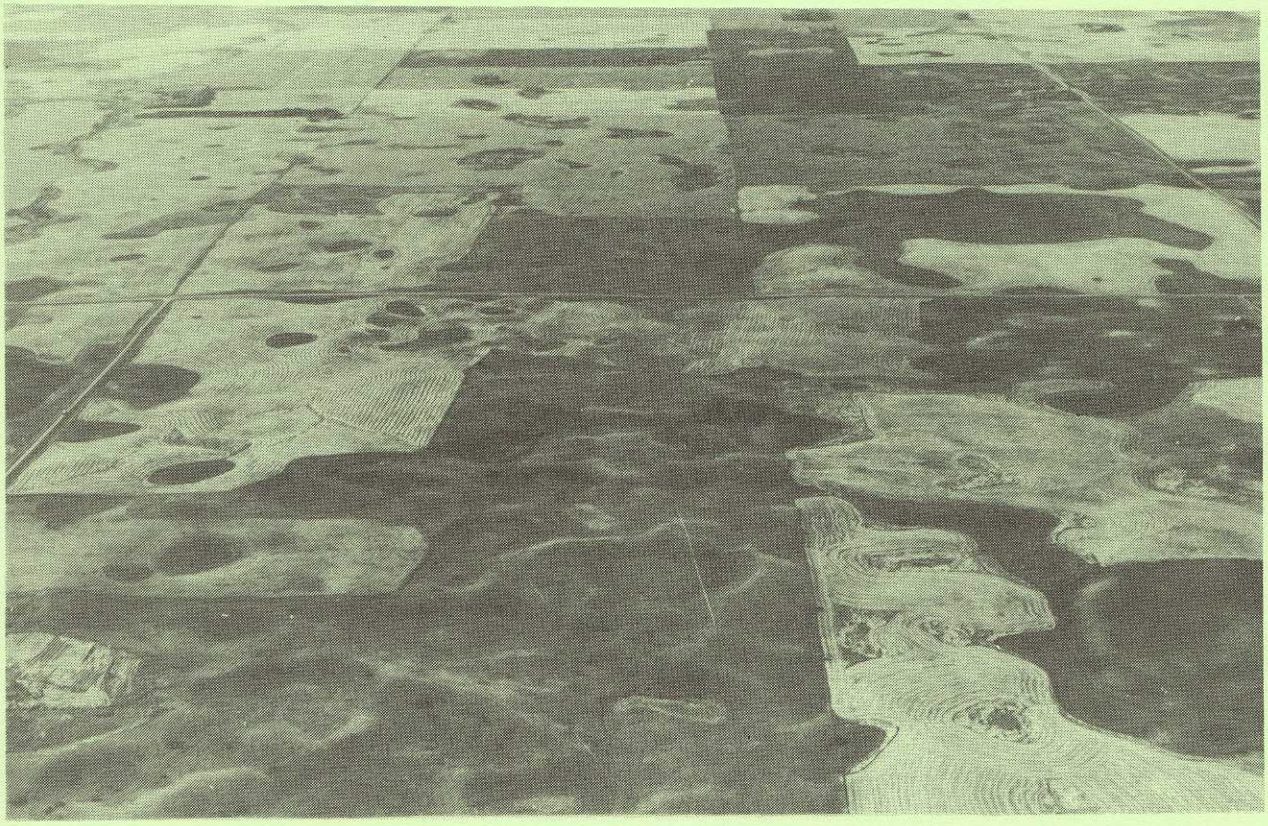
NEWSLETTER NDGS

John P. Bluemle, Editor



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COVER PHOTO

Aerial view of typical low-relief, ice-disintegration topography near Blue Mountain in western Nelson County, a few miles north of Tolna (see article in this Newsletter describing North Dakota's physiography and landforms). This type of topography is widespread throughout the Glaciated Plains of eastern and northern North Dakota. It was formed when relatively thin, stagnant, debris-laden glacial ice melted. When the glacier melted, a variety of landforms resulted. This photo shows irregular ridges, some of them nearly circular "doughnuts," (center, lower portion of the photo) and kettles -- depressions left when buried blocks of ice melted (upper part of photo). The light colored, lined areas are fields with windrows of grain; darker areas are pasture.

EDITOR'S NOTE **John Bluemle**

This is a somewhat abbreviated version of the NDGS Newsletter, written as the Geological Survey is in the process of moving its offices and facilities from Grand Forks to Bismarck (see following article). As I've noted in the next article, the Geological Survey will now be housed with the Oil and Gas Division of the Industrial Commission. I've asked some of the Oil and Gas Division personnel to write articles and these are included in this Newsletter (articles by Kelly Carlson and Doren Dannewitz).

We should be back to a more normal situation by the time the next newsletter comes out at the end of the year. In the future I expect to incorporate news and information from the Oil and Gas Division in our newsletter.

GEOLOGICAL SURVEY MOVES TO BISMARCK

John Bluemle

Governor Sinner recently signed Senate Bill No. 2261, which was passed during the recently adjourned legislative session. As a result of this legislation, the North Dakota Geological Survey will soon come under the jurisdiction of the State Industrial Commission. Prior to the passage of the new legislation, since 1895, the Geological Survey was under the Board of Higher Education and associated with the University of North Dakota in Grand Forks. With the new legislation, the Survey will be located in Bismarck, where it will be more easily accessible to other state agencies. The move will also re-unite the Geological Survey with the Oil and Gas Division of the Industrial Commission. Prior to 1981, the Survey had regulatory authority over all oil and gas activities, but the portion of the Survey that dealt with these issues was transferred to Bismarck at that time and became the Oil and Gas Division. With the move, the two agencies -- the Geological Survey and the Oil and Gas Division -- will again share a common clerical staff, even though each agency will retain its separate identity.

Ten full-time Geological Survey positions are being transferred to Bismarck. We expect eight people to make the move. People moving include Sid Anderson, who has been named Acting State Geologist; John Bluemle, Assistant State Geologist; Randy Burke, carbonate geologist; Ken Harris, Quaternary geologist; John Hoganson, paleontologist; Ed Murphy, environmental and coal geologist; Marv Rygh, petroleum engineer (Marv has been assigned to the Oil and Gas Division); and Eula Mailloux, clerk.

Julie LeFever, stratigrapher, will remain in Grand Forks in charge of the Wilson M. Laird Core and Sample Library, which will continue to be located in Grand Forks for the foreseeable future. In addition to Julie, Rod Stoa and Mickey Rood will remain at the core library. Kathleen Miller, our computer programmer, will not be moving to Bismarck, but she has not yet decided whether to return to the University to complete her degree or to take another job.

Two of our geologists, David Brekke and David Fischer, have resigned their positions with the Geological Survey. The positions of several of the Survey's clerical staff in Grand Forks were not transferred to Bismarck, and most of these people have found employment in other positions on the University of North Dakota campus; these include Marvelyn Bohach, Linda Carlson, Debra Kroese, and Janna Molstad. Our publications clerk, Kent Hollands, resigned his position with the Survey. Marilyn Rood will also be resigning her position with the Survey. Connie Borboa, the Survey's Administrative Officer, does not plan to move to Bismarck but she has not yet decided what she will be doing. Palmer Roos will be retiring at the end of June. David Lechner, our lab technician, plans to move to Ohio.

