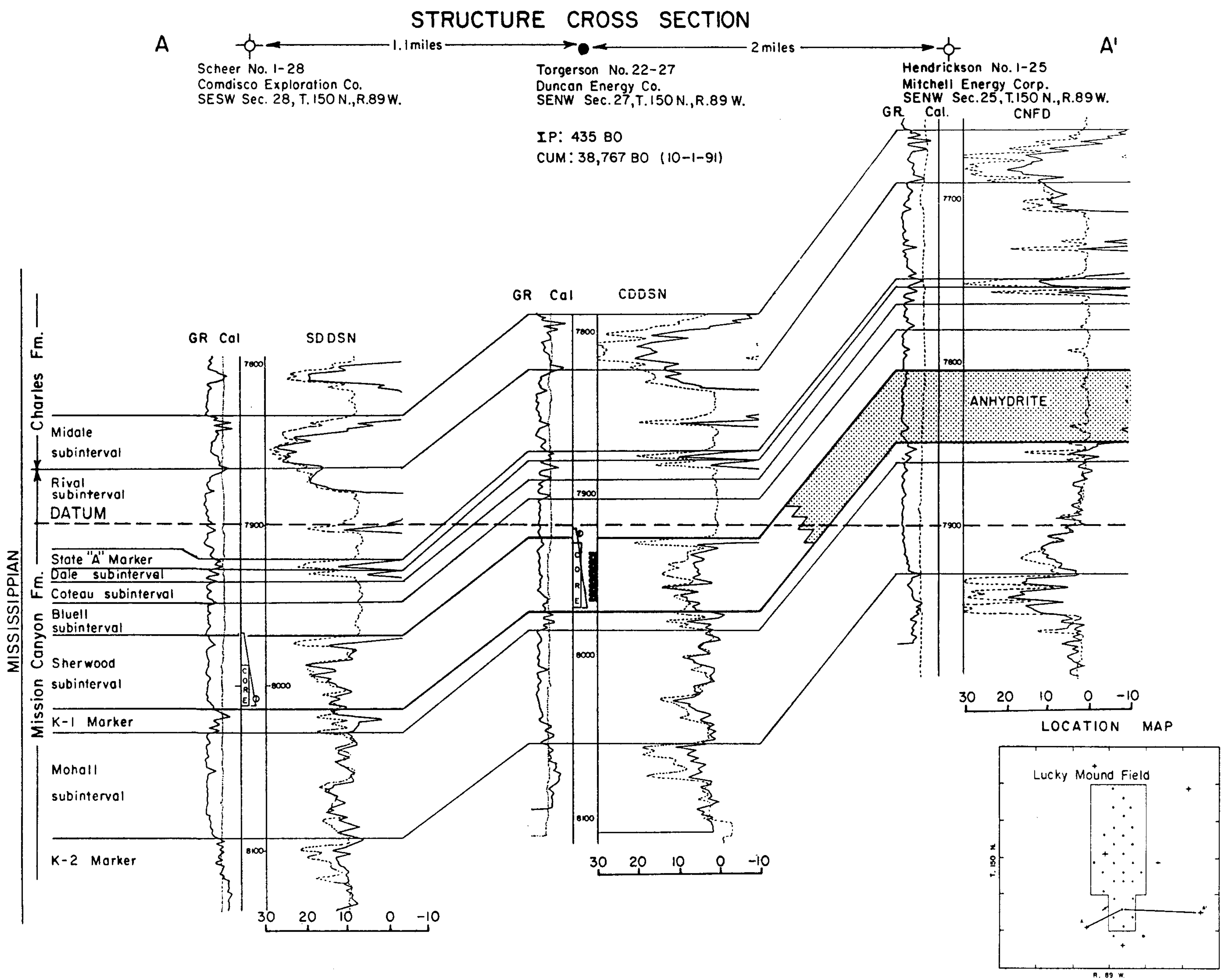
OPERATOR & NAME: Balcron Oil Co., Wahner #33-15
LOCATION: NW SE Sec.15 T150N R89W
ELEVATION: 1980′ sl
COMPLETED: 8/16/90
TOTAL DEPTH: 8150′ in the Glenburn subinterval of the Mission Canyon Fm.
DISCOVERY METHOD: seismic with geologic and log stratigraphic analysis
PRODUCTION HISTORY:
IP: Oil 324 BPD; Water 36 BPD; Gas 241 MCF
Status of Well: flowing (11/7/91)
Cumulative: 30,630 BO (10/1/91)
65,132 BW (10/9/91)
Casing: Production - 5 1/2" set 8143′
Surface - 9 5/8" set 787′
PRODUCING HORIZON: Sherwood subinterval of the Mission Canyon Fm.
Lithology: dolostone with lesser amounts of limestones
Thickness: 26′ net (4% Ø)
Porosity: 4%-12% (10% average)
Permeability: 2 md (core average); 7 md (pressure test)
Perforations: 7,934-37′, 7942-48′, 7952-56′ (15 holes total)
Water Saturation: 37% (log analysis)
H_2S: 0.46 ppt
Pressures: @ 7946′ on 8/5/90
Reservoir Pressure: 3762 psi
Bottom Hole Final Flow (period 2): 366 psia
Bottom Hole Shut-in (period 2): 3675 psia
Bottom Hole Temperature: 168° F
Fluid Data:
API Gravity: 37.6°
Solution GOR: 882 SCF/STBO
Water Resistivity: 0.024 ohm-m @ 168° F
Total Dissolved Solids: 307,972.9 mg/l

RESERVOIR INFORMATION

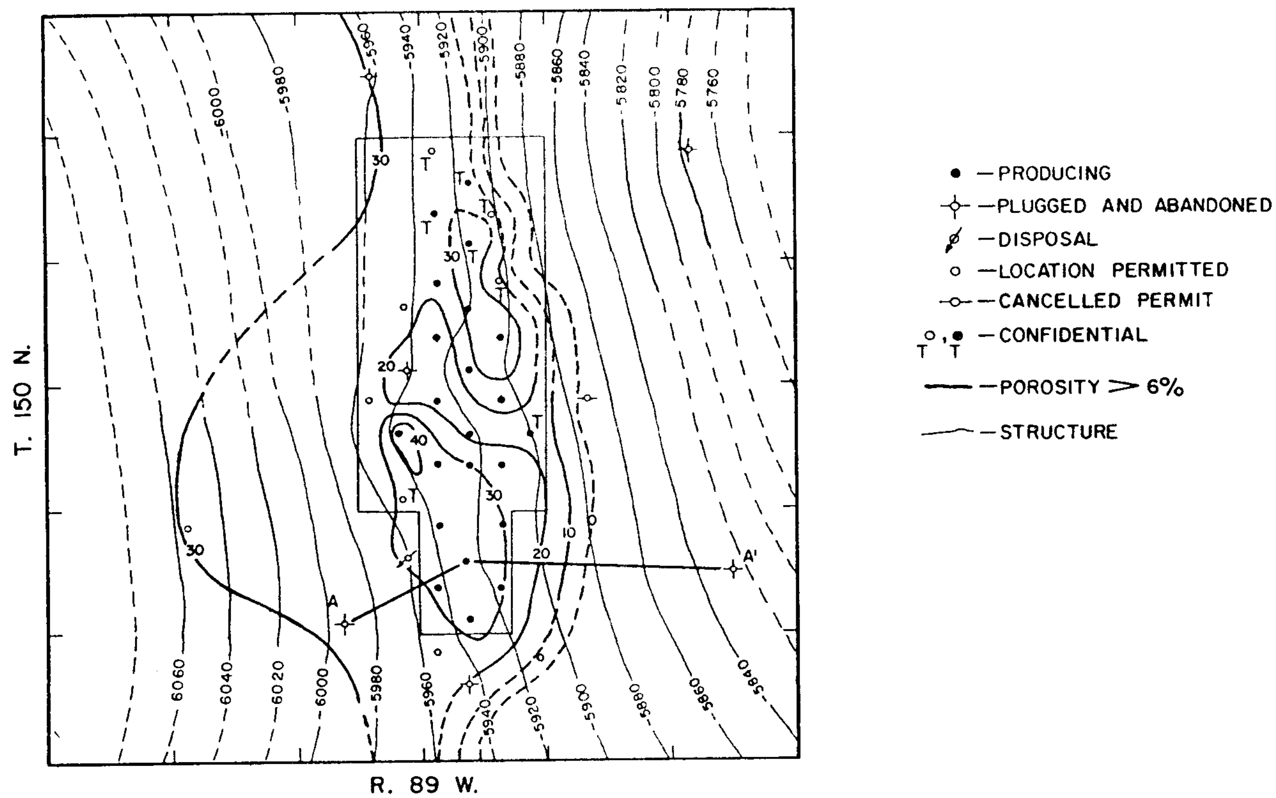
PROVED ACREAGE: 5019 acres
APPROVED WELL SPACING: 80 acres
RECOVERY DATA:
Cumulative Production to (Date): 10/1/91
Oil: 338,973 BO
Water: 120,113 BW
Estimated Original Oil in Place:
14,817 MSTBO
Ultimate primary recovery:
3,704 MSTBO
1991 Production (Sept. '91):
Oil: 42,640 BO
Water: 10,575 BW
Gas Sold: 0 MCF
AVERAGE DEPTH: 5,923′ sl
GROSS THICKNESS PRODUCING HORIZON: 24′ average (range: 7 - 39′)
NET THICKNESS PROCUCING HORIZON: 20′ average (range: 7 - 32′)
POROSITY: 9.5% average (range: 6.1 - 11.7%)
PERMEABILITY: 2 md average (range: 0.0 - 50.2 md)
FLUID SATURATION (Original):
Oil: 63%
Water: 37%
OIL-WATER CONTACT: 7978.5′ (-5986.5 sl)
API GRAVITY: 36°
RESERVOIR DRIVE MECHANISM: under saturated depletion (initial); solution gas and some water (future)
WELL TREATMENT: 15% HCl and/or 15% SWIC w/PENN 88; 1015 gal. avg. (range: 360-1700 gal.)

REFERENCES

- ND Oil & Gas Commission Case No. 5092
- 1991, Fischer, R.W. and M.L. Hendricks; Lucky Mound Field: A New Mississippian Sherwood Shoreline Field. AAPG 75 (6): 1126.

