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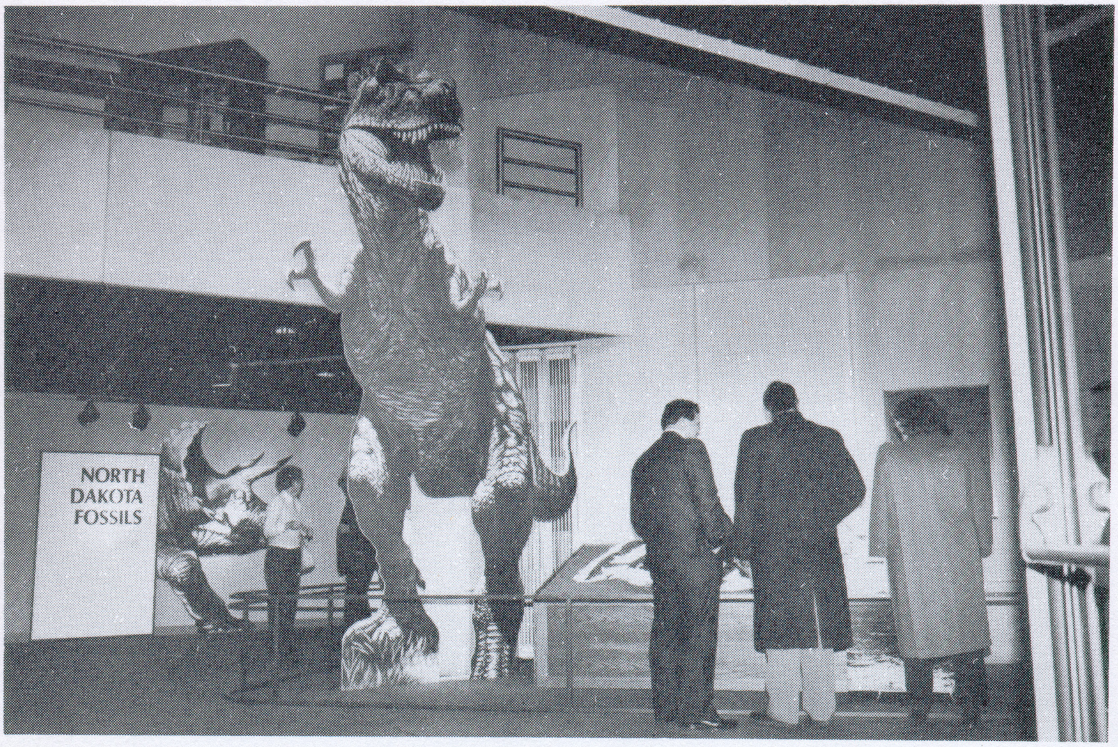


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NORTH DAKOTA GEOLOGICAL SURVEY
1022 E DIVIDE AVE
**Mailing Address:**
600 E BOULEVARD AVE
BISMARCK ND 58505-0840
Phone: (701) 224-4109

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## CONTENTS



## COVER PHOTO

Opening night of the North Dakota fossils exhibit at the Heritage Center, February 21, 1991. Entrance to the exhibit with a Triceratops skull in case and life-size Tyrannosaurus overseeing the proceedings. Photograph by Todd Strand, State Historical Society Photo Archivist.

## SURVEY ACTIVITIES

As was noted in the last issue of the *NDGS Newsletter*, **Sidney B. Anderson** retired from the North Dakota Geological Survey in August. Sid had been with the Survey for 39 years and served as Acting State Geologist since 1985. **John P. Bluemle** was appointed State Geologist on May 13, 1991 after a nationwide search lasting several months (see copy of press release issued by the Industrial Commission).

The NDGS suffered a series of severe funding and staffing cuts through the 1980's, culminating with the move to Bismarck two years ago. However, with the transfer of the Survey to the Industrial Commission and recent increases in funding and staffing by the Legislature, the Survey is finally regaining its former strength at a time when the need for geologic information about environmental concerns and energy sources is at an all-time high.

The NDGS is currently advertising to hire three people to fill one vacant position and two new positions created during the recent legislative session. We are seeking a geologist to work mainly with subsurface stratigraphic problems and two geologists to work on environmental problems and on surface mapping. At this time, the position of Assistant State Geologist remains vacant, although we may soon advertise for this position.

One of our new positions is an environmental geologist to examine landfills in North Dakota (this position is funded through June 30, 1995). Solid waste issues continue to be a major concern in the state. In responding to the heightened concerns about solid waste problems, the 1991 Legislature directed the NDGS and the State Water Commission to evaluate all of the existing landfills in North Dakota, about 60 of them, over the next four years and make recommendations. The NDGS does not have regulatory authority in these matters, but acts as an advisor to the State Health Department.

Our geologic surface mapping program has been making very slow progress since, as a result of the cuts mentioned above, we have not had sufficient personnel to do the needed geologic mapping; the staffing shortages have been especially acute during the past two years. With the addition of one person with mapping duties, we should be able to get more surface mapping done and undertake more vulnerability mapping. We recently completed our third 1° x 1° quadrangle in our Atlas Series (AS 14) along the Minnesota border. This map will be authored by **Ken Harris** and **Mark Luther** (Ken was formerly with the NDGS, but is now with the Minnesota Geological Survey). Drafting, which was done by the Minnesota Geological Survey, is complete for this map and the NDGS will be publishing it within the next several months. We hope to complete mapping of an additional area in northeasternmost North Dakota next year. The completion of this map will round out our Atlas mapping of the Red River Valley.

**Mark Luther** has also been studying lithic resources that were exploited by Native Americans. His work may lead to better methods of identifying the sources of these materials by archaeologists. Results so far indicate that it is possible to recognize at least 14 distinct lithic sources or types in North Dakota. Mark attended the National Earth Science Information Center (ESIC) meeting in Washington, DC in May and provided input for major restructuring of the ESIC Network.

**John Hoganson** is continuing his work on the vertebrates of the Cannonball Formation with Alan Cvancara, geology professor at the University of North Dakota. He is also working with Alan on the molluscs of the Alkali Creek archeological site. John is studying Cretaceous fish in North Dakota and he is working with fossils of the Breien Member of the Hell Creek Formation. He is working with Alan Ashworth, geology professor at North Dakota State University, on fossil insects as indicators of Ice Age climates.

John recently completed an exhibit of North Dakota fossils at the North Dakota Heritage Center (see separate article). He is continuing his work at developing the State Fossil Collection and he handles the issuing of fossil collecting permits for State lands. John has also been involved with evaluating oil and gas lease tracts for possible impact on paleontological resources. Over the past six months, John gave about ten lectures to service groups.

**Ed Murphy** is in the process of completing reports on two three-year studies. The first was on six North Dakota landfills, and the second was on subsurface pesticide movement in McHenry County. Ed and John Hoganson recently completed a four-year study of the Oligocene and Miocene sediments of North Dakota (along with Nels Forsman of the University of North Dakota geology department). They are currently waiting for age determinations to be completed on volcanic ash samples that were submitted to the USGS laboratory in Denver. When that information is received, their report will be published by the NDGS. We recently received notification from the USGS that they are funding a Cogeomap project for mapping the Cretaceous/Tertiary boundary in south-central North Dakota. This project involves Ed, John, and Nels, with the addition of Doug Nichols from the USGS in Denver.

Other projects underway by NDGS geologists include a study by **Julie LeFever** of a sandstone unit within the Bakken Formation in North Dakota, Manitoba, and Saskatchewan and another study of the Bakken as a source rock. The Bakken has been a major target for horizontal drilling activity in the Williston Basin. Julie will be giving talks on both topics at the Rocky Mountain Section AAPG meeting in Billings in late July.

**Randy Burke** is continuing his work on the Devonian system in southwestern North Dakota and on Devonian System reefs in northwestern North Dakota and Saskatchewan. Part of the Devonian project, done with Tom Heck, was the recently published Report of Investigation No. 90 on Devonian stratigraphy of North Dakota from wireline logs sections. This report consists of seven statewide cross sections of the Devonian System. Another project, showing the coincidence of the edge of the Charles Formation F-salt and Mississippian Mission Canyon Formation production, will be published at the Williston Basin Symposium in Regina, October 7-9, 1991.

**Tom Heck** recently completed a report which we published on oil and gas activity in the state during 1988-1989 (NDGS Miscellaneous Series 74). We recently released a condensed version (NDGS Report of Investigation 91) of the report we did for the Forest Service on oil and gas potential in the Little Missouri Grasslands area in western North Dakota. The authors of this report are David Fischer, Julie LeFever, Tom Heck, and Richard LeFever. Other new publications include reports on Devonian stratigraphy

(NDGS Report of Investigation 90) and one dealing with stratigraphic nomenclature problems along the North Dakota-Manitoba border (this last report, Report of Investigation 92, will be released shortly).

**John Bluemle** completed a report on radiocarbon dates on the beaches and outlets of Devils Lake (Miscellaneous Series 75). He also recently published a map (with Jim Aber of Emporia State University in Kansas) showing the locations of glaciotectonic features in the northern plains states and provinces (Miscellaneous Map 32). Most of John's activities during the past six months centered on the recently completed legislative session, testifying on pertinent bills including the Survey's budget and other concerns. John attended the annual meeting of the Association of American State Geologists, held in Saratoga Springs, New York in early May.

The Survey has recently accepted a lead role in the development, implementation, and coordination of Geographic Information Systems (GIS) in the State. In addition to its other GIS-related activities, the NDGS is responsible for maintaining a "clearinghouse" of digital spatial data (see separate article in this newsletter).

## INDUSTRIAL COMMISSION NAMES STATE GEOLOGIST

*[Editor's Note: This is a copy of a press release issued by the Industrial Commission of North Dakota on May 13, 1991].*

The state Industrial Commission has hired John P. Bluemle, Bismarck, as state geologist after a nationwide search.

Bluemle has served as acting state geologist since June 28, 1990. He was assistant state geologist from 1987-1990 and has been involved with the state Geological Survey since 1962.

Bluemle earned his Ph.D. in geology from the University of North Dakota in 1972. He has a master's degree in geology, which he received from Montana State University in 1962. Bluemle obtained his bachelor's degree in geology from Iowa State University in 1960.

Agriculture Commissioner Sarah Vogel, who represented the Industrial Commission on the search committee, said the committee sought applicants from across the nation. She said 62 people applied for the position. The 3 member search committee was assisted by representatives of the industry, federal and state agencies, and higher education, who work closely with the Geological Survey. The search committee consisted of Vogel, Wes Norton, Oil and Gas Division Director, and David Sprynczynatyk, State Engineer.

"We are pleased to hire John, as he is clearly qualified for the job, has a proven track record and is a resident of North Dakota," Vogel said.

Bluemle is a member of several professional organizations, including the American Association of Petroleum Geologists, the Geological Society of America, the American Institute of Professional Geologists, and the N.D. Natural Science Society, of which he served as president from 1977-1979 and 1988-1989.

## NDGS SEEKS ADDITIONAL GEOLOGISTS

The North Dakota Geological Survey currently has three positions available for geologists. We are currently advertising to fill these positions and we hope to hire people within the next several months.

We are seeking to hire a stratigrapher/petroleum geologist, a person who to do well log correlation as well as core analysis, basin analysis, and sequence stratigraphy. This person should have a knowledge of Williston Basin geology and he/she should also be familiar with computer applications in geology, particularly with GIS systems.

The other two positions are both related to environmental geology and surface mapping. During the last Legislative Session, the Geological Survey and State Water Commission were directed to evaluate all of the existing landfills in North Dakota. This evaluation is to be completed within the next four years, and we intend to hire a geologist specifically to do this job for us. This position is funded for four years.

The other position, which is a permanent one, is for an environmental geology/surface mapper. We are currently proceeding very slowly with our mapping, with only one geologist able to devote a portion of his time to mapping. In addition, our one environmental geologist is rapidly becoming "buried" by the amount of concerns caused by increased environmental awareness, etc. The new person will take over a portion of this work and also enable us to undertake additional projects.

The advertisements for these positions will appear in various national geologicaljournals--Geotimes, Groundwater, AAPG Explorer, and others. If any of the readers of this newsletter are interested, we will be happy to provide copies of the ads.

--Mark Luther

## NDGS IS DESIGNATED GIS CLEARINGHOUSE

The NDGS, with the support of the North Dakota GIS Technical Committee, has recently accepted the responsibility of maintaining a listing of digital data (spatial or map-related) produced for areas within the state. Acting as a "clearinghouse", the NDGS will be a centralized, focal-point for inquiries about the availability of digital spatial data. Benefits to agencies (both federal and state) and the general public will include greater ease of locating needed data, and a reduction in expensive data duplication.

The listing of available data will be based on USGS 7.5 minute quad map names. Once the system is fully operational, individuals needing digital data will need only to call the NDGS clearing house coordinator and give the following information: the name of the 7.5 minute quad map for the area of interest; and the type of data (ie. geologic, soils, land use, roads, etc.) that they need. The clearinghouse coordinator will, in turn, provide a description of: the type of digital data available for that quad; who produced the data (including a contact person); the scale it was mapped; the relative quality (determined by the producing agency); and its availability (whether or not it is available for general distribution). In addition, information such as when the data was produced, the project that it was produced for, and when and if the data has been updated will also be available.

The NDGS hopes to have forms for soliciting information sent to potential producers of digital data during the month of July, 1991. As the responses are received, they will be entered into our system. The NDGS would like to encourage all North Dakota producers of digital spatial data to contact our office so that a record of their data can be included in the "clearinghouse". We hope to have the "clearinghouse" operational by September, 1991, and would like to encourage users and producers of digital spatial data to use this service.

The current "clearinghouse" coordinator is Mark R. Luther, Phone (701) 224-4109

## AAPG-SEPM-EMD/ROCKY MOUNTAIN SECTION MEETS IN BILLINGS

The combined meeting of the Rocky Mountain Section of the American Association of Petroleum Geologists (AAPG), the Society for Sedimentary Geology (SEPM), and the Division of Professional Affairs (EMD) will meet in Billings on July 28-31, 1991. The meeting will be at the Plaza Holilday Inn & Convention Center.

AAPG, SEPM and EMD sessions cover a wide variety of topics including shallow gas resources, thrust-belt and Basin and Range exploration, new techniques in exploration, general stratigraphy, and fractured reservoirs. In addition, poster papers covering a variety of topics will be presented each day, with one session devoted entirely to the ongoing Western Interior Cretaceous study.

Four field trips include: 1) Nye-Bowler Lineament-Beartooth Front, July 27 and 28; 2) Colorado Shale Revisited, Central Montana, July 27; 3) Sequence Stratigraphy of the Cretaceous Eagle Sandstone near Billings, August 1; 4) Coalbed Gas Potential, Tertiary Fort Union Formation, Powder River Basin, Montana, August 1.

Three pre-convention short courses are: 1) Fractured Reservoirs, Characterization and Production, July 27; 2) Carbonate Reservoir Evaluation, July 28; 3) Shaley Sandstone Evolution, July 28.

For further information, contact AAPG 1991 RMS Meeting, Tulsa, OK or W. W. Ballard/W. R. Cronoble, Co-Chairmen, Balcron Oil Co., (406) 259-7860.

## WILLISTON BASIN SYMPOSIUM AND PETROLEUM CONFERENCE FILLED WITH STIMULATING TECHNICAL PRESENTATIONS: -- Randy Burke

Geologists and petroleum engineers from the Rocky Mountains and the northern Great Plains of North America will be flocking into the Ramada Renaissance Hotel in Regina to learn about the most current ideas on petroleum geology and technology being applied to exploration in the Williston Basin. The program is offering 49 oral presentations by geologists and engineers. An additional 20 poster presentations will provide ample opportunity for one on one discussions of minute details of the authors ideas. For those interested in the truth, four core displays in a workshop format are slated to provide a chance to look at the rocks that hold the truth and contain the oil in the Williston Basin. Horizontal drilling technology will be illuminated to all interested in a comprehensive workshop. A complete listing of the technical programs for both the symposium and the Conference follows. For complete details on registration or social functions, please contact me at the Survey.

