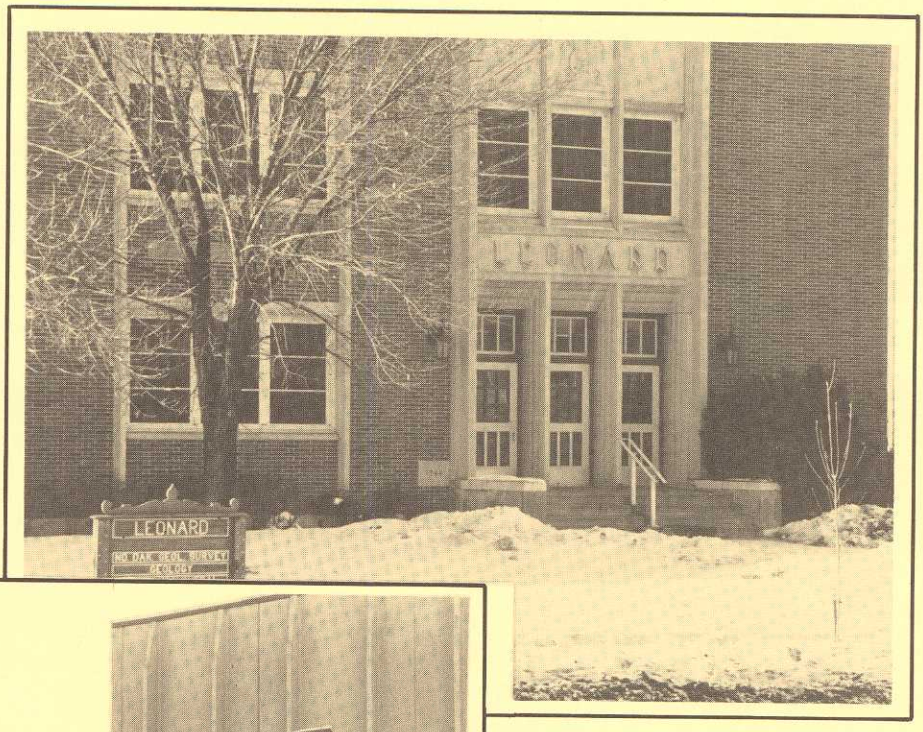
NEWSLETTER

NDGS

John P. Bluemle, Editor



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The North Dakota Geological Survey has its offices on the third floor of Leonard Hall on the University of North Dakota campus in Grand Forks. The Wilson M. Laird Core and Sample Library is located across the street from Leonard Hall.

EDITOR'S NOTE

--John Bluemle

In addition to current topics of interest and background information about the geology of North Dakota, which we normally include in our newsletter, this issue of the NDGS Newsletter contains a series of short articles that describe the duties and responsibilities of the North Dakota Geological Survey. We've done this for several reasons. Many of you are not aware of some of the things we do; we may be able to help individuals and agencies in ways they have not realized before. Another reason for the summaries of our activities is to help our North Dakota legislators understand our agency as they consider our budget during the 1987 legislative session. We have found that, each time the legislature meets, there are new senators and representatives who are not familiar with the North Dakota Geological Survey. Hopefully, some of the information in this newsletter will be useful to them. We have found too, that a periodic reappraisal of our own goals and projects is useful for our own purposes.

As I was compiling this issue of the newsletter and reading through the several articles that were submitted to me by our geologists, certain things became apparent. A number of articles emphasized the fact that the NDGS serves as the principal source of geologic information and advice for problem solving, decision making, and policy setting in North Dakota's natural resources and environmental arenas. Our concerns reflect the major issues of our times because we exist at the (sometimes uncomfortable) boundary of science and public policy, but herein lies our uniqueness, which makes our special contributions possible. We have much to challenge us: many environmental issues; the oil glut, which has led to lower prices and declining North Dakota production; public concern about toxic wastes and paranoia toward everything nuclear; state budget tightening; water and air pollution; and aggravation of geologic hazards by population and industrial expansion.

Fortunately, the North Dakota Geological Survey has the personnel and the programs in place to meet these and other new challenges.

THE ROLE AND RESPONSIBILITIES OF THE NORTH DAKOTA GEOLOGICAL SURVEY

--John Bluemle, Randy Burke, and others

The NDGS was founded in 1895 for the purpose of providing geologic expertise to the citizens and agencies of North Dakota and to help in the efficient utilization of the state's resources. As defined by the legislature at that time, the constitutionally defined responsibilities of the NDGS are as follows:

1. to provide a complete account of the minerals and geology of the state,
2. to collect and preserve such specimens,
3. to determine the economic value and accessibility of the substances, and
4. to prepare maps and reports on the above.