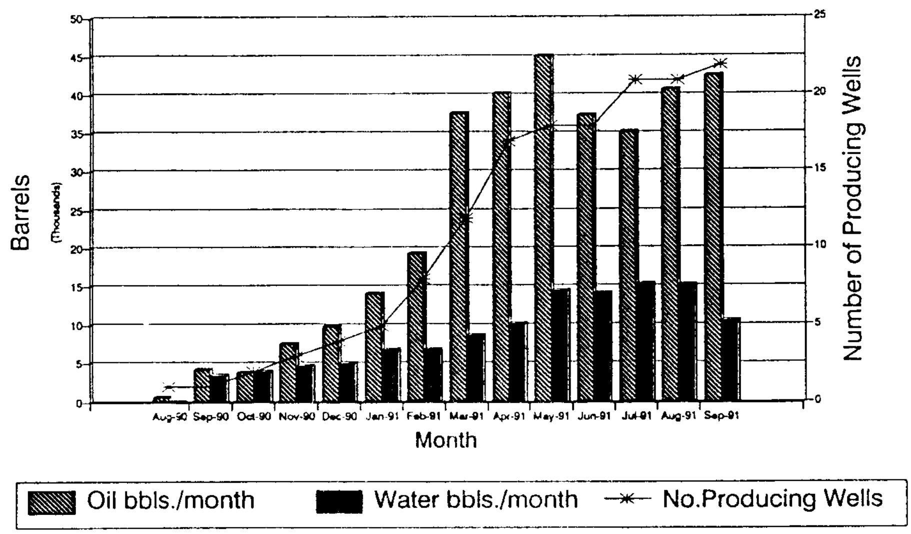

STRUCTURE CROSS SECTION
A
A'
1.1miles
2 miles
Scheer No. 1-28
Comdisco Exploration Co.
SESW Sec. 28, T.150 N., R.89 W.
Torgerson No. 22-27
Duncan Energy Co.
SENW Sec. 27, T.150 N., R.89 W.
IP: 435 BO
CUM: 38,767 BO (10-1-91)
Hendrickson No. 1-25
Mitchell Energy Corp.
SENW Sec. 25, T.150 N., R.89 W.
GR Cal SDDSN
GR Cal CDDSN
GR Cal. CNFD
ANHYDRITE
DATUM
MISSISSIPPIAN
Charles Fm.
Mission Canyon Fm.
Midale subinterval
Rival subinterval
State "A" Marker
Dale subinterval
Coteau subinterval
Bluell subinterval
Sherwood subinterval
K-1 Marker
Mohall subinterval
K-2 Marker
CORE
7700
7800
7900
8000
8100
30 20 10 0 -10
LOCATION MAP
Lucky Mound Field
T. 150 N.
R. 89 W.

COMBINED STRUCTURE AND FEET OF POROSITY > 6%



LUCKY MOUND FIELD

Monthly Production History



SIXTH INTERNATIONAL WILLISTON BASIN SYMPOSIUM

--Randy Burke

The Sixth International Williston Basin Symposium and the Fourth Saskatchewan Petroleum Conference were held in Regina on October 7-9, 1991. Registration for the Symposium was approximately 214 and for the Petroleum Conference about 135. The first joint meeting of the geological and engineering societies proved to be successful, with participant access to concurrent oral and poster technical sessions of both societies programs. Presentations about Saskatchewan's successful horizontal drilling play in Mississippian strata and source-rock identification by geochemical oil typing were highlights of the technical programs. A kilt-clad bagpiper playing a traditional tune led the head table procession into the luncheon where Dr. Bill Fyfe gave an enjoyably stimulating and informative talk about energy, the global environment, and geologists' future role with regard to these issues. Many good comments about both the core and the horizontal drilling workshops were frequently overheard.

Symposium Proceedings volumes are a primary source for Williston Basin geology. Coeditors J. E. Christopher and F. M. Haidl have produced another hallmark volume. Registrants received their customary copies of the Symposium Proceedings that includes papers on most of the oral and poster presentations. Hardcover volumes of the Proceedings are available from all three of the sponsoring Societies (Saskatchewan Geological Society, North Dakota Geological Society, and Montana Geological Society). The Proceedings volume includes 33 papers and 3 abstracts contained within 312 pages. Subjects are grouped in the areas of stratigraphy and field studies, tectonics and geophysics, and geochemistry and geohydrology.

The entire event proved successful in every way. Dr. Don Kent, the General Chairman, the Saskatchewan Geological Society, the host society, and all the organizing committees, including those of the cosponsoring geological societies in North Dakota and Montana, continued their tradition of presenting a high quality regional meeting.

RESTORATION OF THE HIGHGATE MASTODON SKELETON UNDERWAY

--John Hoganson

During preparation of the North Dakota Fossils exhibit last February, Chris Dill, Museum Director, Mark Halvorson, Curator of Collections and Signe Snortland, Archeologist with the State Historical Society, ushered me into a back room in the Heritage Center to show me a fossil they were considering using in the new First People in North Dakota exhibit. The First People exhibit, which will debut at the Heritage Center next summer, will focus on life in North Dakota from about 9,600 BC to 1738. Packed in a crate, was an almost complete, well-preserved lower jaw of a mastodon, one of the Ice Age elephants. I was asked if I thought that the specimen would be an appropriate addition to the exhibit. We know that Paleoindians hunted Ice Age elephants for food and clothing, and I concurred with them that including remains of one of these animals in the exhibit would not only be appropriate, but also highly desirable. Chris Dill, and other members of the Historical Society, recalled that more of the skeleton was stored in crates in the Society warehouse. Mark Halvorson and I ventured to the warehouse to assess the completeness and preservation of the remainder of the skeleton. To my surprise, it seemed like most of the skeleton was there. When weather permitted, Mark and I hauled the crates of bones into the Heritage Center for further assessment (fig. 1). The skeleton was found to be about 95% complete and remarkably well preserved.

Members of the First People exhibit planning committee decided to restore the specimen as a full skeletal mount to be a permanent part of the First People exhibit. I was commissioned to be in charge of the restoration. This is the type of cooperation that the Geological Survey and Historical Society were seeking when we entered into the cooperative agreement that I wrote about in the last Survey Newsletter. It is appropriate that the first restoration of a fossilized skeleton of a large extinct animal ever to be exhibited in North Dakota will be the result of cooperation between the Geological Survey and the Historical Society and that that skeleton will be displayed at the Heritage Center.

Mark Halvorson recently uncovered the incredibly fascinating history of the Highgate Mastodon skeleton. The following is a summary of Mark's findings. In the spring of 1890, William Regcraft found the bones while digging a ditch on his uncle's, John Regcraft's, farm near Highgate, Ontario. William Hillhouse, a hardware merchant from Shelburne, Ontario and his uncle, John Jelly purchased the right to excavate the bones from the Regcrafts. A crew was hired to excavate the bones and a photographer, C. Gambles, from Ridgetown, Ontario photographed the excavation (fig. 2). After the bones were removed, they were cleaned and "sized" with hot, white glue. The only tusk found, a "perfect beauty", was apparently dropped and

Figure 1. Part of the disarticulated skeleton (vertebrae and leg bones) of the Highgate Mastodon with Mark Halvorson, Curator of Collections at the Heritage Center.

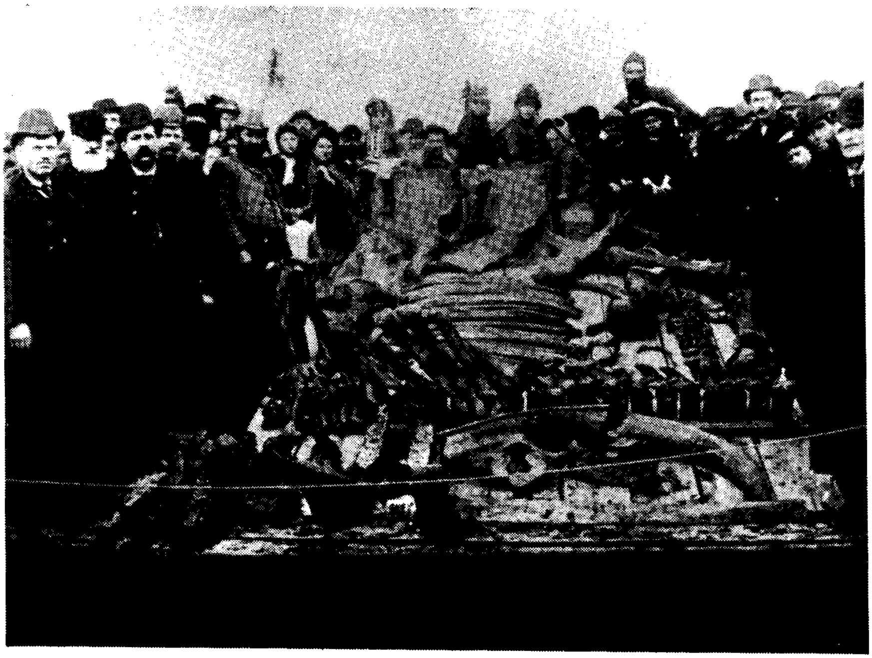


Figure 2. Photograph of the Highgate Mastodon excavation in 1890.

broken at that time and Hillhouse had it "built up and attached solid to a box" (fig. 3). The remainder of the bones were also placed in custom-made chests at that time.

From 1890 to 1892, Hillhouse and Jelly displayed the bones in Ontario. One of the teeth in the upper jaw was stolen in Galt, Ontario sometime during that period. It was during that time that Hillhouse and Jelly hired R. A. Essery at $50 a month to take the bones on the road for display. Essery headed for Winnipeg and other points West. He died somewhere out West and Hillhouse and Jelly lost track of the bones. Hillhouse apparently received a handbill, similar to the one in figure 4, from his niece from Neche, North Dakota in 1892 describing a travelling exhibit of a mastodon collected by Jelly, but now managed by people by the name of Thompson and Glover.

Around 1893 the bones ended up in storage at the Bibb Broom Corn Company in Minneapolis. Here the bones were abandoned and were sold to Harry Dickinson, a Great Northern Railway fireman, to recover some of the storage costs. Harry shipped the bones by rail to his father, C. E. Dickinson, living in Barnesville, Minnesota. The Dickinsons exhibited the bones in Moorhead, Willmar, St. Cloud, and other towns in Minnesota and South Dakota in 1895 and also in Buxton, North Dakota in 1896. At that time, James Grassick, a physician from Buxton, apparently saw the show. In 1898 the mastodon was exhibited in Minneapolis.