**6TH INTERNATIONAL**
**WILLISTON BASIN SYMPOSIUM**
**and**
**FOURTH SASKATCHEWAN**
**PETROLEUM CONFERENCE**
**Regina, Saskatchewan, Canada**
**October 7, 8, and 9, 1991**

**Registration prior to 1 August $200**

## TECHNICAL PROGRAM (TENTATIVE) - WILLISTON BASIN SYMPOSIUM

### Oral Presentations

1. **Binda, P.L., E.M.V. Nambudiri, S.K. Srivastava, M. Schmitz, A. Longinelli, and P. Iacumin**; Stratigraphy, paleontology, and aspects of diagenesis of the Whitemud Formation (Maastrichtian) of Alberta and Saskatchewan.
2. **Burke, R.B.**; Mississippian oil production in part of Burke, Mountrail, and Ward Counties, North Dakota.
3. **Burton, J.**; Reservoir styles and porosity characteristics of the Mississippian Ratcliffe Beds; Oungre to Lake Alma field transect, S.E. Saskatchewan.
4. **Chow, N.**; Dolomitization in Middle Devonian platform carbonates, Elm Point Formation, interlake area, Manitoba.
5. **Daly, D.J.**; Stratigraphy and depositional environments of the Fox Hills Formation, Bowman County, North Dakota.
6. **Halabura, S.P.**; Regional considerations concerning Elk Point Basin paleogeography, Saskatchewan.
7. **Hoff, J.L.**; Sedimentary cyclicity of Mission Canyon and Charles Formations, Williston Basin, North Dakota: constraints on facies models.
8. **Jones, F.W.**; The thermal state of the Williston Basin in Canada.
9. **Kent, D.M., and J. Minto**; Growth patterns of the Middle Devonian Winnipegosis Formation, Bluff Reef, Dawson Bay area, Manitoba.
10. **Kreis, L.K.**; Depositional history of the Jurassic System and Jurassic hydrocarbon production in the Wapella-Moosomin area, S.E. Saskatchewan.
11. **Lake, J.H.**; Transgressive cycles in an overall shallowing upwards sequence, Mississippian Mission Canyon, Nottingham Unit, S.E. Saskatchewan.
12. **Lefever, J.A., C.D. Martiniuk; E.F. Dancsok., and P.A. Manhick**; Petroleum potential of the middle member, Bakken Sandstone.
13. **LeFever, R.D., and J.J. Crashell**; Structural development of the Williston Basin in southwestern North Dakota.
14. **LeFever, R.D.; and J.A. LeFever**; Tectonic development of the northern part of

the Nesson Anticline, North Dakota Williston Basin.
15. **Luther, K.C.**; Gravity modeling of Proterozoic structures in north-central North Dakota.
16. **Martindale, W.**, et al.; Winnipegosis buildups of the Hitchcock area, S.E. Saskatchewan - a case study.
17. **Monson, L.M., and D.F. Lund**; Breaking into Bakken potential on the Fort Peck Reservation in N.E. Montana.
18. **Oglesby, C.A., and D. Fischer**; Sedimentology and petroleum geology of the Triassic Spearfish sandstone reservoir, South Starbuck Field, Bottineau County, North Dakota.
19. **Osadetz, K.G., L.R. Snowden, and P.W. Brooks**; Oil pool compositions in southwestern and west-central Saskatchewan: a preliminary report.
20. **Osadetz, K.G., L.R. Snowden, and P.W. Brooks**; Relationships among oil density, gross composition, and thermal maturity indicators in northeastern Williston Basin oils and their significance for expulsion threshholds and migration pathways.
21. **Potter, D.**; Routledge pool: a model for development of the Virden-Whitewater Lake paleoerosional trend, S.W. Manitoba.
22. **Potter, D., and A. St. Onge**; Minton pool, S.E. Saskatchewan: a model for basement-induced structural and stratigraphic relationships.
23. **Shurr, G.W., F.D. Wosick, M.K. Tozer, and A.D. Tweed**; Cretaceous shallow gas production controlled by basement block boundaries on the margins of the Williston Basin.
24. **Sperr, T., S.T. Stancel, and M.L. Hendricks**; Wabek and Plaza fields: carbonate shoreline traps in the Williston Basin of North Dakota.
25. **Young, H.R., and L.R.P. Rosenthal**; Stratigraphic framework of the Mississippian Lodgepole Formation in the Virden and Daly Oilfields of S.W. Manitoba.

## Poster Presentations

1. **Ahmed, M., and W.M. Last**; Deposition and diagenesis of the MC-3 member of the Mission Canyon Formation, Pierson Field, Manitoba.
2. **Bezys, R.K., and F.M. Haidl**; Regional correlation of Lower Paleozoic carbonates - eastern Alberta to Hudson Bay.
3. **Binda, P.L.**; Anoxic sulphidic diagenesis in the Ordovician Winnipeg Formation of Saskatchewan.
4. **Braun, S.M., and R.B. Burke**, A detailed gravity survey over a known Devonian Winnipegosis carbonate buildup: the Shell Golden reef, northwestern North Dakota.
5. **Carlson, C.G.**; Permain to Jurassic redbeds of the Williston Basin.
6. **Chipley, D., and T.K. Kaiser**, Large scale fluid movement in the Western Canadian Sedimentary Basin.
7. **Edwards, W., and W.M. Last**; Petrology of the middle Bakken member in the Daly Field, S. W. Manitoba.
8. **Husain, M.**; Regional geology and petroleum potential of the lower Amaranth Formation, Coulter-Pierson area, S.W. Manitoba.
9. **Karma, R.**; Conodonts of the Bakken Formation in Saskatchewan.
10. **Kessler, L.G.**; Subsidence-controlled stratigraphic sequences and the origin of shelf sand ridges, Winnipeg Group (Middle to Upper Ordovician) in Manitoba, Saskatchewan and north Dakota.
11. **Kihm, A.J., and J.H. Hartman**; Stratigraphic distribution of *Titanoides* (Mammalia: Pantodonta) in the Fort Union Group (Paleocene) of North Dakota.
12. **Koehler, G., and T.K. Kyser**, Fluid events recorded in the hydration water of

carnallite from the Elk Point Basin of western Canada.

13. **Kovac, L.J., and W.M. Last**; Mineralogy and geochemistry of Cretaceous oil shales in Manitoba.

14. **Kreis, L.K., and L.W. Vigrass**; Subsurface brines in southern Saskatchewan.

15. **Last, W.M., and W.W. Shum**; Winnipeg Formation diagenesis in Manitoba: a regional petrographic study.

16. **Martindale, W., U. Erkmen, D. Metcalfe, and T. Potts**, Winnipegosis of the Hitchcock area, S.E. Saskatchewan.

17. **McTavish, G.J.**; Salt dissolution and its association with outcrop distribution, south-central Saskatchewan.

18. **Monson, L.M., and D.F. Lund**; Cretaceous System stratigraphy and shallow gas resources on the Fort Peck Reservation, N.E. Montana.

19. **Posavec, M.M.**; The value and importance of a more comprehensive concept of development of basinal rhomboidal fault patterns as applied in the search for hydrocarbons.

20. **Sceptre Resources**; Exploitation of a Mississippian carbonate reservoir through horizontal drilling - the Gainsborough North Pool.

## CORE WORKSHOP

**DATE**: Monday, October 7, 1991
**TIME**: 1-5 p.m.
**LOCATION**: Subsurface Geological Laboratory, Regina
**REGISTRATION FEE**: $25(Can) on or after 1 August 1991

## WINNIPEGOSIS FIELD TRIP

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| **Destination:** | The Narrows area of Lake Manitoba and the Dawson Bay area of Lake Winnipegosis |
| **Leader:** | Don Kent |
| **Dates:** | Saturday, 5 October to Monday, 7 October 1991 |
| **Departure and Return Point:** | Ramada Renaissance Hotel |
| **Limit:** | 20 participants |
| **Registration Fee:** | $200(C); includes travel, accommodation, and packed lunches |
| **Registration Deadline:** | 30 June 1991 |

## TECHNICAL PROGRAM (TENTATIVE) - SASKATCHEWAN PETROLEUM CONFERENCE

### Oral Presentations

1. **Bouhroum, A**; Effect of heterogeneity on miscible flooding in porous media.

2. **Butler, R.M., and I.J. Mokrys**; Recovery of heavy oils using vaporized hydrocarbon solvents; further development of the Vapex Process.

3. **Chiwetelu, C.I., V. Horoff, G.H. Neale, and A.E.D. George**; Alkaline water-flooding of Saskatchewan heavy oil reservoirs - Part 1: Screening of caustic reagents.

4. **Collings, D., L. Ngheim, R. Sharma, K.N. Jha, and F. Mourits**; Simulation of horizontal well performance in heterogeneous reservoirs.

5. **Davison, R.J.**; Electromagnetic stimulation of Lloydminster heavy oil reservoirs.

6. **Doan, Q., A.E. George, and S.M. Farouq Ali**; Scaled model experiments on the

effect of liner on the recovery performance of horizontal wells in steamflooding.
7. **Dyer, S.B., S.S. Huang, S.M. Farouq Ali, and K.N. Jha**; Characterization and scaled model studies of prototype Saskatchewan heavy oils.
8. **Farouq Ali, S.M., and S. Thomas**; Emulsions - their importance and role in EOR processes.
9. **Ferris, F.G., L.G. Stehmeir, and A. Kantzas**; Bacteriogenic mineral plugging.
10. **Fox, J.N., and C.D. Martiniuk**; Petroleum exploration and development opportunities in manitoba.
11. **Gillis, R., B. Kristoff, and C. Shook**; Sand transport mechanism in horizontal wells.
12. **Hiebert, A.D., L.S.-K. Fung, VV. Oballa, and F.M. Mourits**; Comparison of discretization methods for modeling near-well phenomena in thermal processes.
13. **Hill, G.A.**; Packed bed slime reactor: new technology for petroleum wastewater purification.
14. **Huang, S.S., S.B. Dyer, and B. Verkoczy**; Miscible displacement in Weyburn reservoir - a laboratory study.
15. **Hutchence, K., and N. Frietag**; An alternative approach to the selection of pseudocomponents for modeling in-situ combustion.
16. **Jespersen, J.**; The Tangleflags North steamflood pilot - a horizontal well steamflood.
17. **Kantzas, A., D.F. Marentette, and B.P. Erno**; Recovery of heavy oils using horizontal wells and gravity drainage with pressure maintenance.
18. **Maini, B.B., H.K. Sarma, and K.N. Jha**; An unsteady-state technique for three-phase relative permeability measurements.
19. **Nasr, T.R., K.D. Kimber, and K.N. Jha**; A novel scaled physical simulator for enhancing horizontal well oil recovery.
20. **Shook, C.A., R.J. Sumner, and K.B. Hill**; Pipeline flow of emulsions of heavy crude oil.
21. **Springer, S.J., S. Asgarpour, and A.K. Singhal**; Incorporating risk analysis in the economic evaluation of two typical western Canadian horizontal well projects.
22. **Sugianto, S.**; Case study on design parameters for effective application of horizontal well technology in conventional heavy oil reservoirs.
23. **Torgerson, T. and B. Burr**; Metal seal technology shown to improve rock bit bearing life in demanding Williston programs.
24. **Verrall, R.E., G.A. Heal, and K.L. Dyer**; Sound velocity studies of pipeline oils as a function of viscosity, density and water content.

## HORIZONTAL WELL TECHNOLOGY WORKSHOP

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| **Date and Time:** | Monday, 7 October 1991, 8:00 a.m. to 5:00 p.m. |
| **Location:** | Ramada Renaissance Hotel |
| **Contents:** | Application and classification of horizontal wells; basic reservoir engineering considerations; regulatory issues and regulations in Saskatchewan; technical and economic screening of candidate reservoirs; well drilling (planning and design); well completions and production systems; case histories - conventional and EOR applications |

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| **Instructors:** | Ashok Singhal, Ben Nzekwu, and additional speakers on well completion and regulatory issues |
| **Registration Fee:** | $170(Can), includes lunch and coffee |
| **Registration Deadline:** | 20 September 1991 |

## NORTH DAKOTA NATURAL SCIENCE SOCIETY TO HOLD ANNUAL MEETING AT LOGGING CAMP RANCH NEAR AMIDON

The members of the North Dakota Natural Science Society will be holding their annual meeting and field trip on August 17 and 18, 1991 at the Logging Camp Ranch near Amidon. Participants will have a chance to see the geology, biology, and archeology of the area and hear explanations about these topics. The Logging Camp Ranch is of particular historical interest as well as natural science, and we will have discussions about the history too.

The geology of the Logging Camp Ranch area is of special interest. The Little Missouri River flows east past the ranch, along the south side of Bullion Butte. The river has carved badlands topography from the Bullion Creek Formation. Exceptional exposures of clinker occur and, until recently, a lignite vein was burning at the Burning Coal Vein Campground. The campground site is noted for its columnar junipers, trees that grew in columnar shapes because of pollution from the burning lignite coal.

The entire area is forested by North Dakota's largest Ponderosa Pine forest, adding to the scenic beauty. North Dakota's only stand of Limber Pines is nearby too, and we will have the option of visiting that.

We will have a banquet on Saturday evening and the formal program afterwards will include a talk by Dr. John Hoganson of the North Dakota Geological Survey. John will discuss the fossil resources in the nearby area. Several other geologists with the North Dakota Geological Survey, who will also be accompanying the trip, will be able to offer interpretations of the geology of the badlands area for tour participants.

If you are interested in coming on the 1991 Natural Science Society Tour, please contact Bonnie Heidel at North Dakota Parks and Recreation, 1424 West Century Avenue, Bismarck.

## SIDE-LOOKING RADAR IMAGES

--Mark Luther

Last summer the NDGS received a set of Side-Looking Airborne Radar (SLAR) photographic image strips from the U.S. Geological Survey. The USGS flew the SLAR project over a one-degree x two-degree area (approximately) in north-central North Dakota (Figure 1) at the suggestion of the NDGS. This area is of great interest to the NDGS due to the great variation in both surface and subsurface geology, and it was hoped that the SLAR images could be used to gain additional information on features as diverse as glacial deposits, Devonian Prairie Salt dissolution, and the boundary between the Precambrian Superior Province and the Trans-Hudson Orogenic Belt. Some interpretations of the images have been made; however, before going into a description of them, a short explanation of SLAR is in order.

SLAR Characteristics -- SLAR is an electronic image-producing system that derives its name from the fact that the radar beam is transmitted perpendicular to the side of the aircraft acquiring the data (Figure 2). The result is an obliquely illuminated view of the terrain, a view that enhances subtle surface features and facilitates geologic interpretation. This enhancing characteristic is one of the reasons why SLAR imagery is so useful to earth resource scientists.

Another important property of SLAR is that it is an active sensor; the system provides its own source of illumination in the form of microwave energy, and thus imagery can be obtained through cloud cover or light conditions found during day or night. The imagery is acquired by measuring the strength of the transmitted radar signal that is reflected from the ground surface back to the radar receiver on the aircraft. The strength of this return signal depends on surface features and is recorded as shades of gray on the processed image.

Since SLAR is an active sensor, when a radar beam strikes a sufficiently elevated topographic feature a radar shadow is cast by the feature; this is an area of no data return. The gradual change of shadow length across the range (Figure 2) perpendicular to the flight path has resulted in the convention of designating the parts of the radar swath: near range, or that half of the radar swath nearest the aircraft; and far range, that half of the swath farthest from the aircraft.

The "look direction" (the Minot SLAR images are "west-looking") of an SLAR image refers to the illumination direction, or the direction that the radar beam is directed. The choice of SLAR project design parameters such as look direction and beam angle is usually based on the geologic structure of the area. For example, linear structures such as faults, valleys, or moraines that are parallel to the look direction may not be easily detected since little radar shadow is present. In analyzing radar imagery, the image should be oriented with the shadows toward the viewer. This practice assists in interpreting hills as hills and valleys as valleys.

It should also be stated that SLAR is a generic term for two distinctly different technologies: real aperture radar; and synthetic aperture radar (SAR). Of the two, SAR gives the greatest on-ground image resolution (approximately 10 x 10 meters or better) and was the type used for the Minot project.

Interpretation of the Minot SLAR Images -- The Minot project SLAR image strips are at a scale of 1:250,000 (1/4 inch on the photo = 1 mile on the ground) and cover the area shown in Figure 1. Dr. Kenneth Harris of the Minnesota Geological Survey (formerly NDGS) was kind enough to provide some interpretation of the images; the following interpretations are condensed from his findings.