Although the legislation transferring the Geological Survey to the Industrial Commission may seem fundamental and, while it certainly does mean significant changes for all NDGS employees, it does not greatly alter the Survey's duties nor will it result in major changes in what our geologists do. We plan to continue virtually all of the programs and technical investigations we now have underway. The legislation includes a statement of the Survey's responsibilities. It reads as follows:

1. Serve as the primary source of geological information in the state.

2. Investigate, describe, and interpret the geological setting of the state with special reference to the economic products, geological hazards, and energy resources of the state's geology.

3. Conduct investigations designed to promote public understanding of the state's natural setting and natural resources.

4. Conduct research relative to the exploration, production, and regulation of oil, gas, coal, and other mineral resources of the state.

5. Conduct investigations and review externally prepared reports pertaining to geological aspects of the health and safety of the citizens and environment of the state.

6. Provide geological information contributing to the development of public health policies and to the use and management of natural resources.

7. Publish bulletins, circulars, maps, and other related materials that make available the results of the geological research and technical studies.

8. Provide educational information about the geology of the state to the public.

9. Operate and maintain a public repository for books, reports, maps, and other publications regarding the geology and mineral resources of the state.

10. Operate and maintain a public repository for fossil and rock specimens, rock cores, well cuttings, and associated data.

11. Provide technical advice and assistance concerning the geology of the state to local, state, and federal governmental agencies and to state educational institutions.

12. Aid in the regulation of the state's natural resources by providing the resource assessment and evaluation information necessary to create and maintain effective regulatory policy.

13. Investigate the kind, amount, and availability of the various mineral substances contained in state owned lands, so as to contribute to the most effective and beneficial administration of these lands for the state.

14. Consider such other scientific and economic questions in the field of geology as in the judgment of the state geologist is deemed of value to the people of the state.

15. Carry out any other responsibilities assigned to it by the legislative assembly.

Some problems remain to be solved as the transfer of the Survey from Grand Forks takes place, but the move has gone smoothly so far. As I write this, in late June, the Manhattan Life Building is being renovated for the Geological Survey and the Oil and Gas Division. After remodeling is completed, hopefully early in July, our two agencies will be able to complete the move to the new facilities, which are located at 1022 East Divide Avenue, Bismarck.

NEW PUBLICATIONS

Bulletin 50, Part 1--"Geology of Renville and Ward Counties, North Dakota," was written by John P. Bluemle. Reports on groundwater basic data and on the hydrology of the two counties are also available. The new report describes the subsurface and surface geology, geomorphology, geologic history, and economic geology of Renville and Ward Counties. It emphasizes the stratigraphy of the near-surface glacial deposits in the two counties.

This report on Renville and Ward Counties should be useful to anyone interested in knowing more about the physical nature of the materials underlying the area. Such people may be water-well drillers or hydrologists interested in the distribution of sediments that have potential to produce usable groundwater; civil engineers and contractors interested in such things as the gross characteristics of foundation materials at possible construction sites, criteria for selection of and evaluation of waste disposal sites, and locations of possible sources of borrow material for concrete aggregate; industrial concerns looking for possible sources of economic minerals; residents interested in knowing more about the area; and geologists interested in the physical evidence for the geologic interpretations.

This bulletin is one of a series of studies being published by the North Dakota Geological Survey and the North Dakota State Water Commission with input from the United States Geological Survey and with the cooperation of the various counties involved. The county studies have generally been published in three parts. Part 1 describes the geology of the county or counties included in the study, Part 2 is a detailed compilation of basic data on the groundwater, and Part 3 is a description and evaluation of the groundwater resources. Parts 2 and 3 have already been published for Renville and Ward Counties. With the publication of this report, only one county geologic report remains to be completed, the report on Dunn County, which we hope to publish next winter.

A colored geologic map of the two counties, drawn at a scale of a half inch to a mile, is included with the report. The report can be obtained without charge from the North Dakota Geological Survey.

"Catalog of Dry Hole Drill Stem Tests: McKenzie County, North Dakota," and **"Catalog of Dry Hole Drill Stem Tests: Billings County, North Dakota,"** were complied by the North Dakota Geological Survey staff. These two publications are compilations of drill stem tests from originally unsuccessful wildcat wells drilled in McKenzie and Billings Counties. A considerable amount of information is included in the listings. Wells are listed according to location: township-range-section. The listing includes ground-level elevation, KB elevation, well name, well number, and operator. DST information is listed by test number (many wells have multiple DST's).

A considerable amount of information is included in the drill stem test listings. It includes (but is not limited to) date tested, formation and interval tested, total depth, bottom hole temperature, type of test, water loss, gas-oil ratio, API oil gravity, and specific gravity of gas. Flows and shut-in times are given along with information on whether gas, oil, or water flowed to the surface. Various pressures are listed (initial hydrostatic, initial flowing, second and third shut-in and flowing, etc.). Sampler pressures, volume of samples, extrapolated pressures and a variety of other kinds of information are also included in the listings.

The McKenzie County report is 231 pages long and the Billings County report is 113 pages. The reports are available from the North Dakota Geological Survey for $5.00 each.

Report of Investigation 88 "An Overview of Devonian Duperow Formation Production, Billings County, North Dakota," was written by Randolph B. Burke. This publication deals with the geology, structure, and oil-production and economic potential of the Duperow Formation in the Billings Anticline area. The Duperow Formation is the second largest producer of hydrocarbons in North Dakota. The report includes production curves for wells that have produced from the Duperow in the area, an isopach and geologic structure map, and statistics on oil and water production from the formation. Also included are four illustrations, inserted as separate plates in the back of the publication.

This report is available from the Survey for $2.00.

<u>Report of Investigation 89</u> **"A Synoptic Overview of the Bakken Formation in Portions of Billings, Golden Valley, and McKenzie Counties, North Dakota,"** was written by David W. Fischer and Marvin E. Rygh. This report is intended to serve as an introduction to the Bakken Formation in the area. Oil exploration activity has recently been focused on the Bakken -- specifically, developing Bakken reserves through horizontal drilling. Considerable interest has been generated in this emerging technology, which has seen significant success in North Dakota, and the information contained in this report should be of interest to anyone involved with it. The report is 14 pages long.

Report of Investigation 89 is available from the North Dakota Geological Survey for $1.00.

FIELD OPERATIONS

Doren Dannewitz

The Oil and Gas Division of the North Dakota Industrial Commission has had field inspectors since shortly after the discovery of oil and gas in 1951. Of course, these personnel were employed by the North Dakota Geological Survey until July, 1981, when the Oil and Gas regulatory staff were incorporated under the direct control of the Industrial Commission.

There are presently three field offices. The Williston office has been in existence since approximately 1952. We added offices in Dickinson and Minot in 1981 to accommodate the added work load of recent years.