Later in 1898, James Grassick bought the skeleton from the Dickinsons for $10 and they shipped the bones to Grassick via Great Northern (the shipping bill was $27.84). In 1902 Grassick loaned the skeleton to the University of North Dakota for display. An interview about the mastodon with M. A. Bramon, curator of the UND museum, appeared in the Grand Forks Herald that year. Hillhouse heard that the specimen was now at

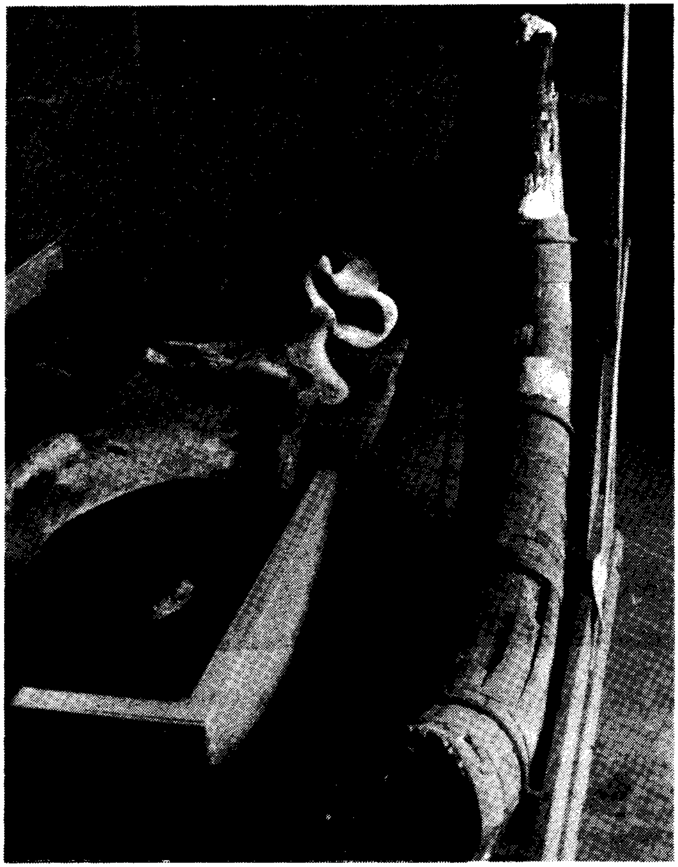


Figure 3. The solitary tusk recovered during the Highgate Mastodon excavation still in its original (1890) packing crate.

UND and wrote a letter to the University president laying claim to the mastodon. Hillhouse's attorney, John Douglas from Shelburne, Ontario wrote that "there is not the ghost of a doubt that the bones with cases were and are the property of Mr. Hillhouse". In the meanwhile, A. E. Morrison, secretary for the UND Board of Trustees informed Grassick that "legal advice to me has been to the effect that in case the railroad (Bibb Broom Corn Co.) made proper legal procedure in the sale of this property, your title to same is complete and final." Grassick quickly sold the mastodon to UND for $100. A few days later an attorney for Robert J. Jelly and Simon Jelly executors of the John Jelly estate, W. A. Stewart from Brockville, Ontario, wrote to Grassick claiming the bones on behalf of his clients. Grassick informed the Jellys that he no longer owned the mastodon.

The specimen fell into obscurity until 1947. That year, Elwyn B. Robinson, history professor at UND, wrote a letter to Russell Reid, Superintendent of the State Historical Society, stating that a "partial mastodon skeleton" had been removed from the rafters of Macnie Hall. The mastodon was transferred to the State Historical Society, was shipped to Bismarck and ended up in the rafters of one of the Historical Society's storage buildings at Fort Lincoln. It was apparently rediscovered in 1974 and was moved to a new storage facility. The crates of bones were

Figure 4. Handbill advertising the World's Greatest Wonder, the Highgate Mastodon.

removed from storage by Mark Halvorson and myself in March, 1991 and the lower jaws were placed in the North Dakota Fossils exhibit at the Heritage Center in February, 1991 (fig. 5).

At this time, we have very little scientific information about the specimen. We know that it was collected in southern Ontario, but we do not know how old it is. We are considering sending a piece of bone from the interior of one of the legs to a laboratory for radiocarbon dating. Apparently, the only article that was written about the find was by a Canadian scientist in 1891. I am currently trying to obtain that article. We believe that the skeleton is from a young, perhaps about 25 to 30 year old, adult male animal because of the size and shape of the tusk and arrangement of the teeth. This animal was over 20 feet long and stood about 10 feet tall at the shoulder.

Reconstruction of the skeleton began in November. Because my experience in fossil skeleton restoration is minimal, we decided it was necessary to bring in an expert as a consultant for the project. Dr. George Lammers, curator of geology at the Manitoba Museum of Man and Nature in Winnipeg, has been involved with several Ice Age elephant reconstructions and is working with us on the project. John Campbell, a UND student who worked for the Survey last summer as a paleontological technician, will also be working with me. Many volunteers have already taken part in the project and many more will before the project is completed. We will have to fabricate two leg bones, the tusks and much of the skull. The main challenge will be restoration of the skull, which is in poor condition (fig. 6). We are currently working on the individual bones--cleaning them, hardening them with an epoxy-like preservative, and repairing the broken parts with wire mesh and plaster. The final phase of the restoration, during which the bones will be assembled, will take place next summer. Gary Just, Artistic Iron Works in Bismarck, will be working with us at that time to construct the frame for the skeleton.

Funding for restoration of the mastodon skeleton is being provided by Mr. Marv Erdmann, President of Super Valu Retail Support System, through the North Dakota Heritage Foundation.

Figure 5. Beautifully preserved lower jaws of the Highgate Mastodon. From front to back is about 3 feet

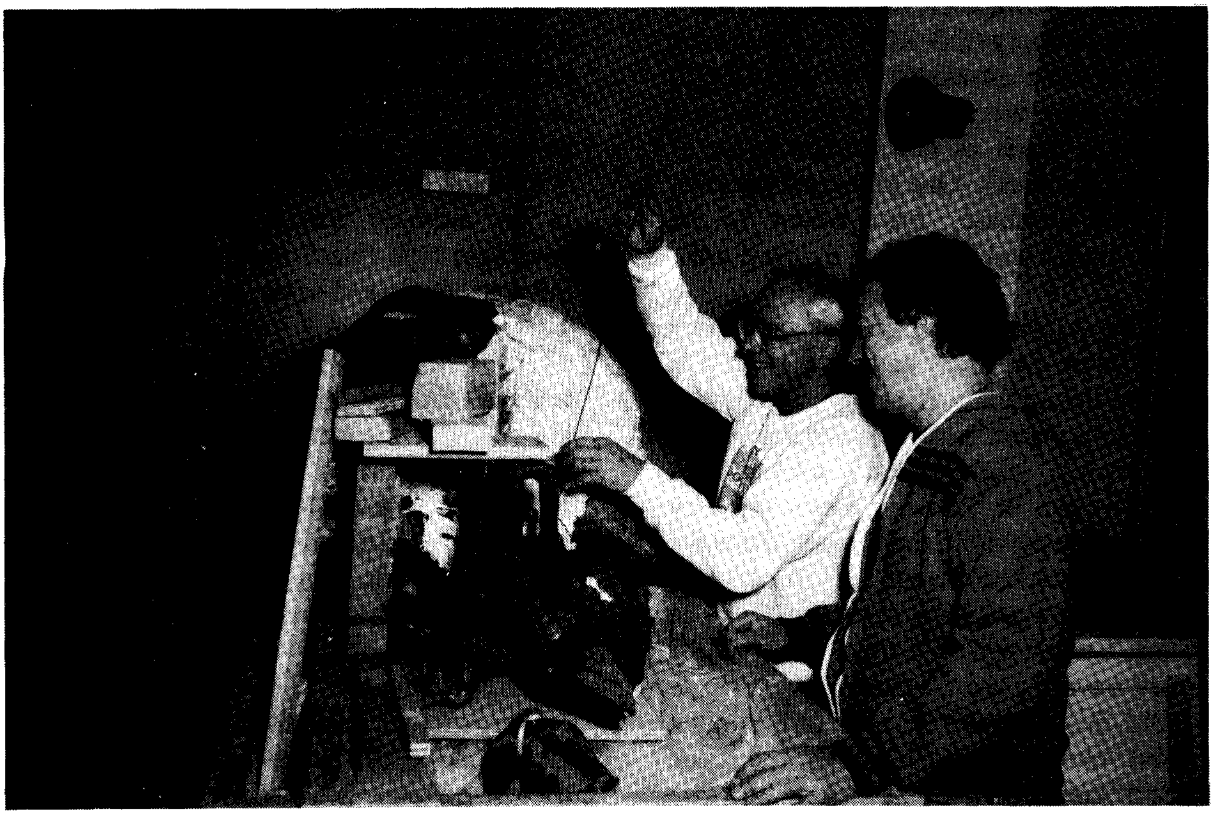


Figure 6. Restoration of the poorly preserved skull of the Highgate Mastodon using wire, screen and plaster. George Lammers (left) and John Hoganson. (Photo by Todd Strand, State Historical Society).

ESIC NEWS

--Mark Luther

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

1991 has been a year of growth in the ESIC Network. There are now sixty-two State ESIC offices nationwide, working together to strengthen the network and produce the most complete listing of earth science related materials possible. The NDGS' ESIC office has also experienced growth during 1991; receiving over 3600 requests for information or products, an average of more than 300 per month.

One of the very useful new tools that the NDGS' ESIC office has recently acquired, is a CD-ROM drive. Mounted in an IBM PS/2, Model 95 computer, the Compact Disk - Read-Only Memory (CD-ROM) drive enables us to use CD's produced by the USGS, containing very large earth science related databases (as much as 600 million bytes of information per disk). One of these databases, the APSRS database, has proven to be extremely useful and in demand by the public.

The Aerial Photography Summary Record System (APSRS) database, is ESIC's system for determining if aerial photographs of a particular area with a particular set of characteristics exist, and where the photographs can be found. There are very few, if any, areas within the United States for which this system does not list 10 or more dates of photographic coverage. The complete, nationwide listing of APSRS summary records are contained on a single CD-ROM disk. Each record describes a set of aerial photographs, including the code number of the project, the agency or firm that holds the photographs, the date of flight, the scale, the type of film used (ie., black & white, color, color infrared, etc.), the percent of cloud cover, and the percentage of the 7.5 minute USGS topographic map covered by the photograph.

An example of the type of data that can be retrieved for a specific area is shown in Figures 1 and 2. Figure 1 shows a listing of airphotos available for the area covered by the Bismarck, 7.5 minute quad, topographic map. Figure 2 shows additional information available for two of the listings (underlined) in Figure 1. This is an example of the type of information that a person would receive following an airphoto inquiry at our ESIC office.