Lithologic changes at contacts between glacial sediment, alluvium, and sand and gravel are readily seen as changes in the gray scale of the images. However, a distinction between eroded

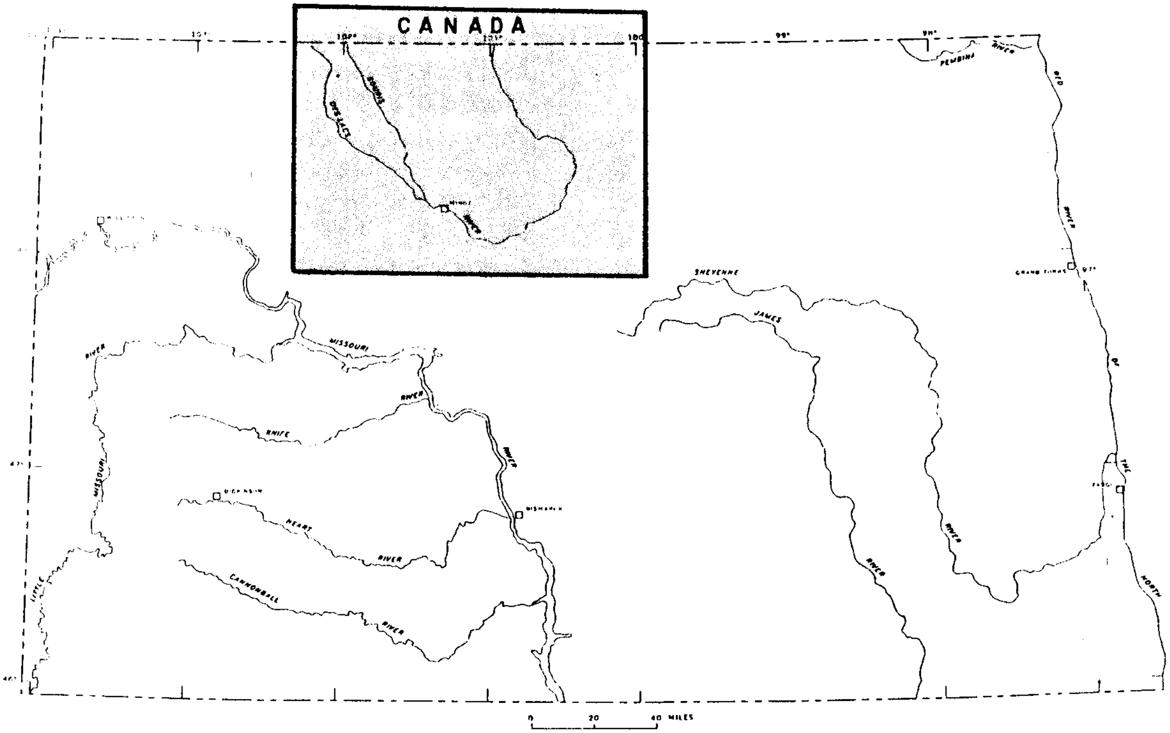



FIGURE I AREA COVERED BY MINOT SLAR PHOTO IMAGES

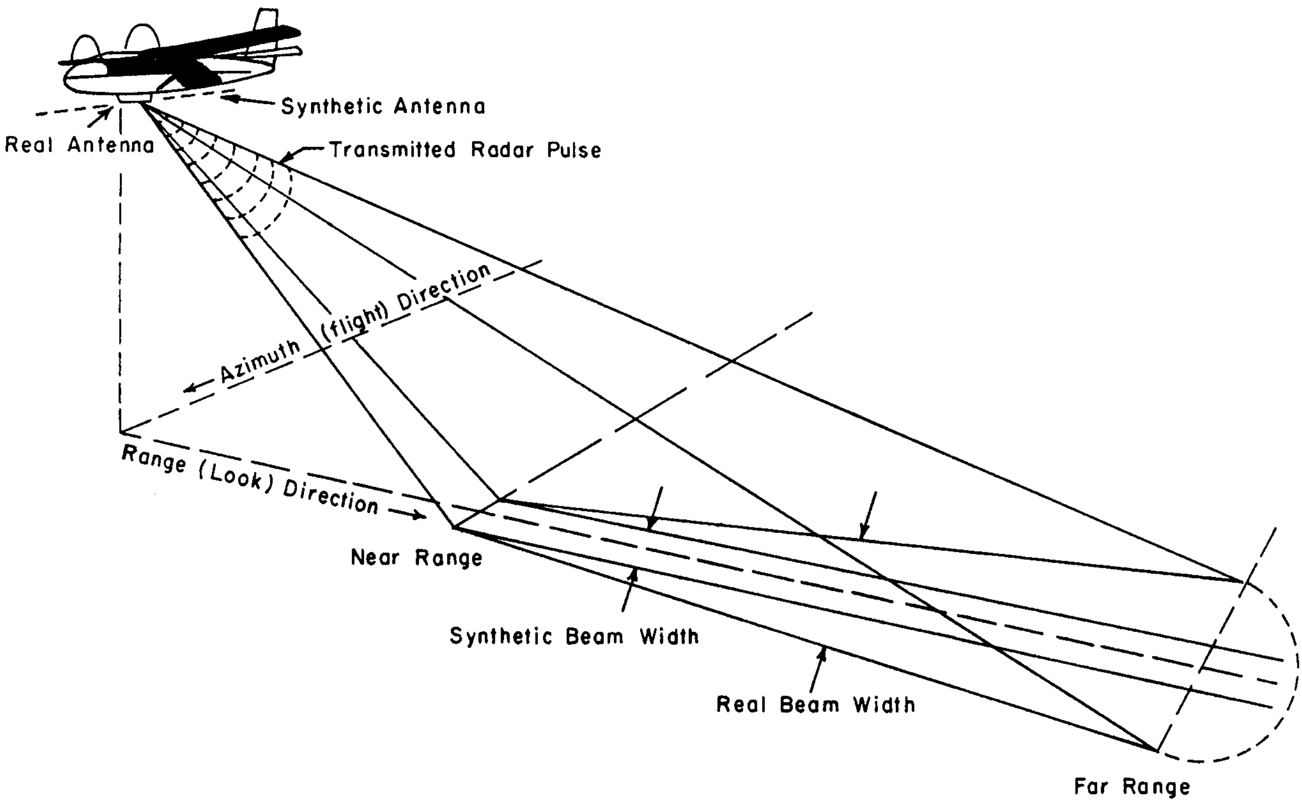

Synthetic Antenna
Real Antenna
Transmitted Radar Pulse
Azimuth (flight) Direction
Range (Look) Direction
Near Range
Synthetic Beam Width
Real Beam Width
Far Range

FIGURE 2

glacial sediment and lacustrine sediment doesn't seem possible. Likewise, some landforms show up in dramatic fashion, while others are very subtle. Some of those that show clearly in the images include: the drumlin swarm near Verendrye; the sand dunes near Denbigh; the river valleys and glacial outburst channels; and the glacial-thrust features present in the northwestern part of the Turtle Mountains.

In addition to identifiable features, Ken noticed the presence of a few unidentifiable features including: some bright, cloud-like spots; and some SW-NE trending lineations. These could be false features (artifacts of the image processing) or some as yet unidentified feature on the ground.

SLAR Availability -- A set of SLAR image strips for the Minot project area are kept at the NDGS office in Bismarck. These are available for viewing by the public at our office. In addition, as part of our Earth Science Information Center (ESIC) responsibilities, The NDGS maintains a microfiche index showing the locations and images for SLAR projects completed throughout the United States. SLAR products are available from the USGS through their EROS Data Center (South Dakota) and come in several forms, including: contact strip images, radar mosaics, and digital data.

SLAR products can provide a great deal of information to scientists involved in mineral and energy exploration, earth hazards studies, and other geologic, hydrologic, cartographic, and engineering applications. In many cases, SLAR may be the only means to detect a given feature and its use, especially in regional mapping, is sure to increase in the future. If you would like to view the image strips from the Minot project, or see what SLAR is available for the rest of the country, please stop in at our Bismarck office and a staff member will be happy to assist you.

## EXHIBIT OF NORTH DAKOTA FOSSILS OPENS AT THE HERITAGE CENTER

--John Hoganson

The largest exhibit of North Dakota fossils ever displayed in North Dakota debuted in the Documentary Gallery at the North Dakota Heritage Center on February 21, 1991. The exhibit, a cooperative project between the State Historical Society and the Survey, focuses attention on fossils as part of our heritage. It is an unprecedented opportunity to see many different kinds of fossils brought together for the first time.

The exhibit traces the progression of life in North Dakota through display of animal and plant fossils from different periods of North Dakota's prehistoric past. The oldest fossils in the exhibit are brachiopods on a bedding plane from the Ordovician (about 425 million years old) Stony Mountain Formation recovered from an oil well core. Fossils of other ancient marine animals found in oil well cores from different Paleozoic formations are also displayed.

The oldest fossils exposed in North Dakota are remains of marine animals that lived here during the Cretaceous, from about 85 to 65 million years ago. Displayed are fossils of invertebrates (ammonites, snails, clams, crabs, etc.) and vertebrates invertebrates (ammonites, snails, clams, crabs, etc.) and vertebrates (sharks, rays, mosasaurs, plesiosaurs, and Hesperornis-- the giant seabird). During the latter part of the Cretaceous, dinosaurs roamed western North Dakota. Remains of Tyrannosaurus, Triceratops, Dromaeosaurus, and hadrosaurs are in the exhibit. Fossils of other vertebrates (alligator, crocodile, salamander, and fish), invertebrates (snails and clams), and plants that lived with the dinosaurs are also exhibited.

During the Paleocene, about 65 to 55 million years ago, after the final demise of the dinosaurs, plants and animals thrived in the swamps covering much of western North Dakota. Remains of crocodiles, turtles, early mammals, snails and many kinds of plants are displayed from this period. East of these swampy lowlands, the last ocean to exist over North Dakota was a habitat for sharks, rays and other fish, corals, snails, clams, crabs, shrimp, lobsters, etc. Fossils of these animals are in the exhibit. The state fossil, "Teredo Petrified Wood", from this age is also on display.

From about 35 to 30 million years ago, during the Oligocene, western North Dakota was a broad floodplain containing rivers and ponds. By this time mammals had become highly diversified and thrived on the open plains. Remains of rabbits, deer, camels, mice, squirrels, rhinoceroses, giant "pigs", sheep-like oreodonts, tiny 3-toed horses, saber- toothed cats, dogs, and insect-eating mongoose-like animals are in the exhibit. Associated with these mammals were turtles, fish, and snails. Very few plants are found with the mammals except for seeds from hackberry trees. Fossils of these plants and animals are also shown.

The youngest fossils in the exhibit are from animals that existed here during and shortly after the Ice Age, a few thousand years ago. These are remains of mammoths and mastodons, the giant elephants, an extinct bison, fish, snails, and clams.

Whenever possible, the fossils are accompanied by drawings and paintings of the life appearance of the animals and murals reconstructing the habitats in which the animals lived. Specimens of modern shells and bones are provided for comparison. Intimacy with fossils is encouraged by some hands-on specimens. A display of field gear used by paleontologists brings a little more life to the exhibit. Included is a display called "Illustrating Dinosaurs," which traces the evolution of dinosaur art.

Opening night of the exhibit began with a special preview and reception followed by the public opening. To "kick off" the event, I presented a lecture titled "The Rise and Fall of the Dinosaurs" in the Heritage Center auditorium. It was the largest group of people that I had ever spoken to--somewhere around 500. During opening night the Heritage Center's education department also had a children's program called "Making Tracks" which included tracing life-size tracks of different kinds of dinosaurs, coloring dinosaur pictures, etc. A fossil identification service was provided by members of the North Dakota Paleontological Society. Members of the Paleo Society also helped with questions about fossils in the exhibit. Dinosaur cookies and cider were served by Center volunteers. It would probably be an understatement to say that the opening was an overwhelming success. Over 800 people attended. It was the largest exhibit opening ever at the Heritage Center. From the opening on February

21 through the end of May, a little over 3 months, nearly 45,000 people have viewed the exhibit.

The popularity of this exhibit documents the public's interest in North Dakota's prehistoric life. Even though this particular exhibit will be up only until December, we have begun plans for permanent displays of fossils in the Heritage Center. The transfer of the Survey to Bismarck is providing us with the opportunity to promote public awareness of North Dakota's fossil resources to the fullest, in cooperation with the State Historical Society, through exhibits at the Heritage Center.

I would like to acknowledge Claudia Berg, Curator of Exhibits at the Heritage Center, for the wonderful job she did with the exhibit. Working with fossils and particularly having to put up with me was a challenge she faced with boldness. I would also like to thank the following institutions and individuals for providing specimens for the exhibit:

The geology departments of:

University of North Dakota
North Dakota State University
Minot State University

Manitoba Museum of Man and Nature
Science Museum of Minnesota
Milwaukee Public Museum
Cranbrook Institute of Science
North Dakota Geological Society
North Dakota Paleontological Society
Central Dakota Gem and Mineral Society

Roger Borchert, Bismarck
Daryl Gronfur, Bismarck
Dean Pearson, Bowman
Mr. and Mrs. John Steinbach, Hettinger
Mr. and Mrs. Clarence Johnsrud, Williston
Mike Hedtke, Clearbrook, Minnesota
Blossomae and Earle Campbell, Bismarck
Johnathan Campbell, Bismarck
John Stumpf, Fort Rice
Viola Obritsch, Dickinson
Ron and Bob Obritsch and family, Dickinson
Mr. and Mrs. Bob Fitterer, Dickinson
Mr. and Mrs. Albert Privratsky and family, South Heart
Merian Schmidt and family, Dickinson
Vernon Miller and family, Rhame
Valentine Gerhardt, Flasher
Bernice and Alvin Houser, New Town

Figure 1. Triceratops skull in case collected by Milwaukee Public Museum from the Cretaceous (about 66 million years old) Hell Creek Formation south of Rhame, Bowman County. (The following photos are by Todd Strand, State Historical Society Photo Archivist.)

Figure 2. Four-foot-long Metasequoia log recovered from the Paleocene (about 57 million years old) Sentinel Butte Formation along the shore of Lake Sakakawea, Mercer County.

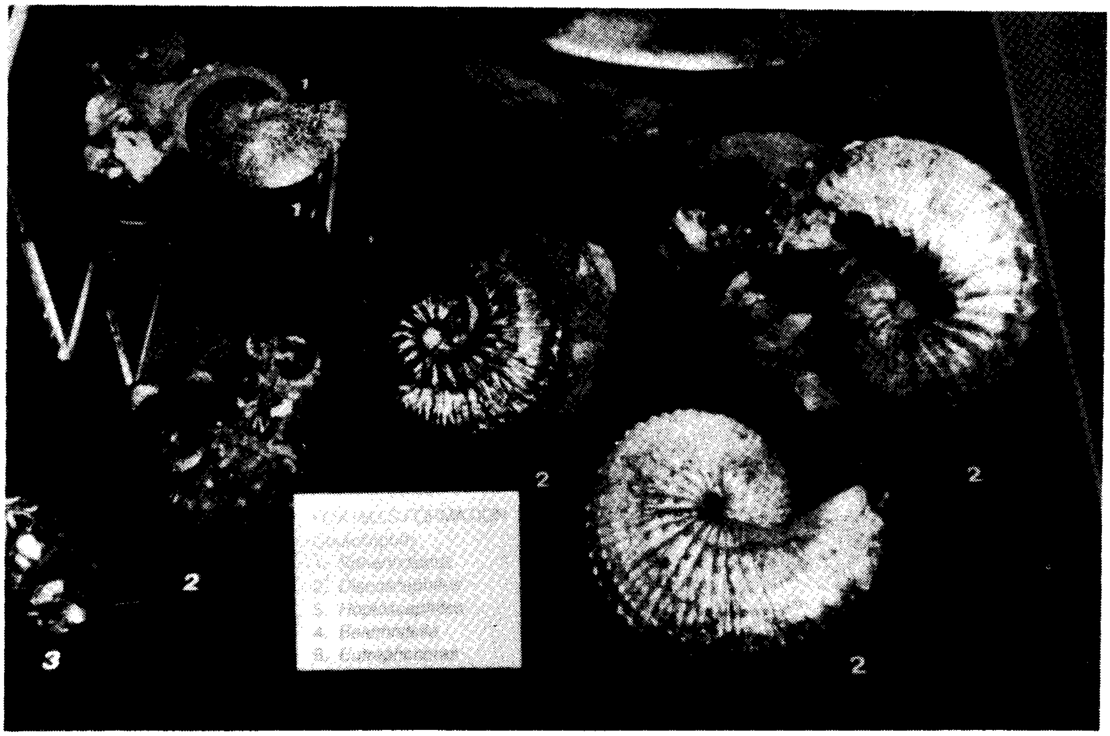



Figure 3. Ammonites from the Cretaceous (about 70 million years old) Fox Hills Formation collected in Emmons County.