Possibly the best way to describe a field inspector's duties and responsibilities is to refer to him as "The Policeman of the Oil Patch." The vast majority of the time is spent in the field following activity from permitting to drilling, completing, production and final plug and abandonment and reclamation of a well site. Probably one of the most challenging aspects of enforcing the Industrial Commission's rules and regulations in the field is getting to know the "Operators" and working with problems which arise periodically between them and landowners.

We presently have eleven field personnel associated with the three field offices and will introduce them, their respective "Alma Maters" and dates of employment.

Williston:

Ellis Haake, District Supervisor, University of North Dakota, 1969.
Tom Delling, University of North Dakota, 1981.
John Axtman, Minot State University, 1981.
Kelly Triplett, Minot State University, 1989.

Dickinson:

Bruce Juenker, District Supervisor, Michigan State University, 1981.
Rich Hutchens, Iowa State University, 1981.
Mark Bohrer, University of North Dakota, 1987.

Minot:

Bob Garbe, District Supervisor, Minot State University, 1979.
Jim Dufty, Central Michigan University, 1980.
Jon Johnson, University of North Dakota, 1981.
Greg Steiner, North Dakota State University, 1988.

We are fortunate to have a fine bunch of people to work with in the field. Close communication with our office here in Bismarck compliments the organization's entire operation.

HISTORICAL AND STRATIGRAPHIC REVIEW OF OIL DEVELOPMENT IN NORTH DAKOTA

Kelly Carlson

Exploration History

Oil development in North Dakota may be divided into two major cycles of activity. Each cycle was influenced by external forces superimposed on exploration success within the state. The first cycle began with the discovery of the Beaver Lodge Field by the Amerada Petroleum Corporation - Clarence Iverson No. 1 well in April, 1951. Oil prices in North Dakota during the first cycle were generally in the $2 to $3 per barrel range. They reached $3.50 a barrel near the end of the first cycle, which ended late in 1973 with the Arab oil embargo and its accompanying abrupt, upward price changes.

The second cycle of activity began with "old" oil at $5.25 a barrel and "new" oil at $12 a barrel. Prices since 1981 have been decontrolled and have followed worldwide prices. In North Dakota, this meant $38 a barrel briefly in 1981, followed by a slide to $28, and then to $25 per barrel by 1985. The price plunged to $10 a barrel in 1986.

Activity during the first cycle peaked in 1958 with 454 completions (fig. 1). In 1959 a total of 266 producing wells were completed. Production reached 27.1 million barrels of oil in North Dakota in 1966. Several pulses of exploration activity occurred during this cycle. The initial surge saw increased activity through 1954. Steady successes were recorded along the Nesson Anticline and initial discoveries in Bottineau County in 1953. Widespread exploration occurred in eastern North Dakota in 1954. This activity, which was unsuccessful, refocused exploration priorities to areas where there had been previous success. Increased activity and success in 1957 and 1958 reflected development in the Burke to Bottineau County area. Producers completed between 1953 and 1957 resulted from steady development of Madison reservoirs along the Nesson Anticline. The 1959 peak for producing wells completed reflected full development of Madison reservoirs along the Nesson Anticline. After early development, production capacity along the Nesson Anticline exceeded the capacity of the

Mandan Refinery until November of 1965. Consequently, production in that area was restricted and the production peak for the first cycle was delayed until 1966. The surge in wildcat wells in 1968 and 1969 reflected a widespread search for Cretaceous Newcastle ("Muddy") sandstone reservoirs -- a response to the discovery of the giant Bell Creek Field in southeastern Montana. Success ratios declined for exploration during the first cycle from 15.3% for the first three years, to 5.4% for the last eight years, with an overall success ratio of 8.8% during the first cycle (fig. 2). Exploration during the first part of the first cycle was concentrated on Mississippian Madison or shallower reservoirs with the average depth of wells decreasing from 8,000 feet in 1952, to less than 6,000 feet by 1965. Exploration and development of Ordovician Red River and Pennsylvanian Tyler reservoirs in southwestern North Dakota during the latter stages of the first cycle resulted in increased depths, except for wells drilled as part of the Cretaceous play in 1968 and 1969.

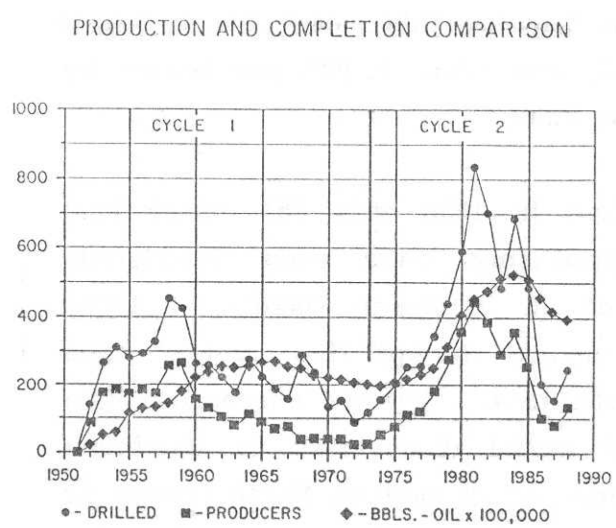

Figure 1

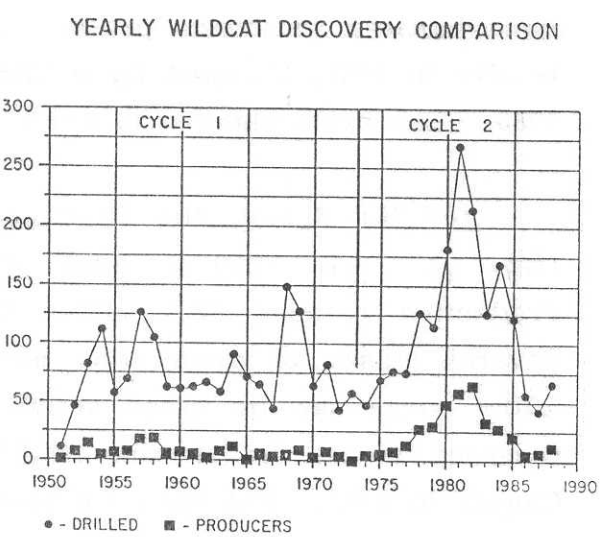

Figure 2

Fig. 1. Graph showing annual fluctuations in wells drilled (circles), producing wells completed (squares), and barrels of oil produced (diamond symbols).

Fig. 2. Graph showing annual wildcat wells drilled since 1950. Circles represent total wells drilled; squares represent producers.

During the second cycle, drilling peaked at 834 completions and 453 producers in 1981. Production reached about 52.6 million barrels of oil in 1984. Wildcat drilling peaked in 1981, when 267 wells were attempted. Discoveries peaked at 64 in 1982 (fig. 2). The higher success ratios in the second cycle reflected a number of factors: improved seismic techniques; Red River exploration, which provided multiple uphole possibilities; and higher prices, which allowed smaller reserves to be economic. The average well-depth drilled increased through 1982 -- a result of the Red River emphasis (fig. 3) -- but as prices decreased, deeper exploration slowed.