Persons wishing to locate existing aerial photography for a given locale can contact our ESIC office with any of the following information: location of interest relative to a town; the name of the 7.5 minute topographic map that the area is located on; or the latitude/longitude numbers located on the southeast (lower right) corner of the 7.5 minute map that the area is located on. Additional parameters that can be considered in an airphoto search include: date of coverage; type (black and white, color, color infrared, etc.); and scale.

Once it has been determined that there is aerial photography available that will meet the needs of the person making the inquiry, the next step is to acquire a copy of that airphoto. The NDGS has a very limited collection of airphotos that are available for use by the public in our office. In most cases, however, airphotos will have to be purchased from the agency or company holding the negatives. The NDGS does not sell airphotos, but through our ESIC office we have the order forms and expertise to assist the public in acquiring them. Most aerial photography can be purchased from one of two Federal Agencies:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
Phone # (605) 594-6151

Aerial Photography Field Office
USDA-ASCS
P.O. Box 30010
Salt Lake City, UT 84130-0010
Phone# (801) 524-5856

Airphotos are available in numerous formats such as paper or film (positive or negative) copies, and in numerous sizes ranging up to 36" x 36". The most commonly used format is the 9" x 9", paper copy. Generally, prices for that format are $6.00 per photo for black and white, and $16.00 for color or color infrared. It takes approximately

F1:Help F2:Full/List F3:Format F4:Sort F5:Output F6:Jump (Image) F8:Done

Brief Columnar: 1 of 39

AGENCY	DATE	PROJECT	SCALE	FILM TYPE
U.S. GEOLOGICAL SURVEY	1986 Jul 01	N46	00058000	COLOR INFRARED
U.S. GEOLOGICAL SURVEY	1986 Jun 01	N46	00080000	BLACK AND WHITE
U.S. GEOLOGICAL SURVEY	1984 Apr 19	CITY4	00062303	COLOR INFRARED
AGRICULTURAL STABILIZATION	1980 Jul 22		00040000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1980 Jul 14		00040000	BLACK AND WHITE
NASA - NATIONAL AERONAUTIC	1979 May 16	02758	00064000	BLACK AND WHITE
NASA - NATIONAL AERONAUTIC	1979 May 16	02757	00064000	COLOR INFRARED
U.S. GEOLOGICAL SURVEY	1976 May 28	VEDF	00036000	BLACK AND WHITE
BUREAU OF LAND MANAGEMENT,	1975	MDAP-4	00024000	COLOR INFRARED
BUREAU OF LAND MANAGEMENT,	1975	MDAP-3	00080000	BLACK AND WHITE
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NASA - NATIONAL AERONAUTIC	1974 Nov 06	2900	00020000	COLOR INFRARED
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NASA - NATIONAL AERONAUTIC	1974 Nov 06	2900	00020000	COLOR INFRARED
NASA - NATIONAL AERONAUTIC	1974 Nov 06	2900	00020000	COLOR
NASA - NATIONAL AERONAUTIC	1974 Nov 06	2900	00020000	COLOR
NASA - NATIONAL AERONAUTIC	1972 Sep 14	2110	00064020	COLOR INFRARED
NASA - NATIONAL AERONAUTIC	1972 Sep 14	2110	00064618	COLOR INFRARED

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Brief Columnar: 39 of 39

AGENCY	DATE	PROJECT	SCALE	FILM TYPE
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NASA - NATIONAL AERONAUTIC	1972 Sep 14	2110	00118258	COLOR INFRARED
NASA - NATIONAL AERONAUTIC	1972 Sep 14	2110	00117864	COLOR INFRARED
AGRICULTURAL STABILIZATION	1971 Aug 22	BAB	00040000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1971 Jul 16	AZY	00040000	BLACK AND WHITE
TOBIN RESEARCH	1969 Sep		00040000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1964 Aug 07	BAB	00020000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1964 May 24	AZY	00020000	BLACK AND WHITE
U.S. GEOLOGICAL SURVEY	1961 Oct 26	VAHX	00024058	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1957 Aug 24	AZY	00020000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1957 Jul 29	BAB	00020000	BLACK AND WHITE
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BUREAU OF RECLAMATION, EDC	1951 Sep 10	203600	00027000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1950 Oct 18	BAB	00020000	BLACK AND WHITE
AGRICULTURAL STABILIZATION	1950 Sep 03	AZY	00020000	BLACK AND WHITE
NATIONAL ARCHIVES AND RECO	1938	AZY	00020000	BLACK AND WHITE
NATIONAL ARCHIVES AND RECO	1938	BAB	00020000	BLACK AND WHITE

Figure 1.

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                                                  Full Vertical: 1 of 39

Agency                    U.S. GEOLOGICAL SURVEY
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Longitude                 1004500W
FIPS State/County
Date of Coverage          1986 Jul 01
Project Code              N46
Scale                     00058000
Focal Length              OTHER
Film Type                 COLOR INFRARED
Sensor Class              VERTICAL CARTO (IMPLIES STEREO)
Cloud Cover               0%
Quadrangle Coverage       100%
Remarks                   0083 0115
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F1:Help F2:Full/List F3:Format (Sort)  F5:Output F6:Jump (Image)  F8:Done

                                                 Full Vertical: 39 of 39

Agency                    NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
Latitude                  464500N
Longitude                 1004500W
FIPS State/County         ND,Burleigh
Date of Coverage          1938
Project Code              BAB
Scale                     00020000
Focal Length              8.25IN OR 210MM
Film Type                 BLACK AND WHITE
Sensor Class              VERTICAL CARTO (IMPLIES STEREO)
Cloud Cover               0%
Quadrangle Coverage       70%
Remarks                   ASCS PROJECT
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Figure 2.

six weeks to receive airphotos following submission of an order.

The aerial photography search service available through the NDGS' ESIC office is a valuable, money saving benefit provided to the North Dakota public. We encourage the use of this service.

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

SURVEY AND U. S. ARMY CORPS OF ENGINEERS SIGN AGREEMENT TO MANAGE FOSSILS FOUND ON CORPS ADMINISTERED LANDS IN NORTH DAKOTA

--John Hoganson

The Survey and the U. S. Army Corps of Engineers recently signed an agreement to cooperatively identify, manage, and protect fossils found on lands administered by the Corps of Engineers in North Dakota. The Corps of Engineers issues permits for fossil collecting on Corps controlled lands in North Dakota. Through this agreement the Survey will now take an active role in this permitting process by evaluating the permit applications and recommending to the Corps whether the permits should or should not be granted.

This agreement also provides for information exchange between the Survey and Corps regarding fossil sites located on or near lands in North Dakota under Corps jurisdiction. In addition, when a potentially significant paleontological site is discovered on Corps lands, the Survey will assist the Corps in assessing the significance of the site and, if the site is threatened, will recommend appropriate mitigation measures.

As a result of this agreement, the Corps will also stipulate in the fossil collecting permits they issue to collectors not affiliated with a North Dakota institution, that after appropriate study, representative samples of specimens collected in North Dakota under the Corps permits will be deposited with the North Dakota Geological Survey for permanent curation.

The Survey signed similar agreements with the U. S. Forest Service--Custer National Forest in 1986 and with the Federal Bureau of Land Management in 1988.

ALAN M. CVANCARA, UND GEOLOGY PROFESSOR, RETIRES

[Editor's Note: I've adapted most of this article from the Fall issue of the Alumni News, the newsletter of the University of North Dakota Department of Geology and Geological Engineering.]

After experiencing several years of severe back problems, without finding a cure, Alan Cvancara applied for disability retirement so that he can work at his own pace on his many writing and research projects. Alan graduated from the University of North Dakota with a BS in geology in 1955 and an MS in 1957. After serving in the Air Force from 1957-1960 as a commissioned officer, he went on as a Fulbright Fellow to Australia and then completed a Ph.D. at the University of Michigan in 1963, after which he joined the geology faculty at UND. During his 28 years at UND, Alan was recognized as an outstanding instructor, researcher, editor, naturalist, and musician. He has never started anything without intending to become an expert--whether it was learning about wild edible foods, scuba diving, winter survival, clams, shark teeth, photography, wood carving, or the banjo. His students know him as a meticulously organized and demanding professor.

Over the years, Alan worked on a variety of projects involving the North Dakota Geological Survey. About 15 years ago I worked with him on clam populations in North Dakota rivers. In 1983 we published his report -- Aquatic Molluscs of North Dakota (NDGS Report of Investigations 78). More recently, Alan worked with NDGS paleontologist John Hoganson on a number of projects including a study of the vertebrate fossils (primarily fish) of the Cannonball Formation in North Dakota.

Alan will be recognized at a Geology and Geological Engineering Department banquet on April 3. All former students are encouraged to plan to attend. If you cannot attend, please send a letter to him c/o Dr. John Reid, and it will be placed in an appropriate book and presented to him at the banquet.

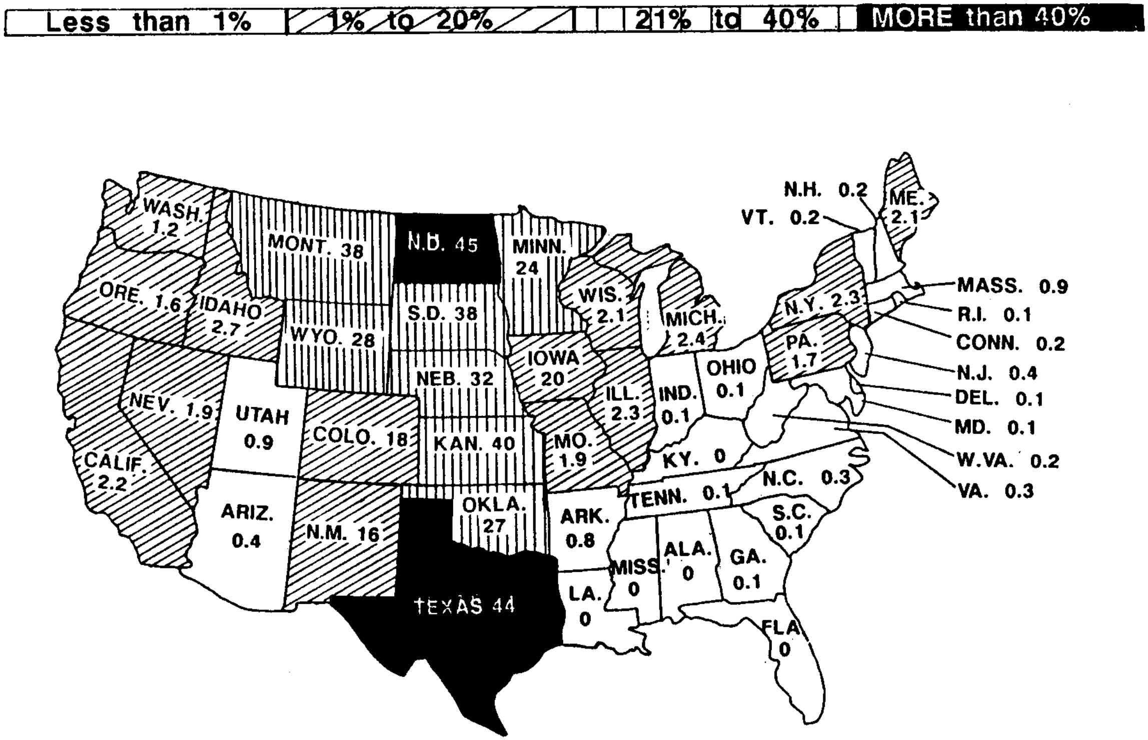
POWER FROM THE WIND IN NORTH DAKOTA

--John Bluemle

Among the 48 states (Alaska and Hawaii excluded), North Dakota could generate the highest percentage of its own electricity needs by using wind power. According to an article that appeared in the *New York Times* on November 8, North Dakota could obtain as much as 45 percent of its electrical needs by using windmills to harness wind power (Fig. 1). Several other Great Plains states could obtain percentages ranging from 20 to 44 percent.