Figure 4. Mammals from the Oligocene (about 32 to 30 million years old) White River Group collected in Stark, Hettinger and Bowman Counties.

Figures 5-6. Opening night at the North Dakota fossils exhibit.

Figures 7-8. Opening night at the North Dakota fossils exhibit.

Figure 9. Opening night at the North Dakota fossils exhibit. North Dakota Paleontological Society members, Johnathan Campbell and Dalles Schneider, identifying fossils for the visitors.

Figure 10. Opening night at the North Dakota fossils exhibit. Chris Dill, Museum Director, welcoming the crowd and introducing the "Rise and Fall of the Dinosaurs" presentation.

## PETRIFIED LOGS EXHIBITED ON CAPITOL GROUNDS DEDICATED TO E. L. "BUCK" WORTHINGTON ON ARBOR DAY MAY 3, 1991

--John Hoganson

In the Survey's June, 1990 Newsletter I wrote about our plan to exhibit a petrified log on the State Capitol Grounds. A Paleocene "forest" of petrified trees, the dawn redwood Metasequoia, had been exposed alone the shore of Lake Sakakawea because of low water levels in the reservoir. The Central Dakota Gem and Mineral Society approached the Survey for assistance in bringing one of these trees to Bismarck for public display. This project was accomplished last summer with the help of the Washburn detachment of the Army National Guard. The 80-foot-long fossil tree specimens are located in the Centennial Grove, on the west side of the State Capitol grounds.

Unfortunately, the leading proponent of the project, E. L. "Buck" Worthington of Mandan, passed away at age 79 shortly after the project was completed in August, 1990. It was decided that it would be appropriate to dedicate the fossilized logs to Buck. Buck, affectionately known as "Mr. Trees," was State Forester for the U. S. Soil Conservation Service from 1936 until he retired in 1970. After his "retirement" he became part-time superintendent of Morton County Parks and part-time Mandan City Forester until 1983. Buck was one of the original supporters of the statewide plan to plant 100,000,000 trees by the year 2000 as a Centennial project.

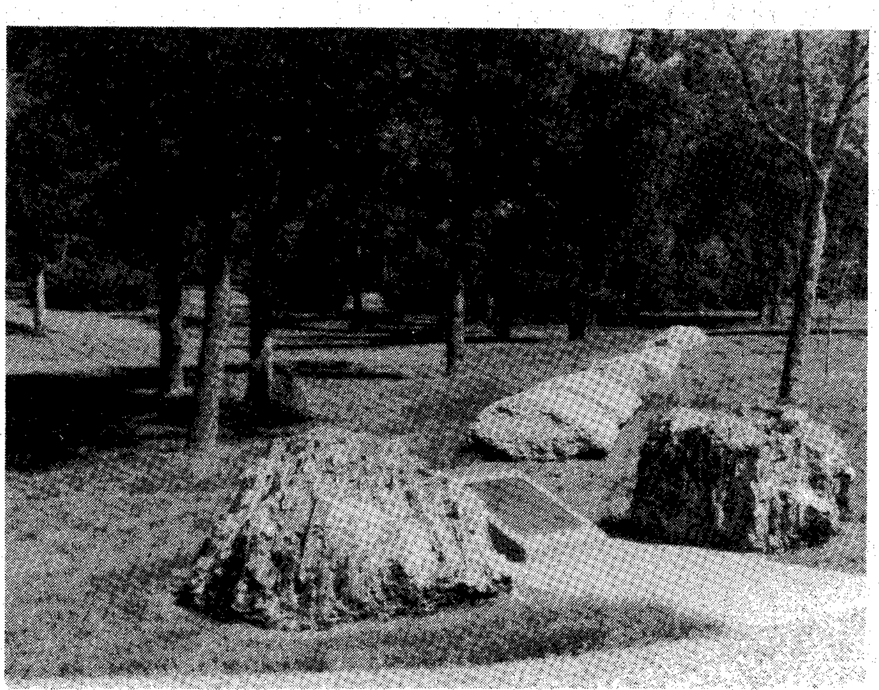
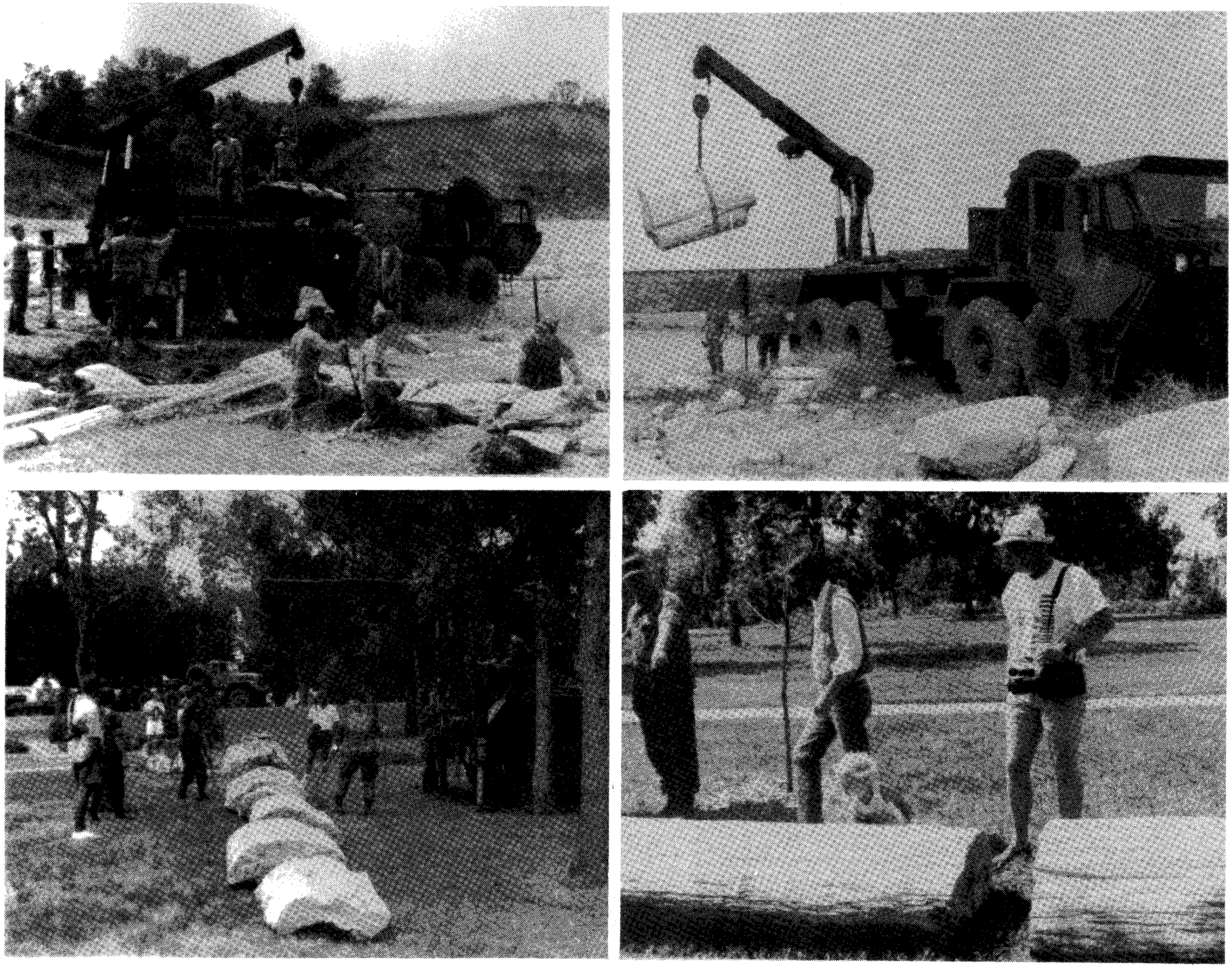


Figure 1. 80-foot-long Metasequoia log from the Paleocene (about 57 million years old) Sentinel Butte Formation displayed in Centennial Grove on the grounds of the State Capitol in Bismarck.



Figures 2-5. Excavation of the <u>Metasequoia</u> fossils near Beulah and placement of the fossils on the State Capitol grounds.

## OIL AND GAS ACTIVITY IN NORTH DAKOTA DURING 1990 --Charles A. Koch

*[Editor's note: The text of this article, along with Tables 1 and 2, were contributed by Charles A. Koch of the Oil and Gas Division of the Industrial Commission. Thomas Heck of the NDGS compiled Table 3, the 1990 New Pool Discoveries].*

The oil production decline that has been occurring for the last five years in North Dakota came to a virtual stop in 1990. A reversal also occurred in drilling activity, with a 42 percent increase from 1989. Oil production in 1990 was 36,720,396 barrels, compared to 36,725,255 barrels in 1989. Gas processed showed a slight increase in 1990, when 58,680 MMCF were processed, compared to 58,071 MMCF in 1989.

The rig count during 1990 was essentially constant throughout the year. The year started with 20 rigs running and ended with 23 rigs running with an average monthly rig count of 21. A primary reason for the stable rig count was the horizontal drilling activity in the Bakken Formation. The average monthly rig count for horizontal drilling was 11 rigs, or about half the monthly average for the year. Permitting was up this year to 292 compared to 230 in 1989. Here again, the increase can be attributed to horizontal drilling for which 97 permits were issued.

A total of 21 wells were drilled in 1990, compared to 176 wells drilled in 1989. The wildcat success ratio was 25 percent, a five percent increase over the previous year. A total of 28 discoveries in 1990 resulted in 17 new fields and 11 new pools in existing fields. The three leading counties were Dunn, with seven; McKenzie, six; and Williams, five. The remaining ten discoveries were distributed among eight counties.

The majority of the discoveries (22) were in the Bakken and Madison Formations. The large number of horizontal wells drilled in the Bakken precludes stating the average depth of a well drilled in 1990. The average footage drilled per well was 9,314 feet, compared to 8,851 feet in 1989.

Monthly drilling activity ranged from a low of 15 wells in April to a high of 32 wells in October. Despite this wide variation, overall drilling throughout the year was relatively constant. Billings County led all counties in drilling with 42 wells, followed by McKenzie and Mountrail Counties with 40 and 36 wells, respectively. The largest share of drilling was for development in existing fields, followed by wildcat drilling and extensions to existing fields.

The introduction of horizontal drilling to North Dakota in the fall of 1987 resulted in a new method of oil recovery from the Bakken Formation. The Bakken Formation consists of an upper black shale, a middle siltstone unit, and a lower black shale. The upper black shale is the member that has drawn the interest for horizontal drilling. Most of the drilling has been in southwestern North Dakota, where the black shale unit feathers out to less than ten feet thick. It is in this "Bakken Fairway" area where the drilling occurs. During 1990, a total of 76 horizontal wells were drilled into the Bakken Formation. Of these, 65 were completed as producers. The oil produced from horizontally drilled wells has had a significant impact on state production totals. In January, production from horizontally drilled wells accounted for five percent of the state total and, by December, the percentage had increased to 9.1 percent of total monthly production.

Expansion of the Bakken play was attempted by a number of operators moving out of the Bakken Fairway. The fairway is characterized by a thin, highly fractured section, as compared with a thicker, and less highly fractured Bakken section away from the fairway. The exploratory effort outside of the fairway area has so far been disappointing. Along the Nesson Anticline, away from the fairway, the Bakken is about 100 feet thick and productive from the lower section in vertical wells. Suitable geologic conditions should exist in the thick Bakken section, just as the "sweet spots" exist in the fairway (Ash Coulee area, etc.), but finding the places where these conditions occur will require more drilling. Horizontal drilling technology is relatively new and finding the appropriate conditions for its application should result in the recovery of additional oil.

The use of horizontal drilling technology has not been expanded to other formations in North Dakota except for one attempt. Meridian Oil, Inc. drilled a horizontal well in the Madison Formation, but the anticipated production potential was not achieved and no further drilling was attempted in 1990. In Saskatchewan, however, 27 horizontal Mississippian wells were drilled in 1990, according to the Saskatchewan Department of Energy and Mines. The increased daily recovery from horizontal wells far exceeded the daily recovery from comparable vertical wells. The success in Canada should result in further attempts at horizontal drilling in the Madison, and possibly in other formations, in North Dakota.

The Madison shoreline trend play continued to interest operators as two new fields were discovered southwest of the Plaza-Wabek area discovered the year before. The two new fields are Lucky Mound, a Bluell pool, and Centennial, a Sherwood pool. Development drilling was continuing in the area at years end. It is rumored that Lucky Mound will be as large as Wabek or Plaza Fields. In 1990, the Wabek and Plaza Fields were the second and sixth leading producers, respectively.

Two Natural Gas Policy Act Certificates were approved during the year. The Natural Gas Wellhead Decontrol Act of 1989, which will eliminate the control of wellhead price, will also eliminate the need for NDPA Certificates.

A summary of the last five years drilling and production statistics are shown in Tables 1 and 2, respectively. The gas volumes shown are for wet gas received at gas processing plants and should not be confused with gas produced. The dollar values shown in Table 2 are for crude oil produced.

Table 3, which was compiled by Tom Heck of the NDGS, lists new oil pool discoveries during 1990.

Table 1. NORTH DAKOTA 5-YEAR DRILLING SUMMARY

| | Wildcats | | Dev. Wells | | | |
|---|---|---|---|---|---|---|
| Year | Prod | Dry | Prod | Dry | Total Wells | Total Footage |
| 1985 | 20 | 114 | 243 | 129 | 506 | 4,579,353 |
| 1986 | 5 | 47 | 86 | 52 | 190 | 1,720,833 |
| 1987 | 8 | 46 | 94 | 42 | 190 | 1,685,793 |
| 1988 | 11 | 55 | 121 | 60 | 247 | 2,072,850 |
| 1989 | 7 | 28 | 101 | 40 | 176 | 1,557,827 |
| 1990 | 15 | 44 | 124 | 34 | 251 | 2,337,749 |

Table 2. NORTH DAKOTA 5-YEAR SUMMARY

| | | Crude Oil (bbls) | | Crude Oil | Natural Gas (MMCF) |
|---|---|---|---|---|
| Year | Avg. Daily | Total Annual | $ Value at Well Head | Total Annual |
| 1985 | 139,579 | 50,946,504 | 1,276,000,000 | 84,438 |
| 1986 | 124,998 | 45,624,120 | 600,896,660 | 70,703 |
| 1987 | 113,327 | 41,364,295 | 686,647,300 | 71,612 |
| 1988 | 107,486 | 39,340,051 | 567,676,360 | 66,093 |
| 1989 | 100,617 | 36,725,255 | 626,532,850 | 58,071 |
| 1990 | 100,604 | 36,720,396 | 825,474,502 | 58,680 |

## TABLE 3. 1990 NEW POOL DISCOVERIES

Pennzoil Exploration & Production Co.-Snowcover #13-22 BN
#10425 Case# 4931 Order# Comp. 1/16/90
Snowcover-Madison IP 11BO 50BW 7MCF
Sec. 13, T147N, R102W, McKenzie County

Oryx Energy Co.-Marmon #1-HD
#12773 Case# 5030 Order# Comp. 2/7/90
Alkali Creek-Bakken IP 15BO 500MCF
Sec. 2, T154N, R95W, Williams County,

Meridian Oil, Inc.-Leland #41-25
#12806 Case# 5029 Order# Comp. 2/26/90
Pierre Creek-Madison IP 223BO 57BW 138MCF
Sec. 25, T147N, R103W, McKenzie County

Duncan Energy Co.-Olive Wells #1-6
#7366 Case# 4991 Order# Comp. 3/2/90
Clarks Creek-Bakken IP 173BO 208MCF
Sec. 6, T151N, R94W, McKenzie County

BTA Oil, Producers-9002 JV-P Haystack #1
#12837 Case# 5014 Order# Comp. 3/24/90
Round Top Butte-Tyler IP 130 BO 6BW 30MCF
Sec. 32, T148N, R97W, Dunn County

Graham Royalty, LTD.-Harold J. Rogness #1
#8372 Case# 5094 Order# Comp. 4/4/90
Timber Creek-Madison IP 11BO 97BW
Sec. 26, T150N, R100W, McKenzie County