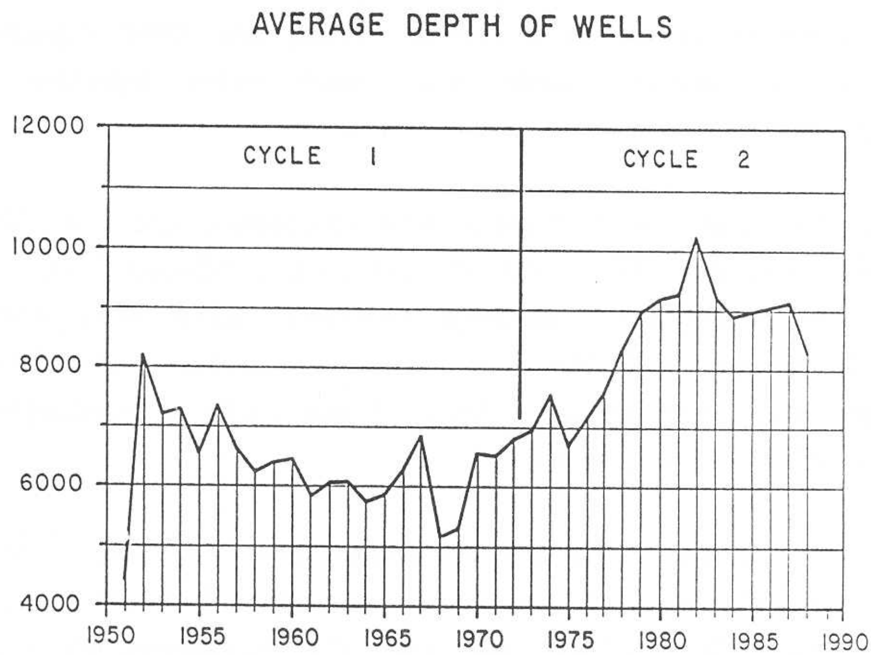

Fig. 3. Average depth of wells drilled in North Dakota since 1950. Note the significant difference between depths during Cycle 1 and Cycle 2.

A comparison of exploration success during the two cycles shows nominal success ratios of 20.3% during the second cycle, compared to 8.8% during the first cycle. However, if the quality of the discoveries, based on estimated ultimate recovery of hydrocarbons is considered, and the classification of the American Association of Petroleum Geologists is used, then the comparison is not so favorable. Eighty-one of the 151 wildcat producers discovered during the first cycle and 84 of the 358 wildcat producers discovered during the second cycle found at least one million barrels of oil. Three of the 5 Class A pools in North Dakota, 4 of the 5 Class B pools, and 21 of the 34 Class C pools were found during the first cycle and much of that success was during the first decade of exploration, during the 1950's (table 1).

Stratigraphic Review

Six of North Dakota's ten largest oil pools are located along the Nesson Anticline. Five of these were found during the first exploration cycle. Eight of the ten largest pools have used water injection to enhance cumulative production (table 1).

Most of the Paleozoic carbonate and sandstone units in North Dakota have produced oil, but 99% of the oil has been produced from nine horizons (fig. 4). The Mississippian Madison reservoirs have been primary targets through both cycles and these account for nearly two-thirds of North Dakota's cumulative production. Most of the Madison production has been from the Frobisher-Alida Interval.

Production from the Spearfish Formation has been limited to an area in central Bottineau County. In that area, sandstone is present at the base of the Spearfish redbeds, and in some areas this sandstone lies unconformably on the Madison Formation at depths of about 3,000 feet. Because many of the wells are perforated in both the Spearfish and Madison Formations, some of these pools are listed as Spearfish-Madison Pools. The Newburg Pool was developed between 1957 and 1959, was unitized in 1967, and has been a successful secondary recovery unit, accounting for about two-thirds of the production credited to these reservoirs.

POOL	DISCOVERY	(1-1-89) CUM. PROD.	(1988) PRODUCTION
CLASS A			
Tioga-Madison	1952	56.708*	.273
Little Knife-Madison	1977	50.861	3.017
Beaver Lodge-Madison	1952	50.832*	.125
Beaver Lodge-Devonian	1951	49.829*	1.295
Big Stick-Madison	1979	39.365*	1.034
CLASS B			
Blue Buttes-Madison	1955	30.745*	.498
Newburg-Spearfish-Madison	1955	26.676*	.542
Charlson-Madison	1952	23.546*	.401
Dickinson-Tyler	1958	23.268*	.562
Charlson-Interlake	1977	13.246	.878
CLASS C			
Glenburn-Madison	1958	18.565	.401
Sherwood-Madison	1958	16.125	.350
North Tioga-Madison	1957	15.880*	.125
Antelope-Madison	1956	15.693*	.159
Fryburg-Tyler	1954	15.310*	.322
Cedar Creek-Red River	1960	14.564*	.370
Rival-Madison	1957	14.133*	.097
Hawkeye-Madison	1955	13.349*	.068
Mondak-Madison	1976	12.624	.338
Rough Rider-Madison	1959	11.718	.821
Capa-Madison	1953	11.621*	.036
Wiley-Madison	1958	11.344	.266
Antelope-Bakken	1953	11.257	.139
S. Westhope-Spearfish-Madison	1956	10.790	.203
Redwing Creek-Madison	1972	10.786*	.543
Fryburg-Madison	1953	10.768*	.296
Tree Top-Madison	1979	8.968	.443
Clear Creek-Madison	1958	8.671*	.119
Beaver Lodge-Silurian	1951	8.165	.143
N. Elkhorn Ranch-Madison	1981	7.881*	.488
Elkhorn Ranch-Madison	1974	7.605	.420
Blue Buttes-Interlake	1980	6.648	.603
TR-Madison	1978	6.315	.457
Medicine Pole Hills-RR	1967	5.841*	.278
Indian Hills-Madison	1982	5.438	.665
Charlson-Duperow	1960	5.198	.109
Zenith-Tyler	1968	5.077*	.345
Lone Butte-Madison	1981	4.331	.533
Whiskey Joe-Madison	1979	3.815	.463
Glass Bluff-Madison	1982	3.006	.372
Elkhorn Ranch-Bakken	1961	2.297	.381
Knutson-Madison	1983	2.254	.460
East Fork-Madison	1984	2.054	.614

Table 1. Listing of Class A, B, and C oil pools including year of discovery, cumulative production as of January 1, 1989, and total 1988 production in millions of barrels (thus, the Tioga-Madison Pool produced 273,000 barrels of oil). Asterisk denotes fields where water injection is or has been used.

The Pennsylvanian Tyler Formation occurs throughout most of southwestern North Dakota. Production has been from channel sandstones at the Rocky Ridge Field and from offshore bar sandstones from the Medora to Dickinson area. These reservoirs occur at depths of 7,500 to 7,800 feet. The largest of these pools, the Dickinson Pool, was fully developed by 1970, was unitized in 1973, and has been a successful secondary-recovery unit.

The Bakken Formation (Devonian-Mississippian) occurs in much of western North Dakota. The initial production and the largest pool has been referred to as the Antelope-Sanish Pool because, in the Antelope area, a sandstone occurs beneath the lower black shale. This sandstone is known as the "Sanish Sand." Since its discovery in 1953, development of the Antelope Field has resulted in production from the Devonian Three Forks Formation, as well as from the Bakken.