U. S. Windpower, Inc. a California firm responsible for most of the wind energy development in the U.S., is now involved in a project planned for generating windmills in the Midwest. The company may submit as many as four separate proposals to Montana Power to supply up to 100 megawatts (Mw) of wind power. The company's director, Barrett Stambler, said "This state (Montana) is sitting on a strategic petroleum reserve of wind." U.S. Windpower claims that, with its advance technology, it can deliver the power to Montana Power at 5 cents/kWh, which is considerably below DOE estimates of 7.5 cents/kWh for wind-produced electricity. The company's ultimate goal is to bring power from Montana to the west coast. U.S. Windpower is also planning to team up with Iowa-Illinois Gas & Electric Company in a joint venture to build and develop a wind energy farm in the nine-state area comprising Iowa, Illinois, Nebraska, North Dakota, South Dakota, Michigan, Minnesota, Missouri, and Wisconsin.

Amount of electricity in 1990 that could have been generated by wind power for each state.*



*Figures assume 50-meter high (54.7yards) wind turbines, operating at 25% efficiency, with 25% energy loss.

[Editor's Note: 1991 is the 40th Anniversary of the discovery of oil in North Dakota. On July 4 - 6, the event was celebrated in Williston -- the Williston Basin Energy Festival II. As a part of the events, Bill Shemorry, a long-time newspaper man in Williston who has covered oil stories in the Basin since before oil was discovered here, published a book titled Mud, Sweat & Oil The early days of the Williston Basin. *It's an interesting book, quite humorous in places, and I recommend it for anyone who would like to know more about the early days of the oil industry in North Dakota. The following article is taken from the book. I had to leave out a few parts to keep the length down, but people who want to hear the whole story can get a copy of the book for themselves. The address is: Williston Chamber of Commerce, 10 Main, Williston, ND 58801 or call 701-572-3767.]*

An imposing granite monument ten miles south of Tioga marks the location of the first producing oil well in North Dakota. It is a historic reminder of the beginning a hustling new state industry.

The No. 1 Clarence Iverson, named for the mineral and land owner, was spudded September 3, 1950. It was the first real oil exploration to take place in western North Dakota since the 1930s. At that time, the Big Viking and California deep tests had been drilled on the Nels Camp farm about 20 miles south.

The possibility of finding oil in North Dakota had been talked about since before World War I. The interest was there and when the Iverson wildcat began drilling 41 years ago, it created a great deal of local excitement. A crowd of 100 or so people, mostly from the Tioga and Ray vicinities, was present to watch.

The spud date was on a Sunday and if the word had gotten out a little better, there likely would have been a much larger crowd, and press and radio coverage as well. However, Amerada Petroleum Corporation and Loffland Brothers Drilling Company officials who were in charge did not deem it necessary to notify the press. As a result, THE BEGINNING of oil in North Dakota was not recorded for posterity. Roy Fuller, Blackie Davidson, and R. E. Tinsley, Amerada and Loffland officials on the scene, in relating the incident later, said there was nothing unusual about it.

"When the rig was up and everything was ready," remarked Fuller, "The motorman released the clutch. The rotary table began to turn and the bit entered the ground for the first time."

As drilling went on, interest increased and so did press coverage. However, the newsmen and radio people assigned to cover the Iverson operation were inexperienced in the reporting of wildcat oil drilling and there were undoubtedly many things that were not adequately covered. As a result, at times many wild rumors circulated.

A comprehensive story on the Iverson well was not told until a year and a half later. At that time, which was April, 1952, the first anniversary of the oil discovery, Charles S. Agey, an assistant chief geologist for the Amerada Company wrote and released what amounted to an official account of the trials and tribulations accompanying the first successful drilling for oil in North Dakota. His story follows:

"On July 18, 1950, a

stake was driven into the good earth of North Dakota at a site on the Clarence Iverson farm. A big rotary rig was moved in and rigged up over this spot.

"At 6 o'clock in the evening of September 3, 1950, a date and hour which is now memorable in the history of North Dakota, the drill bit broke the surface of the ground beneath, and the Clarence Iverson was spudded in.

"On January 2, 1951, four months after spudding, on the second bull-dogged attempt to test this interval, the now famous 'pint of oil' was recovered from a drillstem test at 10,448 and 10,803 feet in the Devonian formation.

This was the first free oil (I certainly am not using the word 'free' in a monetary sense) ever to be found in North Dakota.

"With no help from the weather man, but with the obstinacy of the wildcatter, the hole was carried on down to 11,400 feet without finding additional shows of oil or gas.

"At this depth, we had 10,200 feet of open hole beneath the surface casing...hole which was only kept open by the weight of the drilling mud. Under conditions such as these, the risk of losing the hole was tremendous.

"It was at this time that the decision was made to core ahead as far as possible, set casing and test all possible shows.

"Hole was carried to 11,744 feet where loss of the faced off a core bit made further drilling in the unprotected hole too hazardous. At this depth on February 26, 1951, 11,743 feet of 5 1/2 inch casing was cemented in...I might add...with a great sigh of relief.

"The relief didn't last too long, as Old Man Winter moved in to show us that he had been just fooling around up to this time. It took us a month to make perforations and tests from 11,678 to 11,720 feet, and all we had for our trouble were small shows of oil and gas.

"These perforations were cemented off and additional ones made from 11,630 to 11,660 feet. Through these perforations the well tested 2 million cubic feet of natural gas, and after another 4,000 gallons of acid, the gas increased to 7 million. It was suspected that a light spray of oil accompanied the gas. So a separator was installed to determine whether the well was making any fluid.

"To the happy amazement of all concerned, the suspected spray of oil tanked 307 barrels in 17 hours when tested through the separator. We will not soon forget that hectic day of April 4, 1951 when this occurred and the electrifying news that North Dakota was now an oil producing state was spread to the corners of the earth."

The work on the Iverson discovery location was not finished.

The Iverson No. 1 was now able to produce from the Devonian. However, subsequent drilling discovered oil in the shallower Madison zone in the nearby Bakken, Dilland and Math Iverson wells. So a decision was made to retest the Madison formation under the Iverson. Agey's story continues:

"The Amerada Petroleum Corporation's No. 1 Palmer Dilland well, located in the center of the southwest quarter of the northeast quarter of Section 31, Township 156 North, Range 95 West, was spudded in August 8, 1951, (four months following the Iverson discovery).

"On this well, following successful tests at the No. 1 Bakken near Tioga to the north, which found oil (September 9, 1951) in the Madison, a mud and sample analyzing trailer was installed. This equipment is capable of finding minute quantities of oil and gas in mud and cuttings and helps detect possible producing zones.

"Drill stem tests (in the Dilland) were made at the following intervals: 8,101 to 8,172 and 8,225 to 8,330 feet, all with the same disappointing results, small gas shows. Not to be denied, continuous testing was not abandoned, and on October 10, 1951, we were rewarded when a drillstem test of the interval of 8,394 to 8,444 feet flowed 219.2 barrels of 40 degree gravity oil in four hours. This, then was the date of the first oil production from the Madison formation in the Beaver Lodge pool.

"Consecutive tests from 8,396 to 8,529 feet, a gross interval of 133 feet, flowed oil at a total hourly rate of 159.57 barrels."

The Dilland was located 1 3/4 miles northeast of the No. 1 Clarence Iverson location. To the southeast 1 1/4 miles, the Math Iverson was also drilling. The findings of both contiguous location were considered to be most important. Agey's story concludes:

"The M. B. Rudman-American Viking-Tioga Petroleum No. 1 Math Iverson was spudded in August 21, 1951. On drillstem test at 8,360 to 8,500 feet, gas came to the surface in ten minutes, mud in one hour and forty-five minutes and oil in three hours (November 3, 1951).

"This was the second well in the (Beaver Lodge) pool to find oil in the Madison.

"Following the tests at the Dilland and the Math Iverson, Amerada Petroleum Corporation decided to plug back the original discovery well, the Clarence Iverson, to the Madison horizon. Oil shows were not observed in this section during (the original) drilling but were (later) suspected from various logs run prior to completion.

"After perforating and cementing at 8,555 to 8,557 and 8,475 to 8,477 feet, the well was tested through perforations from 8,530 to 8,540 feet at a plugback depth of 8,543 feet. We were not sure of a shut-off, so re-cemented, and at a plugback depth of 8,529 feet, perforated from 8,520 to 8,528 feet.

"After 2,000 gallons of acid, the well was recompleted for a gauge of 677 barrels of oil in 24 hours, producing through a one-fourth inch positive choke, to become the first well in the Beaver Lodge Field to produce from two zones."

The C. Iverson 1 Madison completion date, as recorded in a North Dakota Geological Survey bulletin, was December 17, 1951.