Slawson Exploration Company, Inc.-Anderson #1-33
#12862 Case# 5068 Order# Comp. 5/22/90
Otter-Red River IP 86BO 63BW 69MCF
Sec. 33, T157N, R101W, Williams County

Pennzoil Exploration & Production Co.-Boxcar Butte #27-33 BN
#10643 Case# 5225 Order # Comp. 6/23/90
South Boxcar-Madison IP 5BO 142BW
Sec. 27, T148N, R102W, McKenzie county

American Hunter Exploration LTD.-Dollar Joe #41-16 H6
#12864 Case# 5177 Order# Comp. 7/2/90
Truax-Bakken IP 15BO
Sec. 16, T154Nn R98W, Williams County

American Hunter Exploration LTD.-AHEL et al Newtown #H7
#12893 Case# 5179 Order# Comp. 7/8/90
Big Bend-Bakken IP 22BO
Sec. 24, T151N, R93W, Mountrail County

Barbara Fasken-Kolbo #1-30
#12951 Case# 5095 Order# Comp. 7/25/90
Stafford-Madison IP 29BO 13 MCF
Sec. 30, T163N, R87W, Renville County

Barbara Fasken-Schmid Estate #1-36
#12931 Case# 5121 Order# Comp. 8/5/90
Lake View-Madison IP 30BO 175BW 13MCF
Sec. 36, T164N, R88W, Burke County

Anschutz Corp.-Watterud #8-14
#12906 Case# 5096 Order# Comp. 8/11/90
Stoneview-Stonewall IP 480BO 20BW 525MCF
Sec. 14, T160N, R95W, Divide County

Dallas Engineering, Inc.-Simpson #1
#9800 Case# 5226 Order# Comp. 8/13/90
New Home-Bakken IP 2BO 3BW
Sec. 27, T158N, R97W, Williams County

Balcron Oil Co.-Wahner #33-15
#12959 Case# 5092 Order# Comp. 8/16/90
Lucky Mound-Madison IP 324BO 36BW 241MCF
Sec. 15, T150N, R89W McLean County

Union Pacific Resources Co.-Andeker 44-34 #1
#12927 Case# 5138 Order# Comp. 9/1/90
Baily-Bakken IP 18BO 13MCF
Sec. 34, T146N, R94W, Dunn County

Maxus Exploration Co.-Carus Fee #21-19
#12785 Case# 5188 Order# Comp. 9/25/90
Big Gulch-Bakken IP 5BO 5BW 8MCF
Sec. 10, T158N, R96W, Williams County

Balcron Oil Co.-BOC Zahnow Federal #42-35
#12946 Case# 5139 Order# Comp. 10/6/90
Centennial-Madison IP 184BO 54MCF
Sec. 35, T149N, R89W, McLean County

Pacific Enterprises Oil Co.-S. E. Russian Creek #42-18
#12972 Case# 5137 Order# Comp. 10/8/90
Simon Butte-Silurian IP 262BO 25MCF 1072BW
Sec. 18, T141N, R95W, Dunn County

Geolinear Co.-Geolinear Packineau #1-17
#12960 Case# 5195 Order# Comp. 12/1/90
Mandaree-Madison IP 40BO 25BW 39MCF
Sec. 17, T149N, R93W, Dunn County

North American Resources Co.-Hansen State #23-16
#10783 Case# 5190 Order# Comp. 12/5/90

Lake Ilo-Red River	IP 38BO 23BW
Sec. 16, T145N, R93W, Dunn County

NORTH DAKOTA OIL PRODUCTION BY FORMATION
(Sorted Stratigraphically)

| FORMATION | BARRELS OIL PRODUCED | PERCENT |
|---|---|---|
| Spearfish | 756,489 | .0725 |
| Spearfish/Madison | 41,641,240 | 3.9893 |
| Tyler (Heath) | 62,430,850 | 5.9811 |
| Madison | 665,628,485 | 63.7694 |
| Lodgepole | 3,797 | .0004 |
| Bakken | 24,634,637 | 2.3601 |
| Birdbear (Nisku) | 2,632,315 | .2522 |
| Duperow | 102,993,579 | 9.8671 |
| Souris River | 16,512 | .0016 |
| Dawson Bay | 2,195,454 | .2103 |
| Winnipegosis | 4,869,198 | .4665 |
| Silurian | 44,561,296 | 4.2691 |
| Stonewall | 5,399,988 | .5173 |
| Stony Mountain | 120,517 | .0115 |
| Red River | 85,719,497 | 8.2122 |
| Winnipeg/Deadwood | 200,858 | .0194 |

CUMULATIVE
OIL PRODUCTION THROUGH
FEBRUARY 1991	1,043,804,712

## TOP 10 PRODUCING COUNTIES DURING 1990

| | (MBO) |
|---|---|
| 1) McKenzie (1)* | 10,809 |
| 2) Billings (2) | 7932 |
| 3) Williams (3) | 5032 |
| 4) Bottineau (4) | 2431 |
| 5) Mountrail (8) | 2047 |
| 6) Renville (5) | 1714 |
| 7) Dunn (6) | 1525 |
| 8) Bowman (9) | 1307 |
| 9) Divide (7) | 1218 |
| 10) Stark (10) | 877 |

## TOP 10 PRODUCING FIELDS DURING 1990

| | (MBO) |
|---|---|
| 1) Little Knife-Madison (1)* | 2062 |
| 2) Wabek-Madison (3) | 1264 |
| 3) Beaver Lodge-Devonian (2) | 1246 |
| 4) Elkhorn Ranch-Bakken (8) | 980 |
| 5) Big Stick-Madison (4) | 861 |
| 6) Plaza-Madison (NR) | 699 |
| 7) Charlson-Silurian (7) | 534 |
| 8) Rough Rider-Madison (6) | 531 |
| 9) Dolphin-Dawson Bay (5) | 523 |
| 10) Red Wing Creek-Madison (NR) | 510 |

(*) 1989 Rank

## ESIC NEWS

**--Mark Luther**

For several years the NDGS has been an affiliate office of the Earth Science Information Center (ESIC (formerly NCIC)) network. This network was organized by the US Geological Survey, which provided training for personnel in affiliate offices, and supplied map and airphoto-related informational materials for dissemination to the public. The ESIC system has worked fairly well over the years, providing map and other earth science-related information and materials to the public. Recent developments, however, are greatly expanding the role that ESIC offices will play in the future.

The introduction of Federal OMB Circular A-16 requires the coordination of Federal surveying, mapping, and related spatial data* activities. In addition, a major objective of A-16 is "the eventual development of a national digital spatial information resource, with the involvement of Federal, State, and local governments, and the private sector." It is expected that this national information resource will "enable sharing and efficient transfer of spatial data between producers and users." The ESIC network, which includes both Federal and State agencies, will now be the group that both collects and disseminates information relating to spatial data (and perhaps the data itself).

The NDGS has already taken a large step toward meeting the objectives of A-16 by accepting the responsibility of operating a digital spatial data "clearinghouse" (see article in this newsletter). In the future, the NDGS-ESIC office will become even more active in soliciting information about spatial data from other agencies and private groups working in the state.

The NDGS-ESIC office currently provides a large variety of information and services to the people of North Dakota. A partial listing follows.

ESIC Services/Information

- Sales of Federally produced **maps** and charts (topographic maps, etc.) covering North Dakota

- Information on map use, scales, availability (nationwide)

- Information on the availability of **airphotos** (dates, scale, color or B&W, where to get, etc.) nationwide. In addition, the NDGS has a collection of B&W air photos that the public can view in our office.

- Information on the availability of **SLAR** images/data (see article in this newsletter)

- **Geographic Names** Information System (GNIS) that can be used to find the locations of features (towns, rivers, etc.) with a given name (nationwide).

- Information on the availability of **satellite** images/data (nationwide).

- Information on the availability of **digital map products** (nationwide)

- **Earthquake data** (worldwide)

In addition, the NDGS has an assortment of publications and brochures that provide information on a wide variety of earth science-related topics. We encourage the public to make use of our services.

The Survey's ESIC Coordinator is Mark R. Luther.

* Spatial data are geographically referenced features that are described by geographic positions and attributes in an analog and/or computer-readable (digital) form.

## EDUCATIONAL INFORMATION AVAILABLE FROM STATE WATER COMMISSION

The North Dakota State Water Commission makes a variety of educational materials available to teachers, students, and other water users. It was recently brought to my attention that the Water Commission staff has written a series of brochures which are available as part of their Water Education for Teachers (WET) program. The brochures are very well done: colorful and easy to understand. They deal with a number of pertinent issues: The Hydrologic Cycle, Irrigation, Flood Control Dams, Cloud Modification, Flooding in North Dakota and several others. They've also included a very useful Glossary of water-related terms and a booklet describing surface and ground water use in North Dakota (North Dakota Water -- A Reference Guide).

Anyone interested in receiving any of these and other educational materials from the Water Commission should contact them at 900 East Boulevard, Bismarck, ND 58505-0187. The phone number is (701) 224-2750.

## PETERSON FIELD GUIDE TO ROCKS AND MINERALS

I recently got a copy of the *Peterson First Guide to Rocks and Minerals*, by Frederick H. Pough, published May 24, 1991. This is a simplified field guide to common minerals, rocks, gems, and ores. The publisher notes that the Peterson First Guides are the first books the beginning naturalist needs. "They make it easy to get started in the field -- and easy to graduate to the full-fledged Peterson Guides." The 128-page paper-back book is illustrated with 175 color photographs and 12 line drawings.

The book is written in layman's language and I think it should be valuable to rock hounds or anyone interested in identifying or collecting rocks. It includes the kind of information beginning rock collectors need: how to identify rocks and minerals, where the best specimens are found, and how to care for a rock and mineral collection. The book gives concise and clear descriptions of the rocks and minerals that are most interesting to collectors and it includes simple accounts of how and where igneous, sedimentary, and metamorphic rocks are formed. The illustrations are excellent.

The *Peterson First Guide to Rocks and Minerals* is published by Houghton Mifflin Company, 215 Park Avenue South, New York, NY 10003. It sells for $4.95

## RICHES OF A DIFFERENT KIND

--Bill Shemorry

*[Editor's Note: Bill Shemorry is a Williston newspaperman who has made several contributions to the NDGS Newsletter. This article is from his new book, Mud, Sweat and Oil -- The Early Days of the Williston Basin, published*

*in conjunction with the Williston Basin Energy Festival II, held on July 4 - 6, 1991 to celebrate the 40th anniversary of oil in North Dakota. The book is illustrated with many of Bill's own photos and includes a lot of history and anecdotes about people Bill knew--people involved in various ways with the discovery of oil. I really enjoyed his excellent account of "how things were" in the oil patch during the early days of the oil industry in North Dakota and I definitely recommend the book. You can obtain a copy of the 208-page book by contacting: Williston Chamber of Commerce, 10 main, Williston, ND 58801. (Phone: 701-572-3767)*

There's a proverb in the Old Testament of the Bible that reads, "The race is not (always) to the swift, nor the battle to the strong."

An analogy to this lies in a story which came out of the North Dakota oil fields during the boom of the early 1950's... proving once more "that the riches of 'black gold' do not always accompany the production of an oil well."

In the year 1952, Lars Fretland was farming in West Bank Township, just south of the town of Tioga. He had homesteaded in the Tioga area in 1907, had weathered the terrible times of the 1930's drought and great depression.

Lars's minerals, like those of most of his neighbors, had been leased by Amerada Petroleum Corporation and it was not long until a crew of men drove up in a pickup and pounded some stakes into the ground. After some delay the word came that a well would be drilled there.

**Lars Got a Well in April, 1952**

It was April 2, 1952, just two days short of a year since oil had first been discovered, that the Rowan Drilling Company set up a rig and spudded in. The location was SWSE Sec. 25-T156-R96. This was about two miles northwest of where the Clarence Iverson discovery well had been drilled.

The photo accompanying this story (Fig. 1) was taken a short time later by the Press-Graphic photographer. It shows how the Fretland well looked on April 24.

By this time, the big bit had reached 7,430 feet and Rowan tool pusher John Culevier remarked happily that things looked "very promising." Twenty-seven days later the well was completed and began flowing a good grade of crude oil through perforations made at 8,555-8,590 feet. Lars Fretland had a good Madison producer.

**Old Friends Met Over Coffee**

About a year and eight months later, in December of 1953, Lars moved to one of the newer sections of Williston. His neighbor was an old Tioga friend, Michael Stangeland, who had farmed just south of Fretland in Dry Fork Township. They got together regularly and often over coffee.

The two were good friends of many years standing and their background was pretty much the same. However, there was one major difference. Lars Fretland had an oil well; Michael Stangeland did not. But it was rather incongruous that Michael, the one who didn't own an oil well, seemed to be getting just about as much royalty off his land as did Lars, the oil well owner.

**Drillers Went Hog Wild**

At first, Lars began receiving some pretty hefty royalty checks as the crude oil flowed out of his well and into the big tanks. But then the drillers seemed to go "hog-wild" and derricks sprouted out there in the Beaver Lodge Oil Field just about as thick as the bristles on a toothbrush.

It was during a period when only so much crude production was allowed in a given field. This was a measure to conserve the oil, recover a larger percentage of what was there. So the production was pro-rated, so many barrels per well. The more producing wells drilled, the less each was allowed to produce.

The prorationing regulations in force cut down the production from the Amerada Fretland No. 1 and with it the size of the royalty checks Lars had been receiving each month.

In the meantime, as the Fretland well was being drilled, Mike Stangeland waited hopefully to get a well of his own. The months went by. He celebrated his 81st birthday and still his land remained out of production.

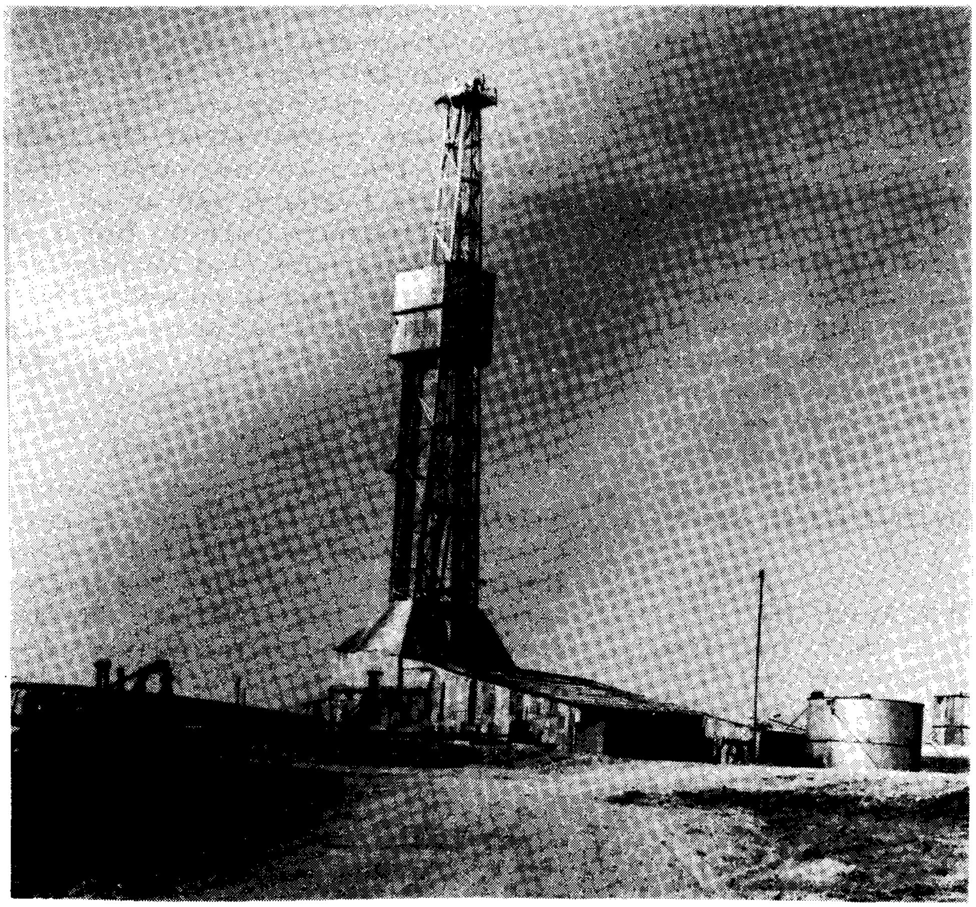
**Wonderful Scoria Deposit**

Then one day the men whose job it was to build access roads into the drilling locations found a wonderful supply of scoria on Mike's land. The rough, cinder-like clinker left when a burning bed of lignite coal baked the land to a rich red color was just the thing for all-weather surfacing of the oil field roads all over the entire area.