FM.	MBO	%
SP/MAD.	39.2	4.0
TYLER	59.7	6.2
MADISON	623.9	64.6
BAKKEN	18.2	1.9
DUPEROW	94.8	9.8
WINNIPEGOSIS	4.1	.5
INTERLAKE	40.3	4.2
STONEWALL	4.3	.5
RED RIVER	76.9	8.0

Fig. 4. Nine main oil-producing horizons in North Dakota. Figures given as millions of barrels of oil and percentage of total production. These nine formations account for 99 percent of North Dakota's oil production. The Madison has produced 623.9 million barrels or 64.6 percent of the oil.

Exploration began in the late 1970's near the southwest limit of the Bakken Formation. Reservoirs discovered since that time have been marked by high pressures, little or no water, and gradual decline rates. This area has become the focus for evaluation of horizontal drilling techniques since the 1987 completion of a horizontal wellbore in the Elkhorn Ranch Field. That well was completed in September, 1987. Through 1988, it produced 109,680 barrels of oil and 258 barrels of water. The upper Bakken shale has been the major target.

Minor quantities of oil have been recovered from sandstones of the Black Island and Deadwood Formations. As a result, clastics account for 8 to 12 percent of the production, (depending upon how much of the Spearfish-Madison production is assigned to sandstone of the Spearfish Formation).

Development of Madison reservoirs began along the Nesson Anticline where these reservoirs range from about 7,800 feet at the north end to 9,500 feet at the south end. The initial development in Bottineau County was from stratigraphic traps at the unconformity with the overlying Mesozoic strata. Subsequent exploration has been largely combination structural-stratigraphic accumulations where facies changes from porous carbonates to updip evaporites or dense carbonates are associated with slight flexures in the area from Bottineau to Burke County. These reservoirs are at depths of 3,000 feet in Bottineau County and progressively deeper westward to 6,000 to 7,000 feet in Burke County. The major Madison development in the southwestern area was during the second cycle, highlighted by the discovery of the Class A Little Knife and Big Stick Fields. Reservoirs in this area are at depths of 9,000 to 9,100 feet at the limit of production and about 9,800 feet at Little Knife. These reservoirs also appear to be combination structural-stratigraphic accumulations.

Secondary recovery operations in Madison reservoirs have given mixed results. Generally, units in Burke County and the northern portion of the Nesson Anticline did not perform as projected and secondary recovery operations were discontinued. Units along the southern portion of the Nesson Anticline and other areas have shown varying degrees of success. A combination of water and nitrogen injection was used in the Clear Creek Unit to exceed preliminary projections.

Production from the Duperow has been from numerous small accumulations in the central basin. These reservoirs, which were found primarily during the second cycle, occur at depths ranging from about 8,500 feet in Divide County, to 11,500 feet in Dunn County. Rapid porosity changes indicate that most of these reservoirs are combination structural-stratigraphic traps.

The Beaver Lodge Field accounts for more than half of the Duperow production. This field was developed on a 320-acre spacing pattern from 1957 through 1959. It was unitized in 1962. In 1973 an infill-drilling program which added injectors in the central part of the field began. A primary recovery of about 24.1 million barrels of oil was estimated. Current production (December, 1988) of about 3,400 barrels of oil per day, with cumulative recovery of nearly 50 million barrels, makes it likely that the projected 61.5 million barrels for ultimate recovery will be attained.

Production credited to the Interlake Formation is primarily from the upper part of the upper member in reservoirs that occur at depths of 11,000 to 11,500 feet along the Nesson Anticline. Early development was in the northern part of the Anticline, while the southern part has seen most of its development in the second cycle.

Red River Formation production is found throughout the western tier of counties. The first significant production and the largest Red River Field, the Cedar Creek Field, extended production from these strata in Montana into North Dakota in 1960. Most of the smaller fields on the east flank of the Cedar Creek Anticline in Bowman County were found in the late 1960's and early 1970's. Reservoirs in this area are found at depths of about 8,000 feet. Most of the development west of the Nesson Anticline was during the second cycle and was concentrated during the time when oil prices exceeded $27 a barrel. Depths there range to 14,000 feet.

The Cedar Creek Field is the largest of the Red River Pools. It has been a relatively successful water-injection secondary recovery unit. The Medicine Pole Hills Field was unitized in 1985 for a fireflood project. The price decline delayed injection until October, 1987. A productive response began in August, 1988, so it appears that this will be a successful project.

GEOLOGIC SIGNS INSTALLED

John Bluemle

A total of 17 signs describing the geology of North Dakota were recently placed in rest areas around North Dakota. This was an officially sanctioned North Dakota Centennial project, with funding from the North Dakota Geological Society and the Centennial Commission and input from the North Dakota Geological Survey. Dr. Eric Clausen, science professor at Minot State University, and I provided the text and illustratory material for the signs. Most of the signs were installed by members of the Geological Society with the remainder installed by Highway Department personnel. Each sign describes the geology in the area in which it was placed with maps and diagrams to help the traveller understand the geology.

The signs were placed as follows:

1. Alexander Henry rest area on I-29 near Drayton
2. Casselton rest areas on either side of I-94 (two signs)
3. Oriska rest area on I-94
4. Glen Ullin and Hebron rest areas (two signs)
5. Camel Hump rest area near Beach (two signs)
6. Rest area on U.S. Highway 85 north of Alexander
7. Rest area at junction of U.S. 2 and N.D. 18 near Larimore
8. Hefti rest area on U.S. 2 east of Devils Lake
9. Pleasant Lake rest area on U.S. 2 east of Rugby
10. Norwich rest area on U.S. 2 east of Minot
11. Rest area north of Edgeley on U.S. 281
12. Rest area one mile west of Sykeston on U.S. 52 and N.D. 2
13. White Earth River valley on U.S. 2 west of Stanley

Be sure to look for the signs as you travel around North Dakota!

THE F. D. HOLLAND SYMPOSIUM: AN OVERWHELMING SUCCESS

John W. Hoganson

The Geological symposium held in honor of Prof. F. D. ("Bud") Holland, Jr., which I mentioned in the last NDGS Newsletter, was an overwhelming success. The event, in recognition of Bud's 35 years of distinguished service to the University of North Dakota, was held in Leonard Hall, UND campus, on April 14, 1989.

Festivities began on the evening of April 13 with an informal reception in the museum area of Leonard Hall. The symposium convened at 9:00 a.m. on April 14 with introductions by Dr. Thomas J. Clifford, UND president, Dr. Frank R. Karner, UND geology department chairman, and Dr. J. Mark Erickson, St. Lawrence University geology department chairman and one of Bud's former students. Fifteen presentations by Bud's former students and colleagues, concerning the results of their current geological research, were given during the remainder of the symposium. Eleven of the presentations dealt with research conducted in North Dakota. The resulting articles will be published in a symposium volume by the NDGS this fall.