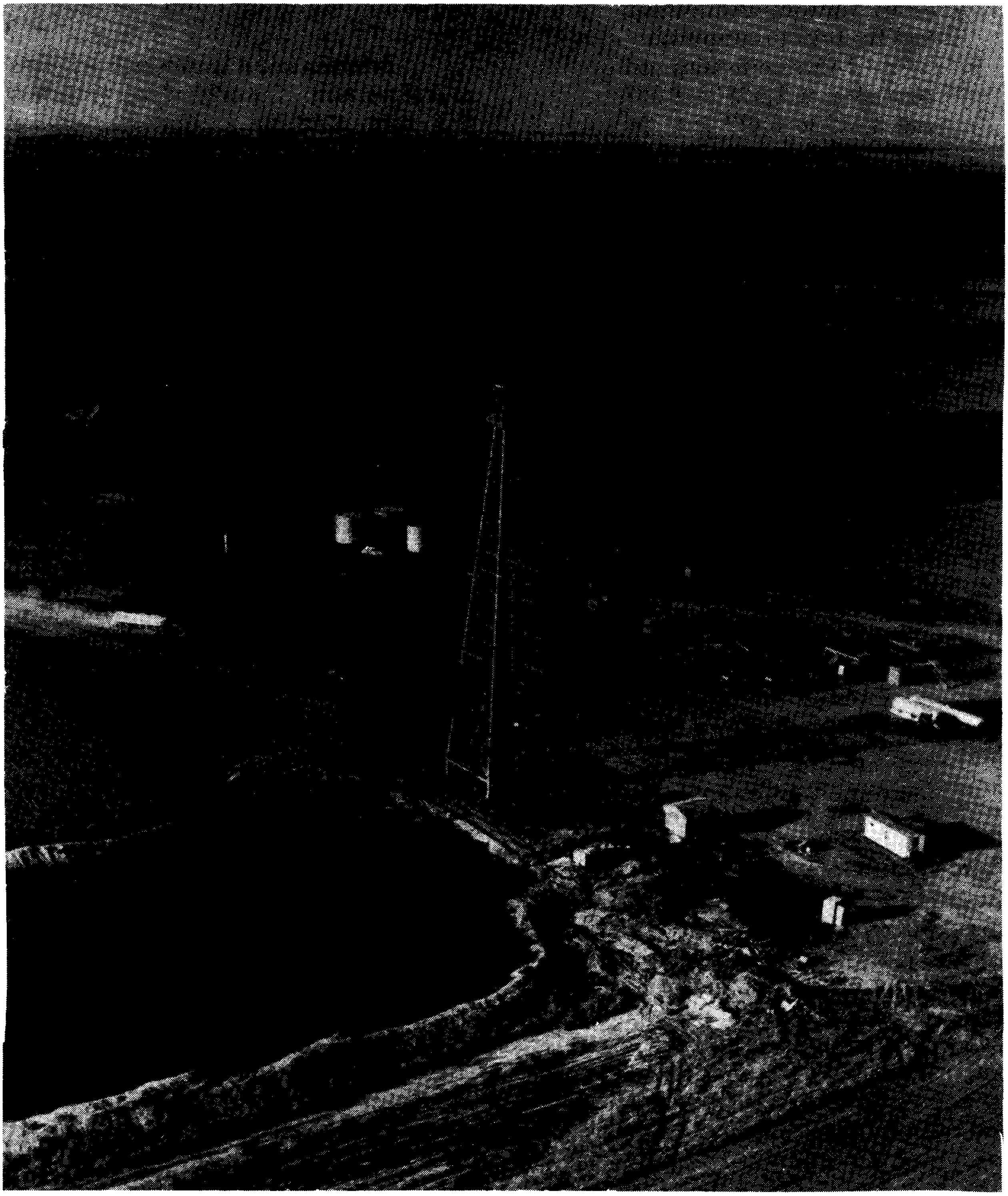
According to later news stories, the Iverson was produced from the Madison formation until September 28, 1959. But after the loss of the hole due to a bad fishing job, it was switched back to the deeper Devonian horizon, crude flowing through perforations at 10,490 to 10,530. Three and one half years later, on February 11, 1963, production began in the Silurian formation at 11,638 to 11,671 feet. The location was shut down for good August 2, 1979 after its 28-year-old casing had collapsed and was deemed impossible to repair.

Amerada said it spent a million dollars to drill this well. The original cost projection had been $208,708. However, drilling problems, worse than usual winter and remoteness from oil field supply hiked the price. To drill the same well under same circumstances today could be as much as five times what Amerada had to pay in 1950-51.

But on the other side of the coin, the well, during its 28 years of life, produced a total of 583,529 barrels of oil and 818 million cubic feet of natural gas. Clarence Iverson received his first royalty check for $172.27 for the period of April 4 to April 30, 1951. There were many more that followed. Although the value of the well's total production is a very tidy sum, changing prices of crude and different gravities from three production zones all have made this a bit of complicated research which has never been attempted.

In 1980, the Amerada-Hess corporation, successors to the original Amerada firm, announced plans to re-drill the Iverson 1, not as a producer on its own but as part of the water flooding project which now exists in the Beaver Lodge Field. A new location was staked out 100 feet from the original hole. Heavy machinery came to the scene and leveled out the location, preparing for a rig, but then the plan was dropped.

As of October, 1988, an Amerada-Hess official, in response to an inquiry, stated no further drilling was planned at the No. 1 Clarence Iverson location.



Amerada Petroleum Corporation's Clarence Iverson No. 1 wildcat location ten miles south of Tioga looked like this as it was being rigged up in early September, 1950. Six months later at this well, oil was recovered in commercial quantities for the first time in North Dakota.

THE ORIGIN OF HOGBACK RIDGE McHENRY COUNTY, NORTH DAKOTA

--John Bluemle, Mark Lord, Nate Hunke

A group of unusual glacial landforms occurs in southern McHenry County in the region between Verendrye and Balfour. Here, an array of about 200 exceptionally long, narrow ridges can be seen. The ridges are commonly referred to as "drumlins," although they are not typical of drumlins found in other parts of the world. The most prominent of the ridges is a feature that is usually referred to as "Hogback Ridge." This ridge is 17 miles long, but most of the ridges are only about 1 to 2 miles long. The long drumlins are also closely associated with an extensive area of ice-thrust topography that occurs to the southeast of them (Fig. 1).

During June of 1987, we spent about a week examining Hogback Ridge. We used a backhoe to dig trenches in the ridge (Fig. 2). The trenches were as long as 400 feet, as deep as 15 feet, and about 3 feet wide. Groundwater flowing into some of the trenches as they were being excavated caused caving and made it necessary for us to inspect the geology as quickly as possible. The poor lighting conditions in the deep, narrow trenches made photography difficult. Even so, a complex array of sedimentary and glaciotectonic structures was revealed by the excavations. We were able to observe, photograph, and record many of the features.

In this article I will briefly describe the structure and morphology of the features we found during our excavations, and I will discuss the origin of the drumlins. I won't try to explain all of the theoretical considerations here. We expect to publish a technical article on the long drumlins sometime next year.

Description of the Drumlin Ridges. The most obvious characteristic of the McHenry County drumlins is their <u>extreme</u> length to width ratios. Typical drumlins in most parts of the world have length to width ratios of about 3 to 1 (meaning they are three times as long as they are wide). Most of the drumlin ridges in McHenry County, on the other hand, have length to width ratios that range between 1:30 and 1:50. The largest and longest of the drumlin ridges, Hogback Ridge, is 17 miles long, 180 to 400 feet wide at the base (averaging about 375 feet wide). It is about 25 feet high through most of its length, giving it a length:width ratio of about 1:240.

Hogback Ridge, along with nearly all of the other drumlin ridges in the area, trends from northwest to southeast, indicating the direction of glacier movement through the region. All of the drumlin ridges in the area are exceptionally straight (Figs. 3 and 4), so straight, in fact, that they might at first be mistaken for artificial features. Hogback Ridge resembles a large railroad or highway grade; in fact, a segment of it was once used as a road. At the southeast end of Hogback Ridge, and slightly offset from it, a second ridge begins and continues for another 4 miles. Some of the drumlin ridges, including Hogback Ridge, are bordered, on one or both sides, by long, narrow, pond-filled depressions. These depressions are 3 to 6 feet deep, up to 0.1 mile wide, and average about a mile long.

Hogback Ridge, along with other long drumlins nearby, occurs within a zone situated 3 to 6 miles upglacier from a band of ice-thrust topography (Fig. 1). The drumlins splay or radiate parallel to the direction the glacier was flowing when it emplaced the thrust features in the area to the east and southeast. The long drumlins occur in an area in which a thin layer of silty to sandy glacial sediment (till) overlies bedded silt and sand

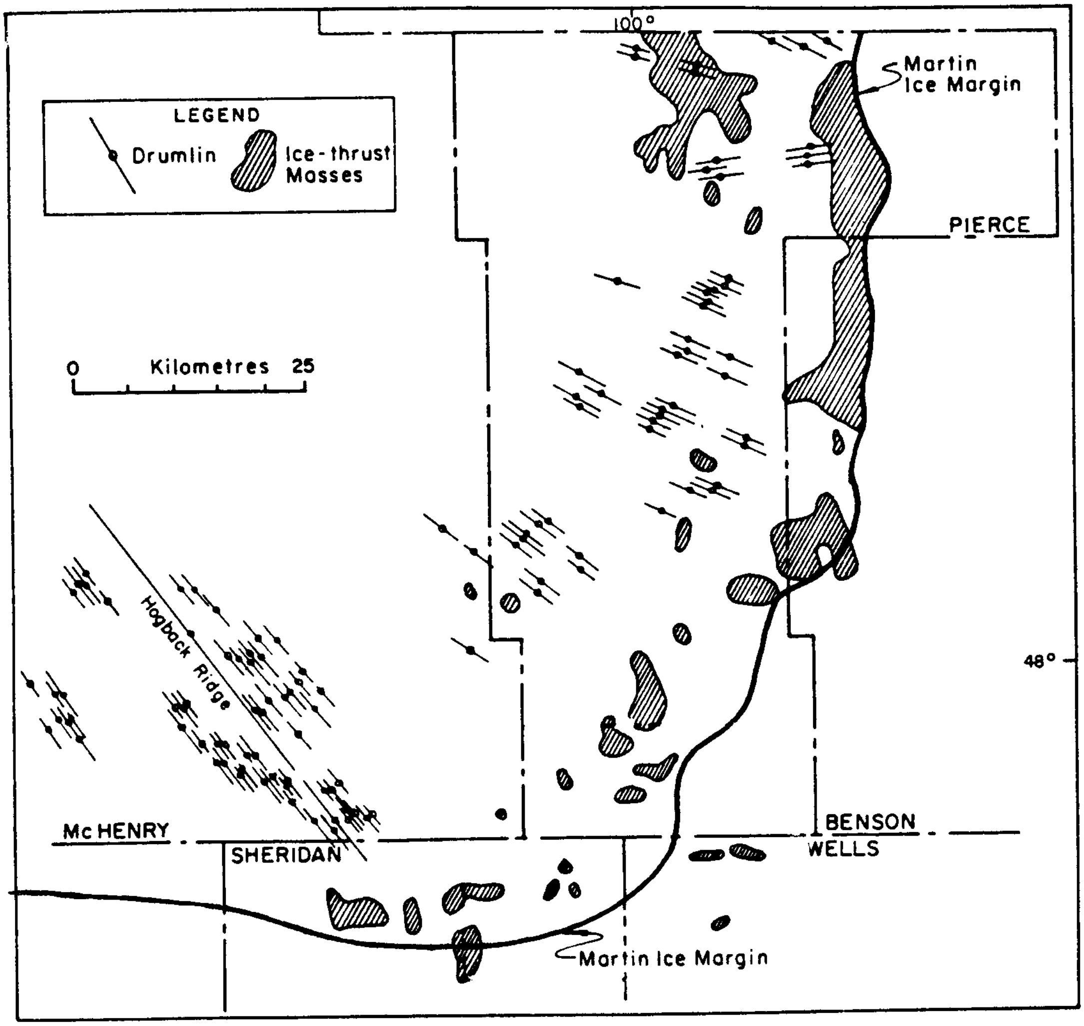


Figure 1. Map of a part of central North Dakota showing the zonal relationship of the ice-margin position, thrust features, and long drumlins. Although similar situations can be recognized in other parts of North Dakota, Alberta, and Saskatchewan, it is difficult to find a place where the position of the ice margin can be verified as well as here. This map shows known areas of thrusting (shaded areas); and long drumlins (line symbol).