The road builders brought in bull-dozers and began scooping out that red, burned clay. They paid a royalty for it... so much a cubic yard. That was how things were going at the time the two old friends had moved to Williston. The more wells that were drilled, the more access roads that were needed... and the more scoria taken out of the ground.

Lars's royalty checks kept getting smaller and smaller as production on his well was curtailed more and more. Mike's checks kept getting larger and larger as the bulldozers scooped out more scoria.

Then one day Mike's scoria check was bigger than Lar's oil check. It was at this time Mike remarked, "Who needs an oil well?"



Lars Fretland well drilling near Tioga, April 24, 1952.

## GLACIAL ERRATICS IN NORTH DAKOTA

--John Bluemle

Millions of glacial erratics, boulders that were carried to North Dakota from someplace else by the glaciers, are found throughout the glaciated portion of the state. Geologists define erratics as stones or boulders that have been carried from their place of origin by a glacier (the term "*erratic*" is taken from a Latin word, *erratus*, meaning "to wander"). Erratics are found throughout the glaciated portion of North Dakota, wherever they happened to be left stranded when the glacier melted. Most of the erratics found in North Dakota were brought here from Canada. The only erratics that we actually see are those that are lying on the surface of the ground. Throughout the northern and eastern parts of North Dakota, the glacial sediment averages between about 150 and 250 feet thick and many more erratics than are exposed at the surface remain hidden from view, buried within the covering of glacial sediment.

When the land was settled, farmers had to clear their fields of rocks so that they could plow. In Scandinavia and the British Isles and also in the New England states and parts of the central United States, erratics were often used to build fences and foundations, while others were simply piled along fence rows or thrown into unused field corners. In North Dakota, the erratics were usually gathered into piles, which can be seen in many fields today.

Clearing farm fields of glacial erratics is a never-ending chore because, over time, seasonal freezing and thawing causes the rocks to work upward from below the plow zone to the land surface. Every spring a new batch of stones has to be removed from the fields. The smaller rocks can be picked up with rock-picking equipment and carried from the field; larger ones are sometimes blasted with dynamite and the pieces hauled away. Some of the very largest are simply left in place and avoided.

The lithologies (rock types) of erratics have been studied in several places in an effort to learn where they came from. If you pick up a granite rock, composed of interlocking crystals of quartz and feldspar and assorted dark-colored minerals, you can be sure it had a Canadian source, although usually it isn't possible to pinpoint just what part of Canada it came from. Boulders composed of carbonate rock can sometimes be characterized as to source area. In the area north of Winnipeg, for example, several Paleozoic carbonate formations outcrop and we can sometimes determine from which formation a boulder was derived. Most boulders of sandstone, on the other hand, were moved only a few miles by the glacier from nearby outcrop areas within the state. The sandstone is not well consolidated and any extensive transport of sandstone boulders by the glacier would break it down into much smaller fragments, or simply reduce them to sand. Occasionally I've found boulders of shale included in the glacial sediment. Such boulders are very fragile and have been moved only a few tens or hundreds of feet from their original source.

Generally, in places where large boulders, those two feet or more in diameter, are especially numerous, igneous and metamorphic rocks predominate. They may amount to between 50 and 70 percent of the total number of boulders found. If exceptionally large boulders occur, 90 percent or more of them are likely to be of igneous and metamorphic rocks. In places where large boulders are numerous in eastern

North Dakota carbonate rocks like limestone and dolostone commonly account for 5 to 15 percent of the total; in the western part of the state the percentage tends to be slightly lower. Locally-derived bedrock types, mainly sandstone, may amount to 1 or 2 percent of the total erratics in central and eastern North Dakota, perhaps as much as 5 percent in the northwestern part of the state. In places where smaller boulders predominate, carbonates and local bedrock types tend to make up a larger proportion of the total.

Glacial erratics are especially abundant in places. It is impractical to provide an exhaustive listing of all the bouldery areas in North Dakota, but a few places where erratics are particularly abundant include the stream-eroded till plain near Milnor in Sargent County; parts of the Missouri Coteau, such as between Minot and Williston; certain areas of slopewash erosion on the face of the Missouri Coteau--an example is in southwestern Dickey County; and the slopewash-eroded surfaces on the escarpment at the edge of the Turtle Mountains, as in the Dunseith area (Figs. 1 and 2). A particularly bouldery area occurs near Forman in Sargent County on the Prairie Coteau where boulders are many times more numerous than they are in similar areas of till in other parts of North Dakota.

Generally, boulders are most abundant on the ground surface where they have been washed by the winnowing action of waves along the shores of glacial lakes. Wave action removes the finer materials, transporting them offshore and leaving behind a lag of cobbles and boulders. Examples include areas near Pisek in the south-central part of Walsh County along the wave-worn shore of glacial Lake Agassiz; along the wave-worn shore of Devils Lake in Benson County; along the wave-worn glacial Lake Agassiz shore near Hankinson in Richland County; and along the wave-worn shores of modern lakes, such as Lake Addie and Lake Sibley, in Griggs County and Krueger Lake, in Sheridan County (Fig. 3).

In some places, uncommonly large igneous erratics, rocks 10 feet or more in diameter, are especially numerous. A few examples include the walls of the Sheyenne River valley near Fort Ransom (Fig. 4); many of the high bluffs along the Missouri River; along the Souris River near Velva; and along the White Earth River in Mountrail County.

Most glacial erratics are rounded and worn in appearance, and some of them have beveled or faceted surfaces. During the course of their journey, the rocks were jostled against one another, or against the rock over which the glacier was flowing, rounding off the corners and planing smooth surfaces. Glacial transport also caused some boulders to fracture, producing fresh, angular edges. Rocks carried by rivers also undergo abrasion and become rounded in the process. Some glacial erratics are grooved or polished, a result of abrasion by the moving ice (Fig. 5). Coarse sand and gravel within the ice scraped against the boulders, scratching them, sometimes as the boulder moved along with the advancing glacial ice, and other times as the glacier (and the abrasive material contained within the ice) flowed over a stationary boulder. Striated boulders can sometimes be used as indicators of the direction of glacial flow, provided that the boulder has not been moved from its position at the time glaciers flowed over it.

Glacial erratic boulders that were probably deposited by glaciers prior to Late Wisconsinan time are abundant in parts of Emmons County. Apparently, the finer fraction of the

Early Wisconsinan (or possibly pre-Wisconsinan) till was removed by erosion, leaving the lag, or "pavement," of boulders. In places where early boulder deposits were covered by layers of younger glacial sediment, buried boulder pavements may be found (Figs. 6 and 7).

Large, isolated erratics are sometimes found standing in depressions, or they may be surrounded by a depression, a result of animals such as bison and, more recently, cattle using the boulders as rubbing stones, and loosening the soil around the boulders with their hooves. The wind then carries the loose soil away, forming the depressions around these "buffalo boulders" or "cattle rubbing stones" (Fig. 8).

Glacial erratics have been used in the construction of foundations and, in a few places, for complete buildings. They have been utilized for concrete aggregate and as rip rap to stabilize stream channels and on the faces of dams. But mainly, the erratics are simply a nuisance, making more work for the farmer.

And, finally, I'd like to close with a quote from a book titled Blue Highways by William Least Heat Moon (published in 1982 by Little, Brown and Company):

> *East of Fortuna, North Dakota, just eight miles south of Saskatchewan, the high moraine wheat fields took up the whole landscape. There was nothing else, except piles of stones like Viking burial mounds at the verges of tracts and big rock pickers running steely fingers through the glacial soil to glean stone that freezes had heaved to the surface; behind the machines, the fields looked vacuumed. At a filling station, a man who long had farmed the moraine said the great ice sheets had gone away only to get more rock. "They'll be back. They always come back. What's to stop them?"*

Figure 1. A view to the northeast of the escarpment that forms the southwest slope of the Turtle Mountains in Bottineau County. Large numbers of glacial erratic boulders cover the surface as a result of extensive washing by slopewash from the Turtle Mountains.

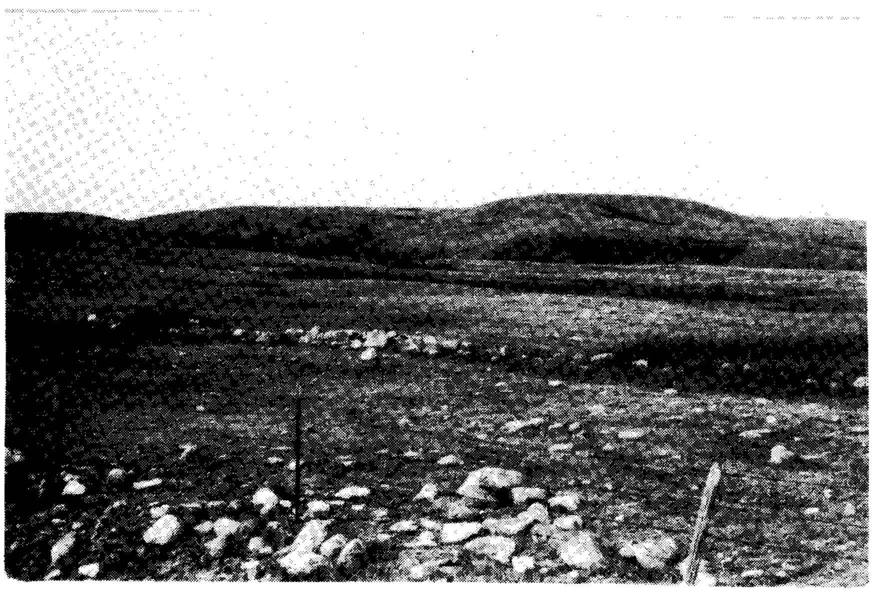


Figure 2. A view of the Missouri Escarpment in southwestern Dickey County. Large concentrations of glacial erratic boulders are typical of the slopes on the escarpment in many places.

Figure 3. Bouldery surface on shale along the shore of Krueger Lake in northwestern Sheridan County a few miles east of the town of Butte.

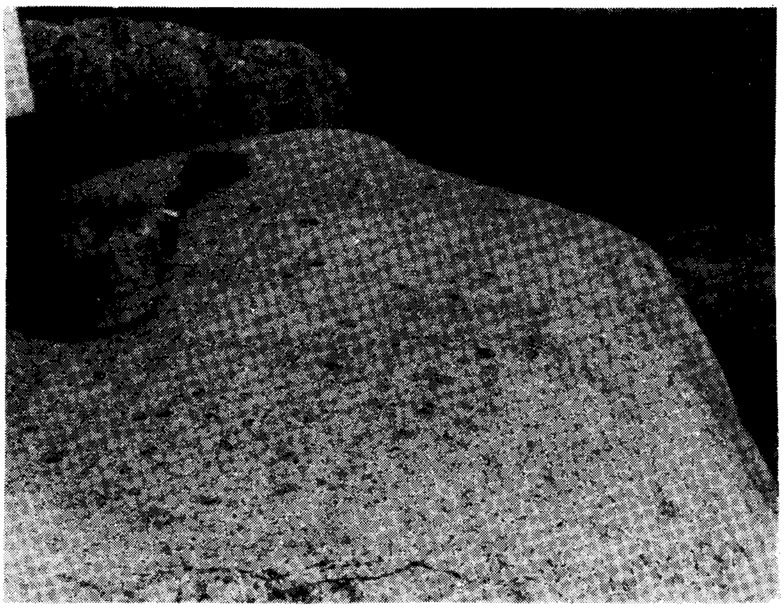


Figure 4. A large glacial erratic boulder near Fort Ransom in the Sheyenne River valley in Ransom County. The upper surface of this 200-ton boulder was flattened by the glacier as it scraped the rock surface. Long straie, or grooves, were carved by the ice (parallel to the shovel handle), as it moved over the rock.

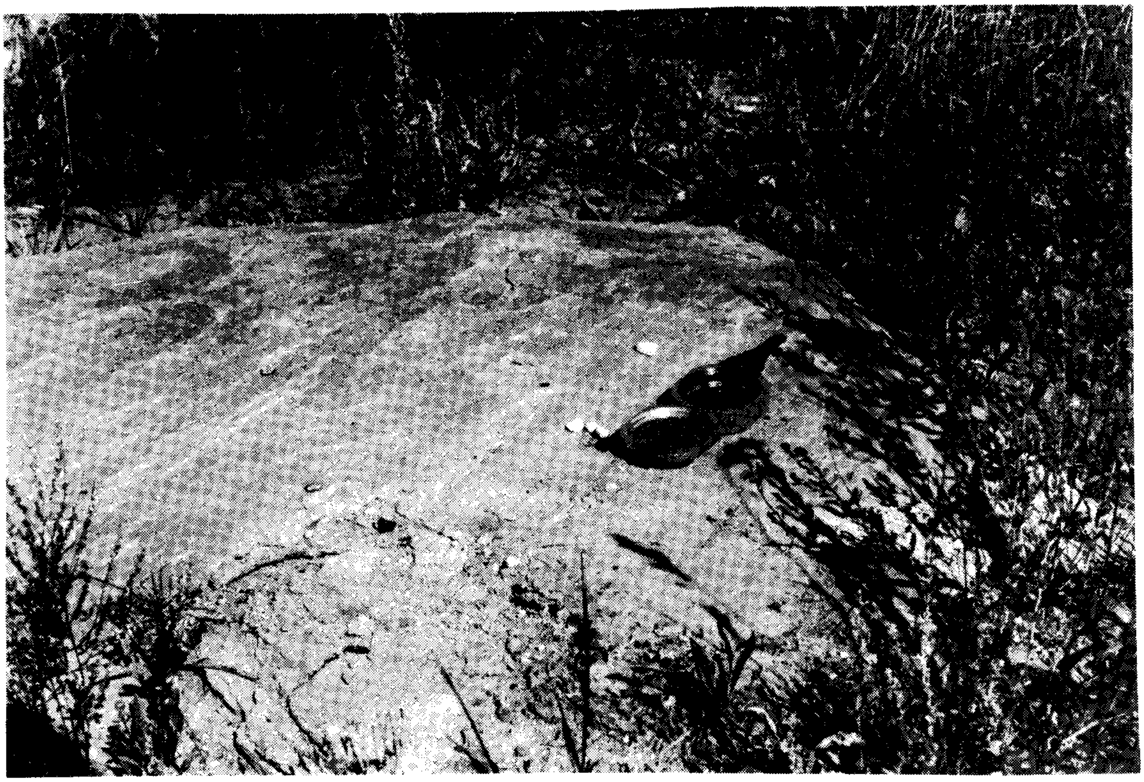


Figure 5. A large (several ton) striated (grooved) boulder of relatively soft, Fox Hills Formation sandstone just west of the Turtle Mountains in Bottineau County.

Figure 6. Boulder pavement exposed in a road cut along the western edge of the Turtle Mountains in Bottineau County. The boulders lie on top of Cretaceous age Fox Hills Formation bedrock and they are overlain by Late Wisconsinan age glacial sediment.

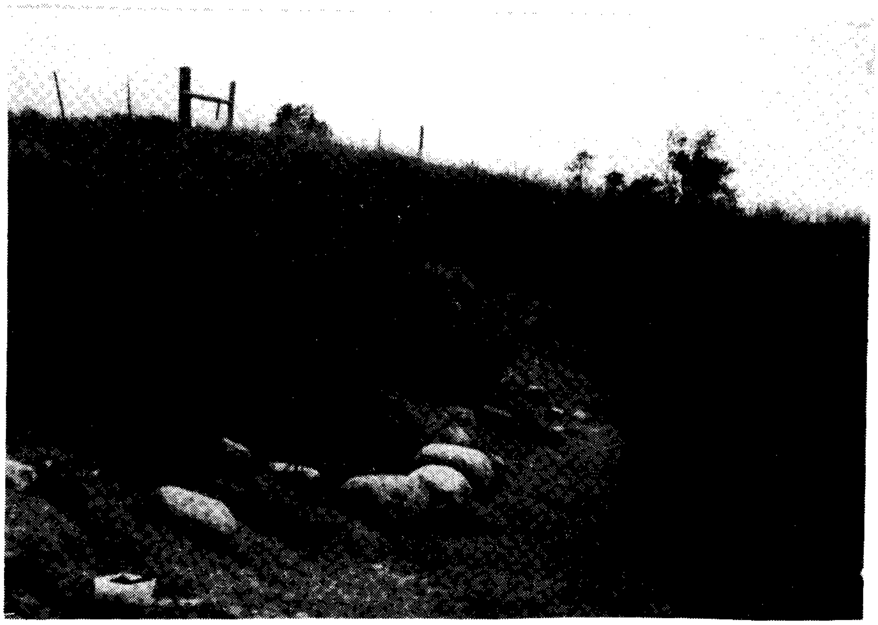


Figure 7. Road cut exposure of a boulder pavement near Niagara in Grand Forks County. The boulders are lying on top of Cretaceous Pierre Formation shale and they are overlain by Late Wisconsinan glacial till. The boulders are concentrated at an "unconformity" that represents a gap in the geologic record of about 75 million years--between the time the shale was deposited and the time glaciers flowed over the area.