Over 125 people registered for the symposium although at different times during the day it was obvious that many more people were in attendance. This was especially true during the keynote address at noon by the renowned dinosaur expert, Dr. John R. Horner, who presented a talk on "Transgression, Regression, and Evolution of Dinosaurs." During that presentation, the Leonard Hall lecture bowl, with a seating capacity of over 200, was completely filled. Participants travelled here from all parts of the U.S. and included many of Bud's 20 former masters students and 8 of his 9 doctoral students. One of the highlights of the event was a special surprise recognition ceremony during which the UND geological library was renamed in Bud's honor; it is now the F. D. Holland, Jr. Geological Library. At the conclusion of the symposium, a reception was held in the F. D. Holland, Jr. Geological Library, where a large plaque with Bud's portrait was unveiled. The plaque will be mounted in the library.

The annual Sigma Gamma Epsilon banquet topped off the event. Dr. Horner gave an exciting and, at times, animated speech about dinosaur ecology. In recognition of his many years as advisor to Sigma Gamma Epsilon, Bud was presented with a 15-foot-long mounted mural depicting mammal evolution. The mural will be displayed in Leonard Hall. Dr. John Bluemle also presented Bud with a plaque in behalf of the North Dakota Natural Science Society for his many years of involvement with that organization. The banquet ended with a slide show of pictures (many of Bud in compromising positions) taken over the years on field trips organized by Bud.

As co-conveners of the symposium, J. Mark Erickson and I would again like to take this opportunity to thank those who participated and attended the event and the many people who made the symposium a success. If you are interested in obtaining a copy of the symposium volume, please contact me.

North Dakota's landforms can be broadly grouped into two categories: erosional and depositional. Most of the topography in the southwestern part of the state is the result of erosional processes -- the action of wind and running water -- that operated apart from the action of glaciers or processes directly related to glaciation. The southwestern North Dakota landscape formed over a long period of time -- hundreds of thousands of years. Some of the upland surfaces in parts of southwestern North Dakota may be over a million years old. On the other hand, most of the landforms in northern and eastern North Dakota were shaped by glacial ice and by water associated with melting glacial ice (by water flowing in rivers and streams and eroding large valleys, by running water transporting massive amounts of gravel and sand, and by water ponded in lakes on and in front of the glacier forming shore features and depositing flat-lying beds on the lake bottoms). Most of the landforms found in the glaciated areas date back only to the late Pleistocene, mainly to the Late Wisconsinan glaciation, which ended about 12,000 years ago. Earlier glaciers also played an important role in shaping the landscape, although the changes they wrought are largely indirect, insofar as the modern landscape is concerned. All of North Dakota probably drained to Hudson Bay before the first glaciers advanced into the state. The routes of these preglacial rivers in eastern North Dakota were changed by the early glaciers and their valleys were filled with glacial sediment.

The portion of North Dakota southwest of the Missouri River is known as the Missouri Plateau (figure 1). Although some parts of the Missouri Plateau near the Missouri River were glaciated, in most places the only visible evidence of glaciation is an occasional boulder or thin patch of glacial sediment. The Missouri Plateau is an extension of the Great Plains, which slope eastward, away from the Rocky Mountains in Montana and Wyoming. The landscape throughout this vast region is largely the result of erosion, during Late Tertiary time, of flat-lying beds of sandstone, shale, and lignite (primarily the Fort Union Group deposits). These sediments

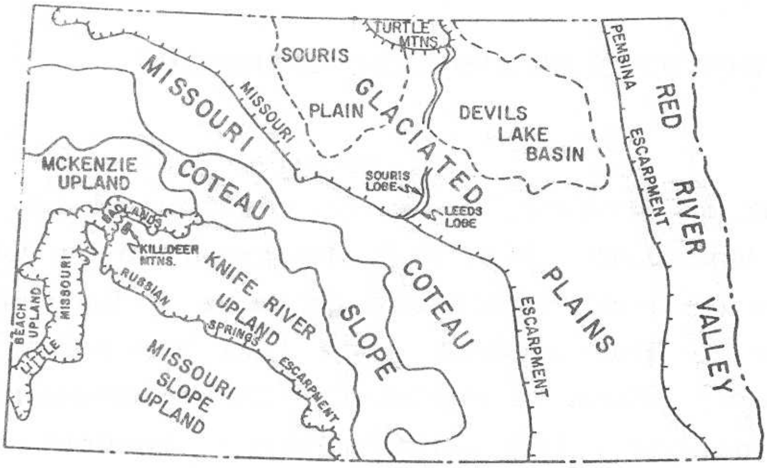

Figure 1. Map identifying the various physiographic regions generally recognized in North Dakota. Even though considerable individual variations characterize the landforms that occur within each region, overall internal similarities make it possible to generalize about the geomorphic processes that operated to shape each region. The original version of this map was drawn by Lee Clayton. I've modified some of the northern and eastern areas from Clayton's original map. The double line south of the Turtle Mountains shows the boundary between the two main Late Wisconsinan glacier lobes, the Souris lobe, which flowed around the west side of the Turtle Mountains, and the Leeds Lobe, which flowed around the east side of the Turtle Mountains. The term "gently sloping" in the above explanation refers to areas that have slopes of less than 8 percent. Local relief is defined as the maximum difference in elevation within any township-sized area.

EXPLANATION

CENTRAL LOWLAND (EAST OF THE MISSOURI ESCARPMENT)

Red River Valley: Flat plain resulting from sedimentation on the floor of glacial Lake Agassiz; more than 95 percent of the area is gently sloping with local relief less than 25 feet in most places.

Pembina Escarpment: Steep, glacially-modified escarpment that marks the boundary between the Red River Valley and the Glaciated Plains.

Glaciated Plains: Rolling, glaciated landscape; more than 80 percent of the area is gently sloping with local relief generally less than 100 feet in most places, but ranging up to 100 to 300 feet in some places.

Devils Lake Basin: Closed drainage basin with drainage to Devils Lake; topography is mainly typical of the Glaciated Plains.

Souris Plain: Flat to gently sloping plain resulting from sedimentation on the floor of glacial Lake Souris; the surface has been considerably modified by wind action.

Prairie Coteau and Turtle Mountains: Hummocky, glaciated irregular plains that resulted from collapse of superglacial sediment; gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 300 to 500 feet.

Missouri Escarpment: Steep, glacially-modified escarpment that marks the boundary between the Glaciated Plains and the Missouri Coteau.

Missouri Coteau: Hummocky, glaciated irregular plains that resulted from collapse of superglacial sediment; gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 100 to 300 feet.

GREAT PLAINS (WEST OF THE MISSOURI ESCARPMENT)

Coteau Slope: Rolling to hilly plains east of the Missouri River that have both erosional and glacial landforms; gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 300 to 500 feet.

Missouri Slope Upland: Rolling to hilly plains except in badlands areas and near prominent buttes; gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 300 to 500 feet; upland surface is generally 200 to 400 feet higher than the Knife River Upland and McKenzie Upland and slopes upward to the west.

Knife River and McKenzie Uplands: Rolling to hilly plains except in badlands areas and near prominent buttes; evidence of glaciation near the Missouri River; gentle slopes characterize 50 to 80 percent of the area and local relief ranges from 300 to 500 feet.