that were deposited in a lake dammed ahead of the glacier. The glacier that formed the drumlin ridges and ice-thrust masses advanced over the lake floor. The lake formed ahead of the ice again when the glacier advanced for the last time, but when the ice melted, the new lake (glacial Lake Souris) flooded a more restricted area than had the earlier lakes; the area in which the drumlins occur was not flooded by glacial Lake Souris.

Description of the Excavations. During our study, we made several long backhoe trenches in Hogback Ridge in two locations. We located the first series of trenches about 4 miles from the northwest (upglacier) end of the ridge and the second was 5 miles to the southeast of the first. Because of access constraints, we could not make the excavations in directions normal to the axis of the ridge. Rather, we made them in rights-of-way paral-

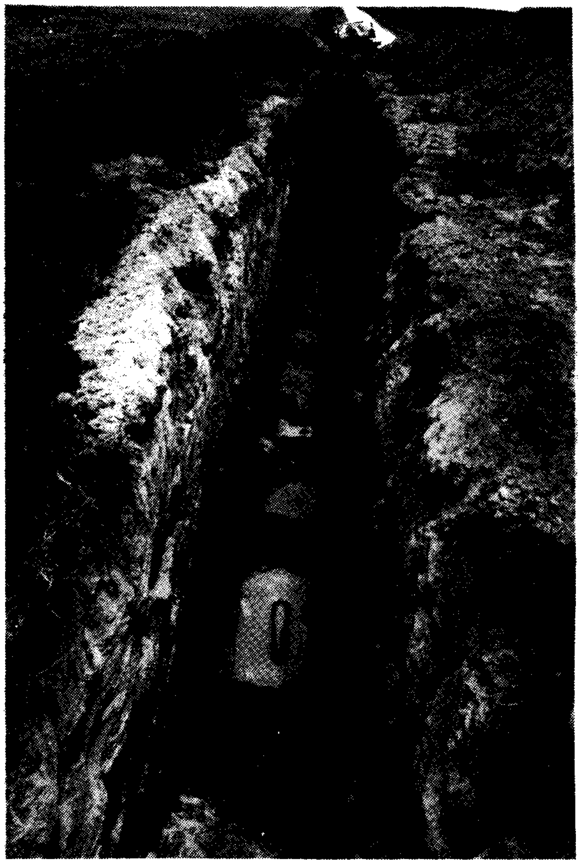


Figure 2. Backhoe excavation across Hogback Ridge. The trench was as deep as 15 feet and about 3 feet wide.

lel to roads crossing the ridge. We made the first series of excavations in an east-west direction and the second series north-south.

The backhoe excavations through Hogback Ridge revealed an intricate system of internal structural and stratigraphic features, some of which are schematically shown on figures 7 and 8. The types of sediments found within Hogback Ridge include bedded silt and clay (lake deposits), sand and gravel (river deposits), gravelly sand, silt, and clay (glacial deposits), and sandstone blocks derived from the Paleocene Cannonball Formation which underlies the glacial deposits throughout the area. The bedded fluvial and lacustrine sediments tend to dip steeply, either toward or away from the center of the ridge; some of the bedding is vertical. We noted hundreds of small-scale, normal (gravity) faults dipping downward, mainly away from the center of the ridge. Although fluvial (river) and lacustrine (lake) bedding were seen in many places, the beds were invariably disturbed (Fig. 5). Originally water-lain materials consisted of blocks that ranged up to more than 6 feet in diameter. In some of the blocks we saw, delicate layering structures are preserved, but in most of them, the original structures have been either greatly altered or nearly complete ly destroyed (Fig. 6).

The longest cut we made, through the central portion of the ridge (pit C on Fig. 8), revealed an almost bewildering array of contorted, twisted, and irregular beds of sand and

Figure 3. Several long, narrow drumlins in the Balfour area of McHenry County.

gravel (material that was originally deposited by running water), laminated fine sand and silt (material originally deposited in a lake), and glacial sediment, consisting of gravelly sand, silt, and clay (till) (Fig. 5). We saw numerous lenses of poorly sorted gravel and well-sorted fine sand, some of them with near-vertical bedding and all containing numerous small gravity faults, along with irregularly distributed masses of till. These lenses, which were apparently pushed or injected upward into the center of the ridge when it formed, were a common occurrence. Settling after emplacement apparently resulted in the formation of the gravity faults.

Associated Features. In the vicinity of the second series of excavations, Hogback Ridge is immediately bordered, on both sides, by long, narrow depressions. The largest depression, along the southwestern side of the ridge, is about 2 miles long, 0.1 mile wide, and 6 feet deep (that is, the bottoms of the depressions are 6 feet below the surrounding, flat land adjacent to the ridge). The depressions are partially flooded, resulting in ponds.

The upglacier ends of some of the drumlins begin at small glacier-thrust masses, which are the same height as the drumlins. Hogback Ridge extends southeastward from a thrust mass composed mainly of glacial till, along with some glaciofluvial material. The thrust mass at the head of Hogback Ridge is about 0.6 mile long (NW to SE) by 0.3 mile wide (NE to SW) and 50 feet high. Some thrust masses found at the upglacier ends of smaller drumlins are composed of blocks of Paleocene sandstone that may be as small as a few tens of feet long and between 6 and 15 feet thick.

An esker extends along the western side of Hogback Ridge. It follows a twisting route, essentially parallel to the ridge for a distance of about 8 miles. The esker is located between 0.6 and 1.0 mile west of the ridge. It begins near the northwestern end of Hogback Ridge (near the thrust mass that forms the upglacier end of the ridge) and extends along approximately half the length of the ridge. The highly segmented, prominent esker is generally between 10 and 20 feet high, and consists of poorly sorted, silty gravel, sand, and till.

In addition to the features I've just described, Hogback Ridge is bordered on either side by washboard moraines (low ridges that formed parallel to the receding glacier margin) (Fig. 5).

Discussion. We calculated that, in the vicinity of Hogback Ridge, at a distance of 80 miles upglacier from edge of the glacier, the ice was thin, not more than 750 feet thick. We also determined that the last glacier, the one that formed the long drumlins during late Pleistocene time, was moving very fast, probably over 100 feet per day.

A glacier can flow at an accelerated

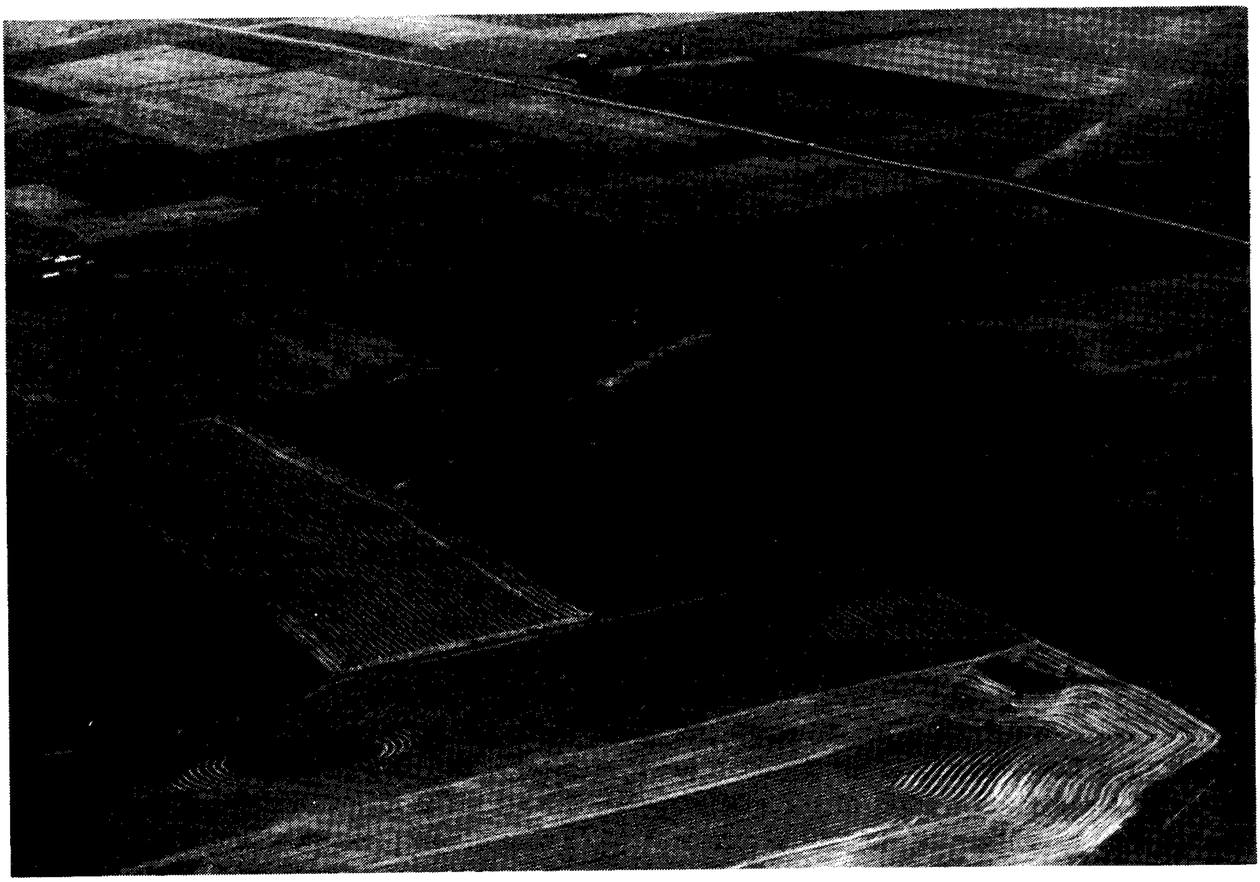


Figure 4. Air view of Hogback Ridge near Verendrye in McHenry County. The ridge (light-colored streak extending from the upper right corner of the picture) is about 40 feet high in this area.