The boulders may have been left behind after erosion of earlier glacial deposits; the finer grained fraction of the glacial deposits may have been removed, leaving a lag of boulders lying on the surface over which the Late Wisconsinan glaciers advanced.

Figure 8. A glacial erratic "buffalo boulder" in Divide County. This boulder, like many others, is surrounded by a depression that was formed by animals such as bison rubbing against the boulder, working the soil around the boulder loose with their hooves. The loose soil was blown away by the wind. Photo by Ted Freers.

# THE ORIGIN OF THE MISSOURI RIVER VALLEY IN NORTH DAKOTA

--John Bluemle

North Dakota has hundreds of river valleys and, although many of them carry modern streams, many more of them are simply abandoned valleys through which no river or stream flows today. Or, in many cases, the stream flowing in the valley is much too small for the size of the valley (Fig. 1). Most of these underfit streams are flowing in valleys that were originally carved by much larger rivers--rivers of meltwater or floodwater derived from the melting glaciers. Some of these *meltwater trenches* were eroded by rivers flowing along the edge of the glacier. Others may have developed at least partially along the edge of the glacier, but the rivers that formed them mainly flowed away from the melting glacial ice.

Some of the more spectacular examples of underfit meltwater trenches in North Dakota are the valleys of the James, Pembina, Sheyenne, and Souris River (Figs. 1 and 2). Consider the size of these valleys, and the rivers that flow in them, at for example, Jamestown, Walhalla, Valley City, and Minot. Although it is quite possible, given enough time, for rivers as small as these to carve large valleys (in the United States, the Grand Canyon of the Colorado River is probably the classic example of a large valley being carved over a long period of time), most of our North Dakota rivers are very young, dating only to the end of the Ice Age, about 10,000 or 15,000 years ago. We know that valleys like those of the Souris and Sheyenne were carved quite recently and over short periods of time, mainly by massive floods of meltwater, released periodically from proglacial lakes. The trenches flowed, full of water, for relatively brief periods while the glaciers were melting.

The origin of valleys like the four I mentioned above is an interesting subject and would be a good topic for another article for this newsletter, but the subject of this article is the valley of the Missouri River. Actually, the Missouri River valley is a much more complex feature, with a more involved history than any of the four meltwater trenches I just mentioned. Although parts of the Missouri River valley were carved primarily as a result of erosion by meltwater, other parts were not (or at least other processes were involved in forming some parts of the valley). Let's look at how the Missouri River valley developed.

If we go back to a time before North Dakota was glaciated, before the first glaciers flowed over the area about 2 million years ago, we know that the drainage over much of the state was considerably different than it is today (Fig. 3). Many of our modern rivers didn't exist. Over much of the state the rivers and streams that did exist flowed in directions different than those followed by modern rivers. However, parts of southwestern North Dakota probably were similar to today. The Little Missouri River, for example, flowed northward, and rivers like the Cannonball, Heart, and Knife flowed toward the northeast. There were major differences though. The Little Missouri River was not bordered by badlands topography. It flowed through a broad, gently sloping valley to the point where today it makes a sharp turn to the east, but from there it continued northward (through its gentle valley), joining the Yellowstone River about 25 miles north of Williston. Downstream from its confluence with the Yellowstone, the river flowed on into Canada, eventually making its way to Hudson Bay.

Rivers like the Knife, Heart, and Cannonball, which today terminate at the Missouri River, flowed on into eastern North Dakota instead, eventually joining into a single, large river in the Devils Lake area (Fig. 3). That large "trunk" stream flowed northward, past the east side of the Turtle Mountains, and into Canada.

So you see, the Missouri River, which intercepts all of the rivers I just mentioned, just didn't exist in its modern form prior to glaciation when all of North Dakota drained to Hudson Bay. Today, with the Missouri River draining almost 60 percent of the state to the Gulf of Mexico, the situation is much different. My intention in writing this article is to explain how the valley of the modern Missouri River formed, and to show why the Missouri River follows the route it does today.

First of all, the Missouri River valley consists of a number of "segments" of valley that are quite different from one another. Some of these valley segments are broad--six to ten miles wide from edge to edge--with gentle slopes from the adjacent upland to the valley floor, while others are narrow--less than two miles wide--with much more rugged valley sides. Generally, the wide segments trend east-west and the narrow segments trend north-south (there are a few exceptions--the Bismarck-Mandan area is one of them and I'll explain why shortly).

The reason the east-west segments are wide is that they coincide with much older valleys, some of which existed prior to glaciation. The best example of this is the 40-mile-long, east-trending segment of the valley upstream from Garrison Dam. This stretch of the Missouri Valley, which is now flooded by Lake Sakakawea, was once the route of a river that flowed eastward past the town of Turtle Lake to near Mercer, where it joined the Knife River (for convenience, I'll refer to this east-flowing river as the "McLean River") (Fig. 4). The portion of the McLean River valley east of U. S. Highway 83 is now buried beneath thick deposits of glacial sediment. It's still a somewhat lower area though--a kind of sag--in which a number of lakes (Turtle Lake, Lake Williams, Brush Lake, and others) occur.

Still other, short, east-west trending segments of the modern Missouri River valley once carried old rivers. The Knife River probably flowed eastward through the segment of the valley from Stanton to Washburn, where it turned slightly northeastward joining the McLean River in eastern McLean County near the town of Mercer.

Another example of an "old" (and wide) segment of the valley is at Bismarck-Mandan, where the Heart River today joins the Missouri River. Square Butte and Burnt Creeks once flowed southward form a point about six miles north of Bismarck, joining the Heart River, which flowed eastward through Burleigh County. The Heart River was probably once a tributary to the Cannonball River, joining it in southeastern Burleigh County.

At Bismarck-Mandan, the Missouri River valley is about two miles wide where Interstate Highway 94 crosses the river. On the south side of Bismarck the valley broadens to about six miles wide, although it retains its steep western edge. Part of the reason for this widening is that, prior to glaciation, the Heart and Little Heart Rivers, which today flow into the Missouri River (the Heart River enters the Missouri at Mandan; the Little Heart enters about ten miles south of Mandan), joined a few miles east of Bismarck. The old, combined Heart-Little Heart valley still exists as the broad lowland south of Bismarck--the much-widened Missouri River valley (see Fig. 5 for a map illustrating these relationships). When the glacier blocked the old Heart/Little Heart River valley east of Bismarck, an ice-dammed lake formed in the valley--the glacial Lake McKenzie.

To summarize the situation at Bismarck-Mandan: the Missouri River valley north of the city is much younger (formed during a glacial event, perhaps 25 thousand years ago) than is the valley for several miles south of the city, where it coincides with the old (preglacial--possibly more than two million year old--northeast-trending Heart River valley.

Most of the narrow, north-south segments of the Missouri River valley formed when glaciers diverted the drainage southward. North Dakota was glaciated many times during the Ice Age and most of the glacial activity tended to be concentrated in the eastern part of the state. However, each time glaciers flowed southward through the Red River Valley and other parts of eastern North Dakota, they also expanded westward, causing the northeasterly flowing rivers to be diverted along the western margin of the glacier.

When the McLean River, for example, was blocked by a glacier in the Turtle Lake area sometime midway through the Ice Age, a large, proglacial lake formed ahead--to the west--of the ice in the valley of the McLean River. This was the "original" Lake Sakakawea! This early ice-dammed lake predated the Corps of Engineers version of Garrison Dam by a few hundred thousand years. Eventually, the proglacial lake overflowed, just about where Garrison Dam is today, and the resulting flood quickly carved the narrow trench southward to the Stanton area. But the Knife River Valley was also flooded by a large proglacial lake because it too was blocked by glacial ice in the Washburn-Wilton area. The lake in the Knife River Valley, in turn, spilled southward into the Burnt Creek-Square Butte Creek drainage, carving a narrow trench in the area just south of Wilton to Bismarck-Mandan.

The youngest, and narrowest segment of the Missouri River Valley in North Dakota is in the New Town area between Four Bears bridge and Van Hook Bay. As recently as 14,000 years ago, a glacier forced the river, which had been flowing through a broad valley known as the "Van Hook Arm," into a new position a few miles farther west (Fig. 6)

I haven't tried to go into a lot of detail about the origin of the Missouri River in this article. It just isn't possible to discuss all of the things that contributed to the final route and configuration of the valley. I will mention though that the modern route of the Missouri River is only the most recent of the many routes that "Missouri" rivers have followed through the state during the Ice Age. (Here I'm using the term "Missouri" to refer to any of several successive, but not closely related glacial age and interglacial age rivers that, at any given time, carried runoff from the entire area east of the Rocky Mountains in Montana, northern Wyoming and the Dakotas, and ultimately flowed to the Gulf of Mexico). Using this definition, any river that drained essentially that same area to Hudson Bay would <u>not</u> be an ancestral "Missouri" River (perhaps it could be referred to as part of an ancestral Yellowstone or Assiniboine River system).

All of the other "Missouri" river routes also flowed to the Gulf of Mexico because the original, northerly routes of all other rivers to Hudson

Bay were blocked each time glaciers advanced southward. Most of these early "Missouri" River valleys are buried today beneath thick layers of glacial sediment in eastern North Dakota. One of them though, in the western part of North Dakota, was formed by an early glacier that advanced much farther southwestward than the modern Missouri River. This one, which geologists refer to as the Killdeer-Shields Channel, carried a river that flowed through Dunn, Morton, and Sioux Counties (Fig. 7). It's a large valley that probably served as a "Missouri" River for a much longer period of time than has the modern Missouri River valley.

In summary, the modern Missouri River valley is a sort of "composite" of old, wide preglacial valleys and younger, narrower valleys that were cut during the Ice Age. The parts of the Missouri River valley that extend east-west are generally wider and these are the older segments. The parts that extend north-south are generally narrower and formed either when lakes that were dammed ahead (to the west) of the glacier overflowed southward, carving narrow trenches, or when rivers were forced to flow southward along the edge of the glaciers. Even though many earlier versions of the "Missouri River" existed during the Ice Age in eastern North Dakota, most of them were later buried beneath thick deposits of glacial sediment. The modern Missouri River valley is simply the latest in a continuing series. After the next glacier has come and gone, the "new" Missouri River will undoubtedly be somewhat different than today.

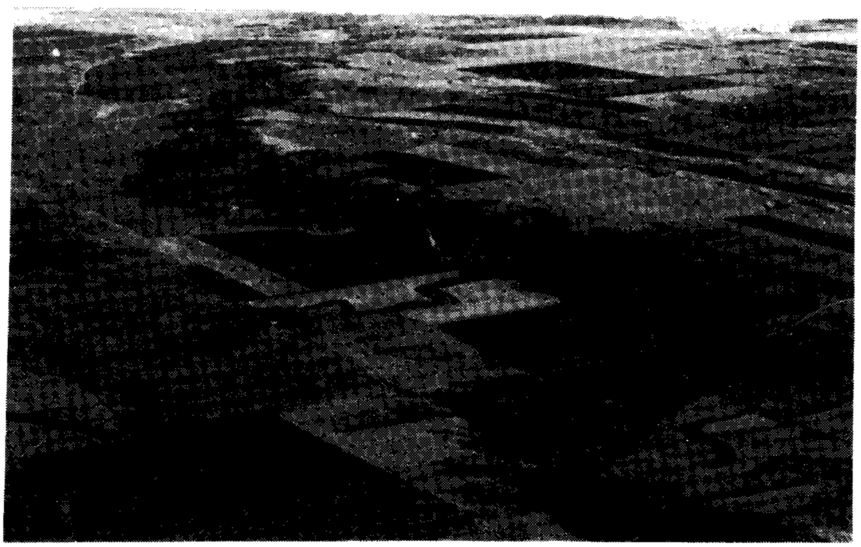


Figure 1. Air view of the Sheyenne River valley near Pekin in Nelson County. The small Sheyenne River flows through a mile-wide valley in this area. Photo by Roger Reede.

Figure 2. View of the Sheyenne River valley in southern Griggs County, near Hannaford. Photo by James Merritt.

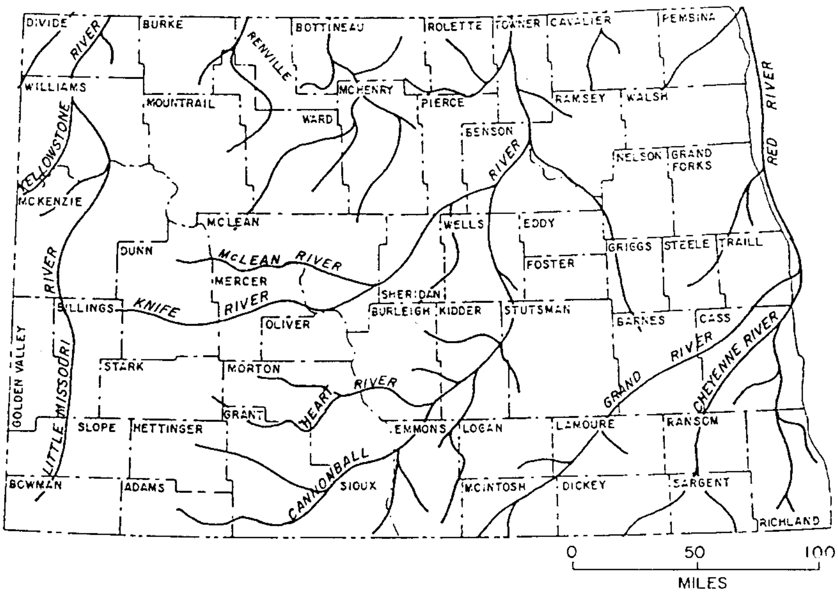



Figure 3. Map of North Dakota showing the drainage pattern prior to glaciation. All rivers flowed north or northeast into Canada. The Missouri River valley did not exist (except for short segments that correspond to portions of valleys such as the Knife and McLean River valleys--see text).