Little Missouri Badlands: Rugged, deeply eroded, hilly area along the Little Missouri River, gentle slopes characterize 20 to 50 percent of the area and local relief is commonly over 500 feet.

have been modified by the formation of clinker (natural brick baked by burning underground coal seams; see article in December, 1988 Newsletter), and by mineral-rich groundwater, which formed layers of silcrete, petrified wood, concretions, and nodules of varying sizes and shapes. It was secondary processes such as these that resulted in the differences in lithification and durability of the various sediments to erosion and weathering. The shapes of individual landforms in the Missouri Plateau region are most notably the result of the differences in resistance of the near-surface materials to erosion by wind and running water.

The carving of the Little Missouri River badlands began during Pleistocene time when the river was diverted by glaciers from its northerly route into Saskatchewan. As a result of this diversion, which first occurred about 750,000 years ago, the Little Missouri River was forced to flow eastward over a shorter, steeper route, resulting in a cycle of vigorous erosion that continues today.

In eastern and northern parts of North Dakota, depositional glacial and glaciofluvial landforms predominate. The overall aspect in this area is one of closely spaced hills and valleys, which have lower overall relief than do the landforms in the unglaciated "wide-open spaces" of southwestern North Dakota, where large buttes and broad, gently sloping areas are found. The unglaciated areas are also well drained. This contrasts with the glaciated parts of the state, where drainage ranges from completely unintegrated in places to areas where only poorly developed stream systems have developed. Landforms throughout the glaciated parts of North Dakota are the result of depositional processes that operated over a drastically shorter period of time than did the erosional process in unglaciated areas. Although some important erosional features, such as certain meltwater trenches, are found in the glaciated areas, most of the topography is the result of relatively small-scale reshuffling by the ice of the materials it flowed over. A layer of reworked sediment, some of it transported great distances, but most of it locally derived, completely changed the overall aspect of the landscape during Quaternary time. This layer of glacial sediment, which reaches thicknesses as great as 750 feet in Sheridan County in central North Dakota, contains a mix of minerals, making possible extremely rich soils, in contrast to the poorer soils developed on some of the Cretaceous and Tertiary marine sandstone and shale formations found farther west and south in unglaciated areas.

The glaciated part of North Dakota can be logically subdivided into four major physiographic areas (figure 1). These are: 1) the Coteau Slope, an area adjacent to and northeast of the Missouri River where glacial deposits are thin and the topography has been only slightly modified by glacial processes; 2) the Missouri Coteau (along with the Turtle Mountains and Prairie Coteau), where glacial stagnation processes predominated; 3) the Glaciated Plains, an area where large scale glacial thrusting, coupled with deposition due to ablation by the glacier, resulted in an intricate glacial landscape; and 4) the Red River Valley, an exceptionally flat area that is largely the surface expression of the glacial Lake Agassiz.

ESKERS IN NORTH DAKOTA

John Bluemle

The word "esker" is apparently derived from an Irish Gaelic word, "eiscir" meaning "ridge." Eskers are ridges that mark the routes of streams and rivers that flowed in tunnels at the bottom of the glacier and in cracks in the glacier. Most eskers are composed of stream sediment, mainly gravel and sand. In places, the streams flowed on solid ground and in other places their beds rested on top of the glacier ice. The materials the streams deposited in their channels can be seen today as long, winding esker ridges. Eskers may be more than 100 feet high, a few hundred feet wide, and a few miles long. Some eskers have nearly level crests, indicating that the streams that formed them flowed entirely on solid ground. Other eskers are uneven on top, suggesting that the streams flowed over glacial ice in places. When the ice beneath the stream beds melted, the overlying gravel slumped, resulting in irregular, sometimes discontinuous features.

Typically, the gravel found in eskers is coarse and contains layers and lenses of silt and clay. The gravel is typically poorly sorted with fine and coarse materials mixed together so that the quality of the gravel is usually not suitable for construction purposes. One of the reasons for this is that, while the glacier was melting, debris contained in the ice melted out and slid, in the form of mud flows, into the streams, becoming mixed with the stream sediment. Cobbles and boulders also slid off the ice into the streams. These can be seen today, mixed in with the stream sediment and littering the surfaces of the eskers. When the glaciers finally melted completely, the gravel, along with all the materials mixed with it, remained as esker ridges standing above the surrounding areas. Thousands of boulder-strewn eskers can be found today in the parts of North Dakota that were glaciated.

The most prominent esker in North Dakota is the Dahlen Esker, which is located about midway between Fordville and Dahlen in the northeastern part of the state (figs. 1 and 2). It is four miles long, about 400 feet

Fig. 1 & 2. Two views of the Dahlen Esker, in Grand Forks, Nelson, and Walsh Counties, about mid-way between Fordville and Dahlen. The upper, air view shows a portion of the four-mile-long, 400 foot-wide esker ridge. The esker ridge has a generally accordant crest level, but the crest appears irregular because of numerous minor gaps.

The lower photo shows the ridge, taken from a vantage on the crest of the esker itself.

wide, and ranges from 50 to 80 feet high. The Dahlen esker has a generally accordant crest level, although the crest appears to be irregular because of numerous minor gaps. These gaps, accentuated and modified by modern stream erosion, were probably formed while the esker was being deposited. They could have formed by collapse of sediment as the underlying glacial ice melted. A mixture of sand, gravel, glacial sediment and boulders occurs in the Dahlen Esker. The sand and gravel are extremely shaly, making them practically useless for construction purposes.

The Dahlen Esker was deposited by a meltwater stream flowing in an ice-walled channel, most likely a tunnel, near the base of a stagnant zone near the edge of the glacier. The stream flow was probably from east to west, toward the margin of the glacier. The stream-flow direction, although suggested mostly by the position of the glacier margin, may be indicated by a kame near the northeast end of the esker; the kame may mark the point where water flowed from the surface of the glacier through an opening to a tunnel or ice-walled channel.

Eskers are particularly abundant in certain parts of North Dakota. Large numbers of them are found in association with areas of hummocky collapsed topography, which formed when broad, debris-covered portions of the glacier stagnated. Eskers are also commonly found in association with areas of ice-thrust topography. These eskers apparently formed when large amounts of ground water were released during the thrusting process. As this water flowed upward from beneath the ground to the base of the glacier, it carried gravel and sand, which it deposited in tunnels at the base of the ice as it made its way to the edge of the glacier.

One area where eskers are particularly abundant is in Towner County, east of the Turtle Mountains. Hundreds of small esker segments are found in that area, along with a few larger ones. An especially well developed esker system extends from north to south through central Towner County, (fig. 3). When viewed on aerial photographs, it can be seen that the eskers in this system, which appear as light-colored lines, are crisscrossed by numerous thin, black lines. These black lines are bison trails, formed over a period of time by herds of animals crossing the ridges.