To comply with obligations 3 and 4, the first two responsibilities--data gathering and management--must be met. We collect data and specimens to "determine the value and accessibility of the substances," and the format we most often use to present the results is a map or a report.

Our mission is to understand the geology of North Dakota sufficiently well to be able to provide the expert advice required for proper management of the state's natural resources. The Survey's role as a regulator and as a technical advisor to elected officials of the state is to protect and assist in the development of our natural resources.

As it applies to the NDGS, the term "survey" means the acquisition, recording, and presentation of knowledge of the state's resources. This process does not necessarily require the use of a theodolite, transit, or stadia rod, instruments many people often associate with land surveying. Rather, our evaluation or survey of North Dakota's mineral resources is intended to inform the people of the existence of these sources.

Although it is not actually a part of the University of North Dakota, the NDGS is situated on the UND campus, a practical arrangement both for us and the geology department. At times we are able to hire students to work on specific projects, an arrangement advantageous to both the University and to the Survey. NDGS staff members regularly teach courses in the Geology Department.

Our total staff of 25 employees includes ten geologists and one engineer. NDGS staff members are currently involved in about 50 separate projects. These include:

1. detailed studies of subsurface geology, environments of deposition, depositional history, distribution, and other properties of the subsurface rocks in North Dakota. These studies help us to better understand the geologic conditions governing the occurrence of oil and gas and other mineral resources in North Dakota.

2. oil and gas production and engineering studies concerning oil production, reservoir characteristics, and other topics related to oil production in North Dakota. We can make data available to producers who may be able to devise more efficient recovery methods, as well as potential exploration targets.

3. appraisals of the geology of various counties. Basically a reconnaissance mapping program that has been underway since 1960, our county geologic studies program is almost completed and is being updated by our more detailed one degree latitude by one degree longtitude geologic studies.

4. studies of specific geologic problems and situations that have the potential to cause environmental damage; these studies will help us recommend solutions to the problems.

5. paleontological studies of near-surface fossils with emphasis on excavation of important sites and preservation of certain significant sites.

6. investigations of various paleoclimatic problems with the intent of learning more about North Dakota's paleoclimatic history, especially since the end of the ice age.

7. various geologic studies so we may better understand the state's geologic history, landforms, and economic geology.

The Survey maintains extensive files of basic data on both surface and subsurface geologic data. These include compilations of oil and gas well data and basic subsurface geology. We maintain a library of core and samples that have been taken in wells drilled for oil and gas. These cores and samples are available for study by geologists from industry and academia, as well as by the Survey staff. In addition to our technical publications, which report the results of our research, from time to time the Survey publishes non-technical, educational materials for use in the state's schools and by the public. Survey geologists have always been available to speak to classes and other groups around North Dakota. Since we've found that this service has been in increasing

demand, we recently established an Extension Section (NDGS Extension) to coordinate the topics, speakers, etc. (article in the June, 1986 NDGS Newsletter). NDGS Extension offers a number of technical talks and laboratory exercises to colleges and universities in the state. Some of these topics are also available as non-technical talks to service groups and high school classes and as background for technical sessions in fields other than geology. The response to NDGS Extension has been excellent and our geologists have been giving increasing numbers of talks.

The NDGS provides large amounts of geologic advice and basic data. As we noted earlier, the data is provided mainly in standard formats (maps, cross sections, etc.). A minimal fee is charged for the printed information; however, advice about North Dakota's geology is available from the Survey for the price of a phone call or transportation to our offices. We estimate that over 8,000 calls for advice or information were processed last year, in addition to several hundred office visits by farmers, ranchers, developers, teachers, scientists, federal government personnel, lawyers, industry representatives and others for one-on-one discussions.

THE REGULATORY DUTIES OF THE NDGS

--David Brekke

The North Dakota Geological Survey is charged with a variety of regulatory responsibilities. Our authority to enforce these rules and regulations is granted through the North Dakota Industrial Commission. The basic purpose of all of the rules and regulations is to conserve the natural resources of North Dakota, prevent waste, protect the environment, protect correlative rights, and promote the orderly development of natural resources.

The Office of State Geologist issues permits and requires performance bonds for several natural resource activities. These include the following:

1. exploration and production of subsurface minerals
2. underground injection for solution mining
3. coal exploration
4. exploration and production of geothermal energy
5. underground storage and retrieval of nuclear and other waste material.