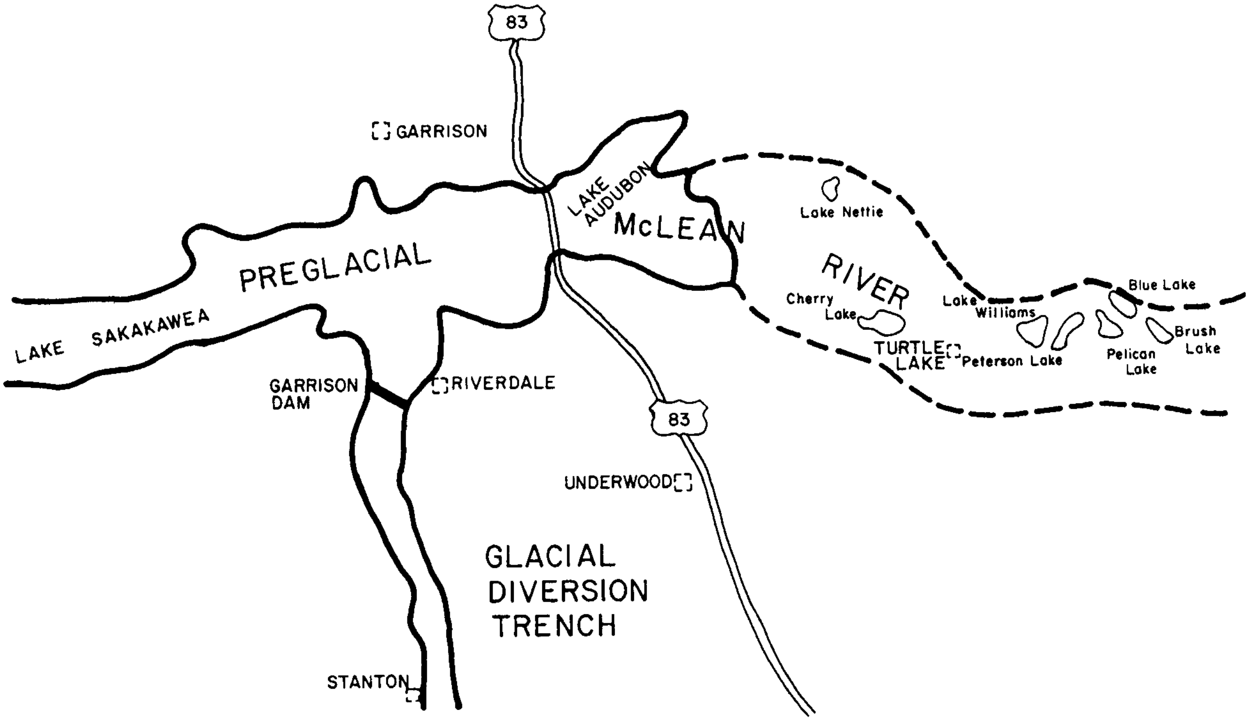



Figure 4. Schematic map showing the a portion of the route of the preglacial "McLean River," which flowed eastward through a broad valley that passed between Garrison and Riverdale, to the Turtle Lake area, and on into Sheridan County. When the McLean River valley was blocked by a glacier, a proglacial lake formed in the valley. When the lake overflowed southward from a point near Riverdale--at the site of the modern Garrison Dam--a narrow diversion trench was cut. The modern Missouri River flows through this diversion trench.

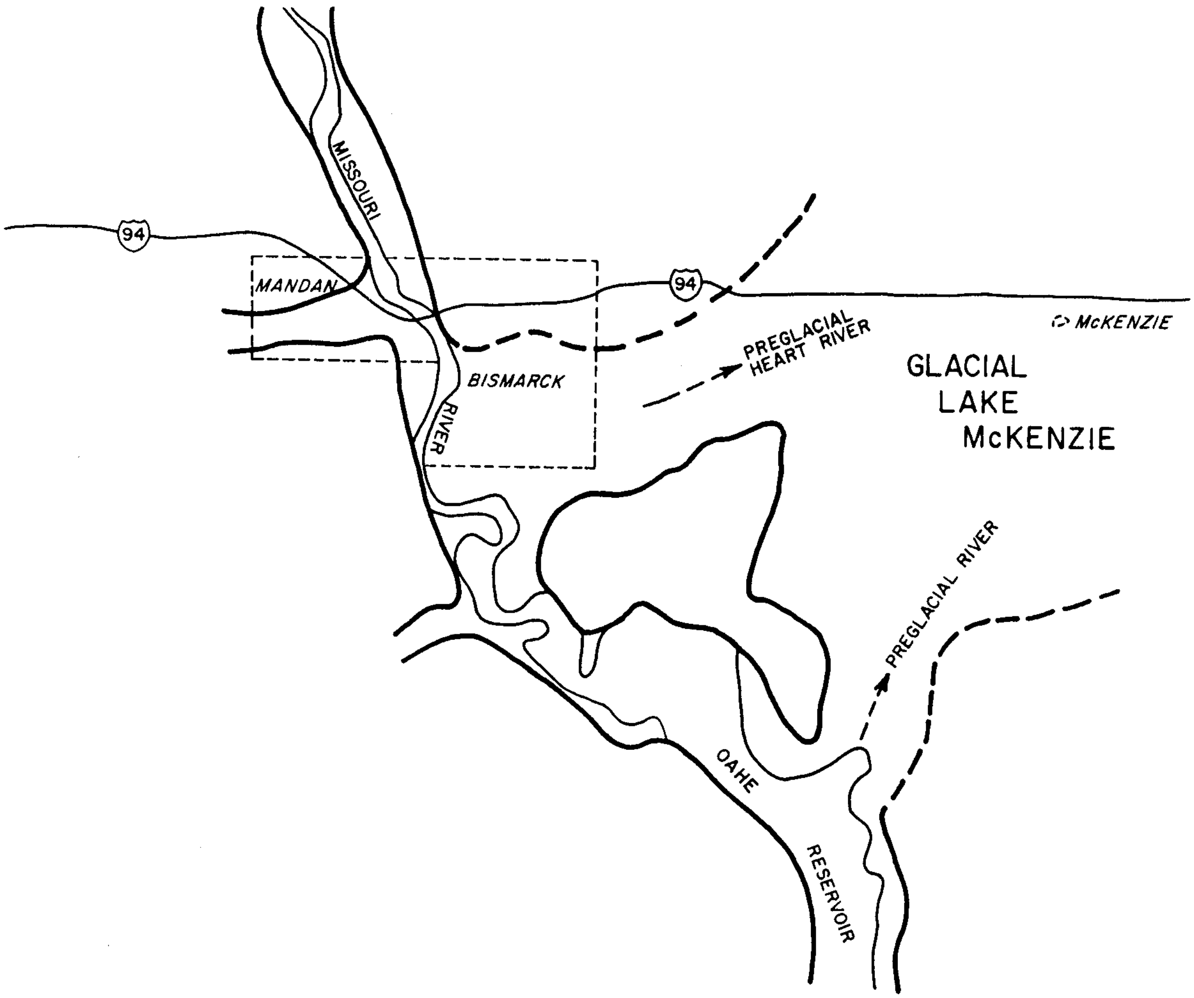



Figure 5. Schematic map showing the Missouri River valley at Bismarck-Mandan. South of Bismarck, the valley is very wide because it corresponds to the old, northeast-trending preglacial valley of the Heart River. North of Bismarck-Mandan, the valley is narrow with quite steep sides. This portion of the valley was formed when an ice-dammed lake to the north in the preglacial Knife River valley overflowed from a point near Wilton. A similar ice-dammed lake existed in the Heart River valley east of Bismarck--the glacial Lake McKenzie.

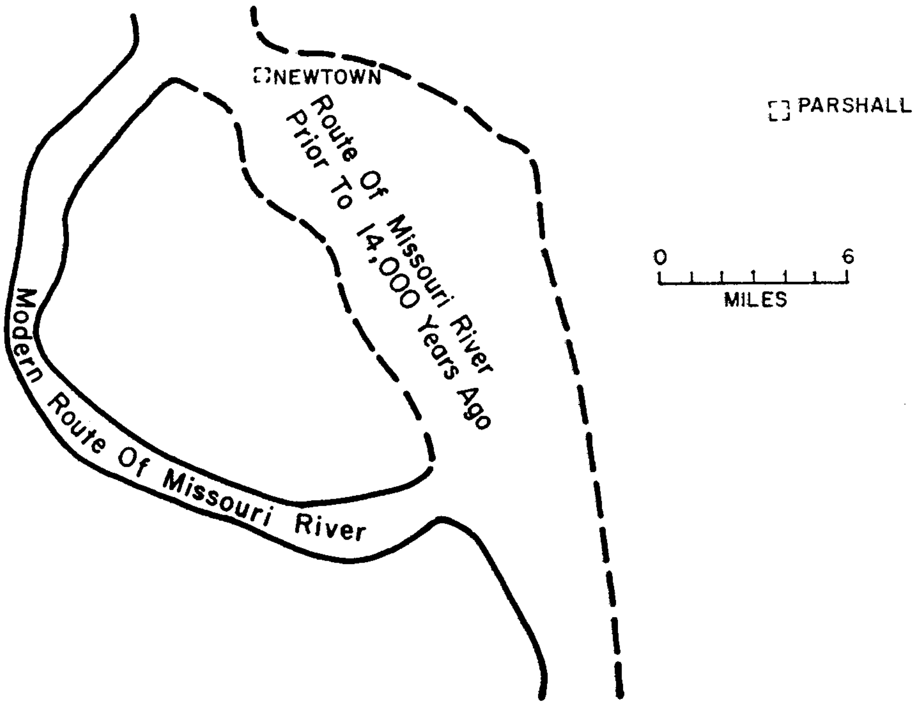



Figure 6. Schematic map showing the old route of the Missouri River at New Town (within the dashed lines) and the more recent route, formed when the glacier diverted the river farther southwest (within the solid lines). This diverted loop of the Missouri River is the youngest portion of its valley through North Dakota. It formed about 14,000 years ago.

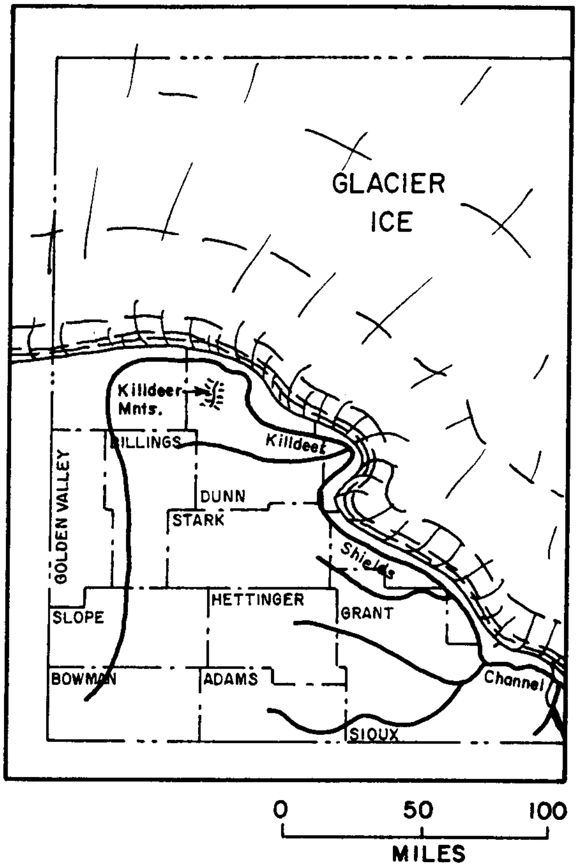



Figure 7. About 600,000 years ago a glacier diverted the Little Missouri River southeastward. All of the other northerly or northeasterly flowing rivers (Heart, Knife, Cannonball, etc.) were also diverted and an early version of the "Missouri River" resulted in the location shown along the edge of the glacier. This early Missouri River remained for several tens of thousands of years after the ice melted and it can be seen today as a (mostly) dry valley that geologists refer to as the Killdeer-Shields Channel.

## STATE FOSSIL COLLECTION TO BE MOVED TO THE NORTH DAKOTA HERITAGE CENTER

--John Hoganson

I am extremely pleased to announce that the Survey and State Historical Society have signed a Memorandum of Agreement to establish a cooperative effort with respect to management and display of North Dakota fossils. Through this agreement, the Historical Society will provide laboratory and storage facilities for the State Fossil Collection and office space for me at the Heritage Center. The Survey will equip the facility and will be solely responsible for curation of the State Fossil Collection. The Survey will provide expertise and specimens for development of fossil exhibits and other natural history displays at the Heritage Center. We will also become more involved with educational activities developed by the Historical Society's education division. This agreement also allows the Survey and the Historical Society freedom to cooperate in the promotion of activities and programs that are of mutual benefit to both the Survey and Historical Society.

We began working toward this agreement about a year ago. Recently both the Industrial Commission and State Historical Board voted unanimously in favor of the plan and the agreement was endorsed. Renovation of the facility will be completed by mid August and we hope to complete the move by the end of August. After then, I will be spending time in both the Heritage Center and in the Survey office building. Fossils are among North Dakota's natural treasures and an important part of our heritage. It is appropriate and logical that North Dakota fossils be housed in the same museum as other reflections of our heritage. I am truly happy to see such widespread support for this concept.

## NEW NDGS PUBLICATIONS

Report of Investigation 90 -- "Devonian Stratigraphy of North Dakota from Wireline-Log Sections" was compiled by Thomas J. Heck and Randolph B. Burke. The publication consists of seven cross sections, four drawn in an east-west direction, and three north-south, of the Devonian System in North Dakota.

The cross-sections are drawn on 28 sheets with a total of 123 well-logs. The areal extent and stratigraphic relations, both within the Devonian strata and between Devonian strata and the under- and overlying formations are shown on the sections. Wells from surrounding states and provinces are included to provide a correlation well to areas outside North Dakota.

These cross-sections are a useful tool for oil explorationists in identifying Devonian strata in the less well studied parts of North Dakota. In addition, the cross-sections show some of the stratigraphic changes that occurred during the various times of dissolution of the Prairie Formation.

Report of Investigation 90 can be obtained from the Survey for $15.00.

Report of Investigation 91 -- "Petroleum Potential of the Little Missouri National Grasslands," was written by D. W. Fischer, J. A. LeFever, T. J. Heck, and R. D. LeFever. The report is a condensation of a longer, open-file report that the North Dakota Geological Survey prepared for the U. S. Forest Service.

The report presents an evaluation of the petroleum geology, a summarization of the oil exploration history, and information on existing wells, oil fields, and enhanced recovery projects in an area that includes all of McKenzie, Dunn, Golden Valley, Billings, Stark, and Slope Counties. It also presents estimates of the recoverable reserves of existing oil and gas pools and it estimates the number of undiscovered pools in the area and the expected reserves in those pools.

In addition to a description of the geology of the area, particularly as it relates to the occurrence of hydrocarbons, the report presents a series of maps detailing the potential for occurrence of oil and gas in the various producing formation in the counties mentioned above.

The 62-page report is available from the Survey for $3.00.

Miscellaneous Series 74 -- "Oil Exploration and Development in the North Dakota Williston Basin: 1988-1989 Update," was written by Thomas J. Heck. The report reviews North Dakota's history of oil and gas discovery and production. It analyzes the several exploration cycles the Williston Basin has undergone and reviews the development of significant oil reservoirs. The author analyzes conditions and offers his best prognosis of future possibilities.

The report includes 9 illustrations to help readers better understand the role of oil and gas in North Dakota's economy. Graphs showing trends, such as wildcat wells drilled annually since oil was discovered, the number of new pools discovered each year, annual crude oil production, tax revenues, and other factors are included. The report includes a listing of all new-pool discovery wells for 1988 and 1989, along with maps showing the locations of discoveries during each of the two years.

The 22-page report is available from the Survey for $3.00.

Miscellaneous Series 75 -- "Radiocarbon Dating of Beaches and Outlets of Devils Lake," was written by John P. Bluemle. The report includes descriptions of samples collected during 1987 and 1988, mainly along the north shore of Devils Lake. The localities studied included buried soil horizons, which were dated using radiometric methods. Among other findings, the report concludes that Devils Lake has risen high enough within the past 1,800 years to overflow, through Stump Lake, into the Sheyenne River.

The 10-page report, which includes 7 illustrations, can be obtained from the Survey for $1.00.

Miscellaneous Map 31 -- "Great Plains Glaciotectonics" was compiled by J. S. Aber and J. P. Bluemle. This map includes North Dakota and parts of Montana, Manitoba, Saskatchewan, and Alberta. It shows the locations of various kinds of glaciotectonic landforms and structures in the northern plains. The map distinguishes between ice-shoved hills that can be seen at the surface, and concealed structures. It also notes the locations of known source basins--the places from which the ice-shoved hills were derived.

The map is printed in several colors and patterns at a scale of 1:2,500,000 and measures 20" x 29". It is available from the Survey for $2.00.

North Dakota Geological Video -- The NDGS recently released a 23-minute educational video, "Landforms of North Dakota," which uses slide scenes and narration to describe the various landforms throughout the state. The program, which explains how our landscape formed, should serve as an introduction to the surface geology of our state. Although the Survey's main purpose in releasing the video is to provide an instructive tool for teachers of earth science in North Dakota schools, the material should also be interesting to anyone who wants to know more about the geology of North Dakota.

"Landforms of North Dakota" is available for $20.00 from the Survey for $20.00.

## 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

| | | |
|---|---|---|
| _______ | RI-90 ($15.00) | Devonian Stratigraphy of North Dakota From Wireline-Log Sections |
| _______ | RI-91 ($3.00) | Petroleum Potential of the Little Missouri National Grasslands |
| _______ | MS-75 ($1.00) | Radiocarbon Dating of Beaches and Outlets of Devils Lake |
| _______ | MM-31 ($2.00) | Map on Great Plains Glaciotectonics |
| _______ | VIDEO ($20.00) | Geological Video on Landforms of North Dakota |

## ADDRESS CORRECTION

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