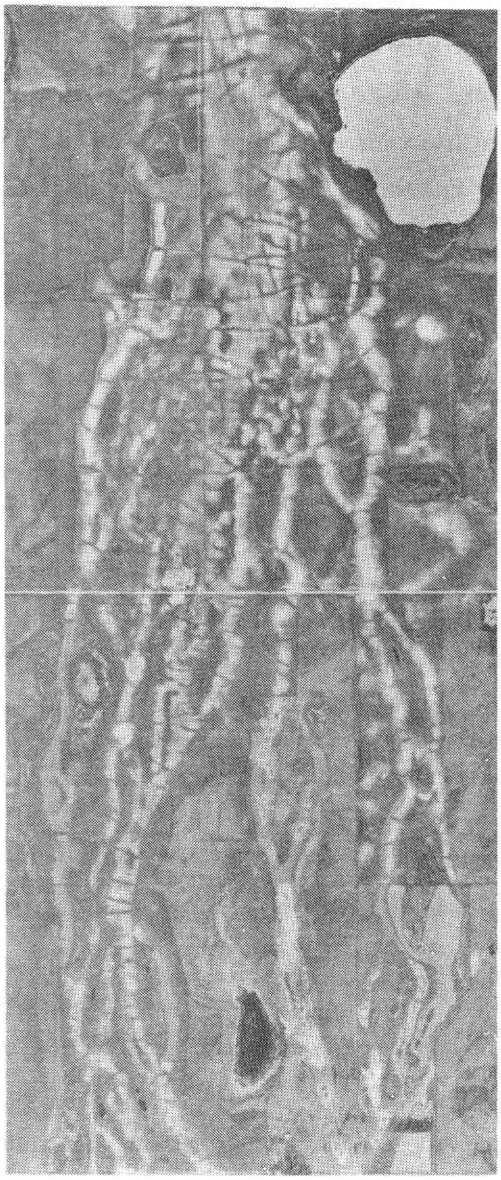

Fig. 3. Air photo of a branching esker system in south central Towner County, about six miles north of Cando. Eskers are discussed later in this report; the purpose of including this photo here is to illustrate how bison trails appear on photos. The eskers are the light-colored, generally north-south trending irregular lines; the bison trails are the narrow black lines that tend to cross the eskers at right angles, or nearly so. The area shown on this photo is 0.8 mile wide and the photo is positioned with south to the top of the page so shadows fall away from the reader, preventing the illusion of negative relief (ridges appearing as grooves, etc.).

Other notable eskers and esker systems occur about ten miles southwest of Pekin in southwestern Nelson County (fig. 4), near Benedict in northeastern McLean County, about ten miles southwest of Carrington in Foster County, east of Dazey in Barnes County, and in northern Sheridan County (fig. 5). The esker in Sheridan County is an example of one that formed when large amounts of water were released at the same time that glacial thrusting was taking place. This esker stands 40 to 60 feet above the level of surrounding Frankhauser Lake and extends about four miles through an area of ice-thrust topography. The esker is situated in a broad depression left when the southeast-flowing glacier thrust a large (three-square mile, 200-foot-thick) block of material a short distance.

I've mentioned only a few of the more prominent eskers in North Dakota. Hundreds -- probably thousands -- of smaller eskers can be found throughout the glaciated parts of the state. Many of them are shown on the geologic maps included with the various county geologic studies published by the North Dakota Geological Survey, but many more were just too small to show on the geologic maps.

Fig. 4. Air view of Forde eskers in southwestern Nelson County about ten miles southwest of Pekin. Photo by Roger Reede.

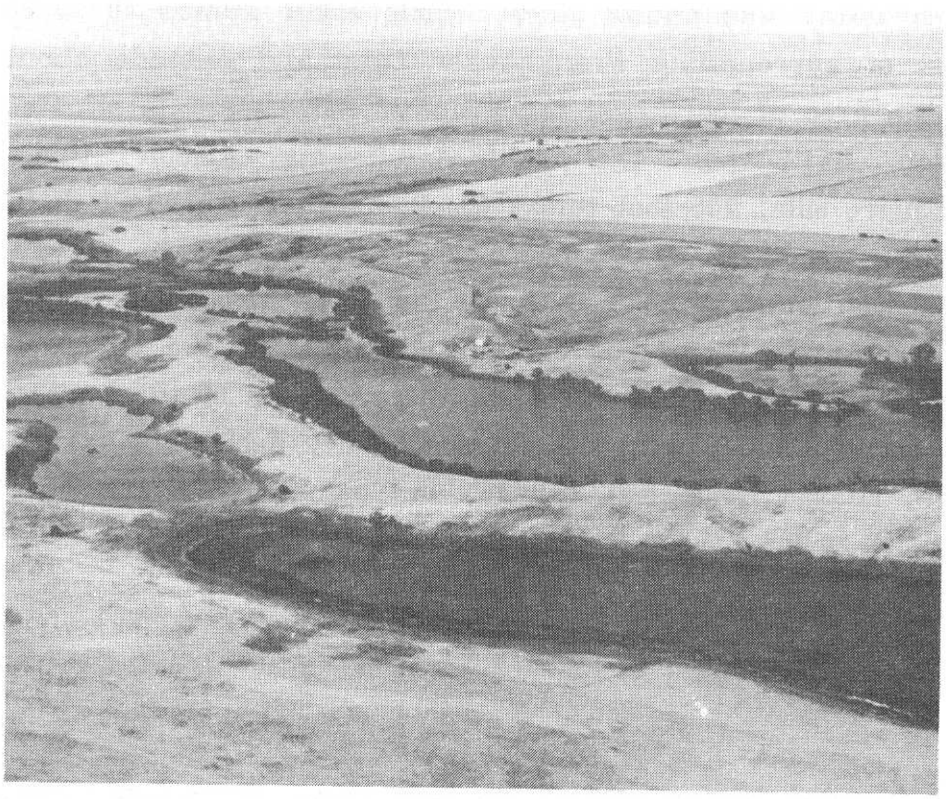

Fig. 5. An esker in northern Sheridan County. This esker stands 40 to 60 feet above the level of surrounding Frankhauser Lake, and extends for about four miles through an area of ice thrust topography. The esker is situated in a broad depression left when the southeast-flowing glacial thrust a large (three-square-mile, 200-foot-thick) block of material a short distance; the ice-thrust material is located immediately to the right of the area shown on this photo. The esker may have formed during the thrusting process, during which large amounts of groundwater were released when the ice-thrust block was removed, thereby allowing the water to escape. Similar eskers, formed during the process of "popping the cork" during thrusting, are commonly found in association with ice-thrust terrane.

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 John Bluemle, NDGS Newsletter Editor, North Dakota Geological Survey, 1022 East Divide, Bismarck, ND 58501.

CHECKLIST FOR NEW PUBLICATIONS

See pages six through eight of this Newsletter for descriptions of publications.

_______	Bulletin 50, Part 1 (free)	Geology of Renville and Ward Counties, North Dakota
_______	Drill Stem Tests ($5.00)	Catalog of Dry Hole Drill Stem Tests: McKenzie County, North Dakota
_______	Drill Stem Tests ($5.00)	Catalog of Dry Hole Drill Stem Tests: Billings County, North Dakota
_______	RI-88 ($2.00)	An Overview of Devonian Duperow Formation Production, Billings County, North Dakota
_______	RI-89 ($1.00)	A Synoptic Overview of the Bakken Formation in Portions of Billings, Golden Valley, and McKenzie Counties, North Dakota

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