Figure 5. Interbedded coarse sand, silt, and banded clay near the center of Hogback Ridge. Notice faulting and contorted bedding.

rate when high pore-water pressures build up beneath the ice. These high pore-water pressures may occur in sediments beneath a glacier where low and high permeability sediments are interbedded. In this instance, the high pressures built up in beds of buried glacial lake deposits over which the glacier was flowing. As each continental glacier flowed generally southward over the area, it blocked the regional, northerly surface drainage and groundwater flow systems, diverting them to the south beyond the margin of the glacier. The low-permeability of the near-surface sediments over which the glacier was flowing offered no easy escape route for the groundwater. Pressures that built up in the groundwater approximated the total normal stress applied by the glacier and helped to support the weight of the ice. This contributed to rapid glacier flow by reducing friction to a very small amount. In addition to causing the fast-flowing conditions in the glacier, the high pressures also facilitated the thrusting.

Conclusions. Hogback Ridge was probably initiated in a subglacial cavity formed as the glacier overrode a previously ice-thrust block. The cavity that resulted at the base of the glacier as it flowed over the block became a zone of low pressure within the glacier, with adjacent higher pressure glacial ice surrounding the cavity. As a result of the pressure differential, the adjacent glacial ice converged, producing elevated pore-water pressures in the

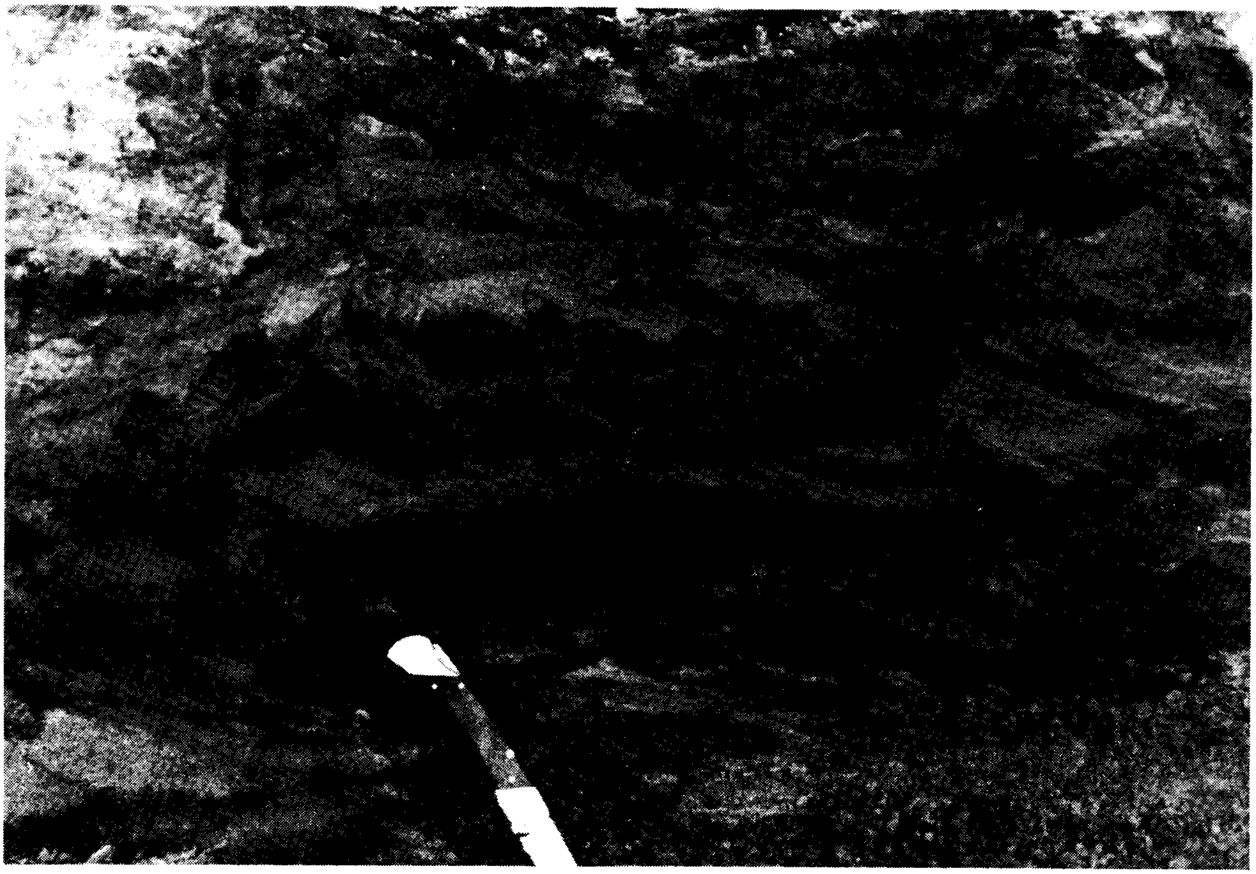


Figure 6. Contorted beds of sand and banded clay in Hogback Ridge.

groundwater immediately beneath the glacier. The cavity in the thin glacier remained open long enough for the long, narrow drumlins to form (had the glacier been thicker, the cavity would quickly have been squeezed shut by the inward flow if ice). Although we postulate that Hogback Ridge formed when the glacier flowed over a small ice-thrust block, any obstruction in the glacier's path could have initiated the drumlin-forming process and it is likely that some of the other long drumlins formed downglacier from other kinds of obstructions.

We believe that Hogback Ridge, and the other long drumlins in this area, were formed by the glacier as constructional features, with glacial and hydraulic transport from the sides, inward, under conditions of high subglacial pore-water pressure conditions. These materials were forced--squeezed, shoved, and injected--to the ridge from the source locations that became the long, narrow depressions along the sides of the drumlins; that is, the materials that make up the drumlins were derived, in part at least, from the nearby depressions. The presence of intact blocks of material with intricate, essentially undisturbed bedding strongly suggests that some sediments were frozen at the time they were emplaced. Some unfrozen inclusions may have slid into position without the bedding being completely destroyed, but it is difficult to see how most of them could have been emplaced without destroying the internal bedding, unless they were frozen at the time.

The presence of the esker that extends southeastward, near the western side of Hogback Ridge, is consistent with features that form during the ice-thrusting process. When thrusting takes place, large volumes of groundwater escape from beds beneath the glacier and flow beneath the ice toward its margin.

Generally, our study of the long, narrow drumlins in North Dakota has led us to the conclusion that a close and consistent relationship exists between the ice-thrusting process and the formation of the long drumlins. Conditions necessary for the formation of long, narrow drumlins, primarily high pore-water pressure and rapid ice movement, also tend to favor ice thrusting.

NEW NDGS PUBLICATIONS

Atlas Series Map 14-A1 -- "Surface Geology of the Goose River Map Area" was drawn by Kenneth L. Harris and Mark R. Luther. Each map in this series covers an area of one degree of longitude by one degree of latitude. This map covers the eastern-most part of North Dakota, including parts of Grand Forks, Steele, Traill, Barnes, and Cass Counties, between 47° and 48° North Latitude and approximately 96° 45' (the Red River) and 98° West Longitude.

This colored Atlas map shows the composition of the surface materials and their and origin. Four elements of the surface geology of the Goose River Map Area are shown on the map: (1) a description of the sediment present, (2) an interpretation of the age of the sediment, (3) an interpretation of the origin of the sediment, and (4) a description of the topography of the map area. Lithologies are shown by the use of color. The age and origin of the sediment are shown by the use of map-unit numbers. A detailed description of the map unit and line symbols is also included.

The Goose River Map Area can be divided into four areas based on the occurrence of similar or genetically related landforms. These areas include the Lake Agassiz Basin, the Elk Valley "delta," the Edinburg Moraine, and the Glaciated Plains. Each of these areas contains a unique set of landforms determined by the geological processes responsible for depositing or modifying the sediment in the area.

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

The map was drafted by Mr. Philip Heywood, cartographer with the Minnesota Geological Survey. We appreciate the help we received from the Minnesota Geological Survey in the preparation of this map.

The map is provided in a 9 1/2" x 12" envelope. As work progresses on the Atlas Mapping Project, we will provide additional maps and other information from time to time, both on the Goose River Map Area and on other map areas.

This Atlas map is available for $5.00 from the North Dakota Geological Survey.

Report of Investigation 92 -- "Correlation Cross-Sections Along the United States - Canada International Border (North Dakota - Manitoba) were drawn by Julie A. LeFever of the North Dakota Geological Survey, Carol D. Martiniuk of the Manitoba Energy and Mines Branch, and Sidney B. Anderson, formerly with the North Dakota Geological Survey. The series of five correlation sheets cover the 1) Cretaceous, 2) Triassic/Jurassic, 3) Mississippian, 4) Devonian, 5) Cambrian-Ordovician-Silurian. The cross sections show log correlations of eight wells, four in Manitoba and four in North Dakota, comparing the terminology used in Canada and in the United States. A formation-by-formation description of each Canadian and American unit is included in the text on each chart. Stratigraphic nomenclature diagrams are also included for each of the five time periods treated. Report of Investigation 92 is also listed as Manitoba Energy and Mines Petroleum Open-File Report POF 12-91.

Report of Investigation 92 can be obtained from the Survey for $10.00.

COMMENTS

Do you have questions, comments, or suggestions regarding the Newsletter, Oil and Gas Division services or North Dakota Geological Survey services? For additional information on any of the items mentioned in this Newsletter, please contact North Dakota Geological Survey, 1022 East Divide, Bismarck, ND 58501, (701) 224-4109.

CHECKLIST FOR NEW PUBLICATIONS

_______AS-14-A1 ($5.00) Surface Geology of the Goose River Map Area

_______RI-92 ($10.00) Correlation Cross-Sections Along the United States - Canada International Border

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