In addition to issuing permits, the Survey collects drilling and production data, inspects drill sites and production facilities for compliance with permit conditions, and approves reclamation of the sites. Up to now, all of our regulatory duties have concerned subsurface minerals, underground injection control, and coal exploration. The Survey is also charged with supervising the orders of the Industrial Commission concerning the resolution of conflicts that may arise between developers of oil, gas, subsurface minerals, and coal.

Other statutory responsibilities of the Survey include providing technical geological services to the Board of University and School Lands, to the Oil and Gas Division of the Industrial Commission, and to the Public Service Commission. The Survey is also a member of the Air Pollution Control Advisory Council and the Water Pollution Control Board.

THE NDGS' ADVISORY ROLE IN ENVIRONMENTAL MATTERS

--Ed Murphy

Sanitary Landfills and Special Waste Disposal Sites. Regulatory responsibility for the safe disposal of solid wastes in North Dakota lies with the North Dakota State Health Department. However, the NDGS is required to provide technical advice to the Health Department in assessing permit applications for the construction and operation of waste-disposal facilities in the state (see photo). Permit applications to construct and operate sanitary landfills for the disposal of garbage or special waste sites for the disposal of non-decomposable wastes not generally suitable for disposal in municipal landfills (examples of such wastes are oil and gas drilling mud, low-level radioactive wastes, fly ash, etc.) are forwarded to the NDGS from the Health Department for evaluation. The NDGS determines the geological and hydrogeological suitability of the areas under consideration as disposal sites, that is, whether or not contamination of surface-water or groundwater is likely if the proposed site is developed. Recommendations and comments on the suitability of these sites are passed on to the Health Department.

Surface Coal Mine Permits. Survey geologists review the accuracy of the Geology and Geohydrology sections of surface coal mine permits. Our comments on the permits in these areas are brought to the attention of the Public Service Commission, the state agency that actually issues the permits for coal mining.

Transmission and Pipeline Corridors. Our geologists review the geology of proposed transmission line and pipeline corridors for the Public Service Commission to identify any areas where the geology or geohydrology of a proposed corridor may lead to problems.

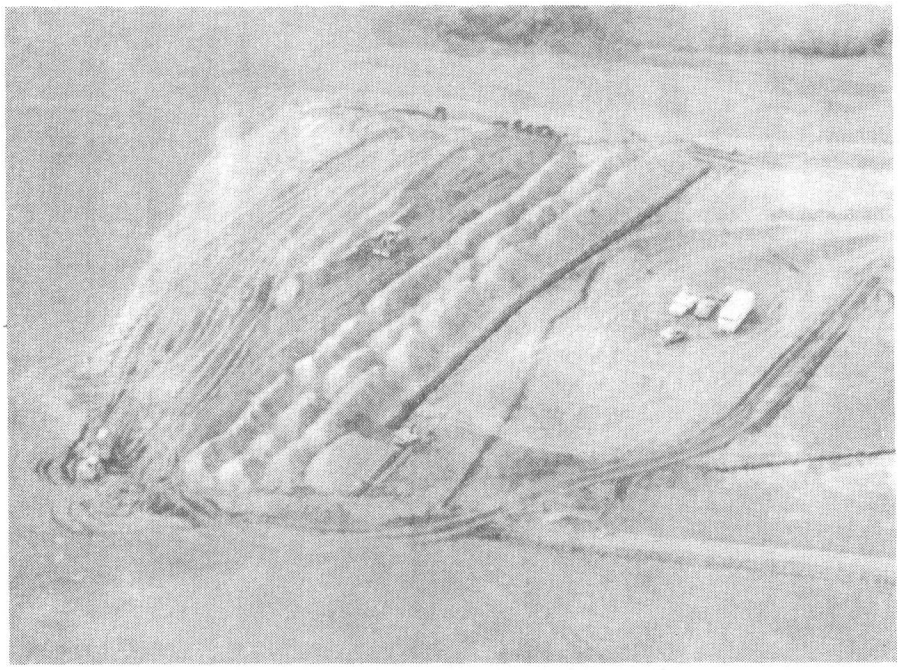
ABANDONED SURFACE-MINED LANDS

--Ed Murphy

Recently (in 1983 and 1985), the North Dakota Geological Survey participated in two studies in cooperation with North Dakota State University and the North Dakota Mining and Mineral Resources and Research Institute and to determine the quality of groundwater in and around abandoned surface lignite mines in western North Dakota (see photo). These studies were sponsored by the North Dakota Public Service Commission and their purpose was to predict what the impact of reclaiming these mines (leveling the spoil ridges) would have on shallow groundwater beneath and adjacent to the mines.

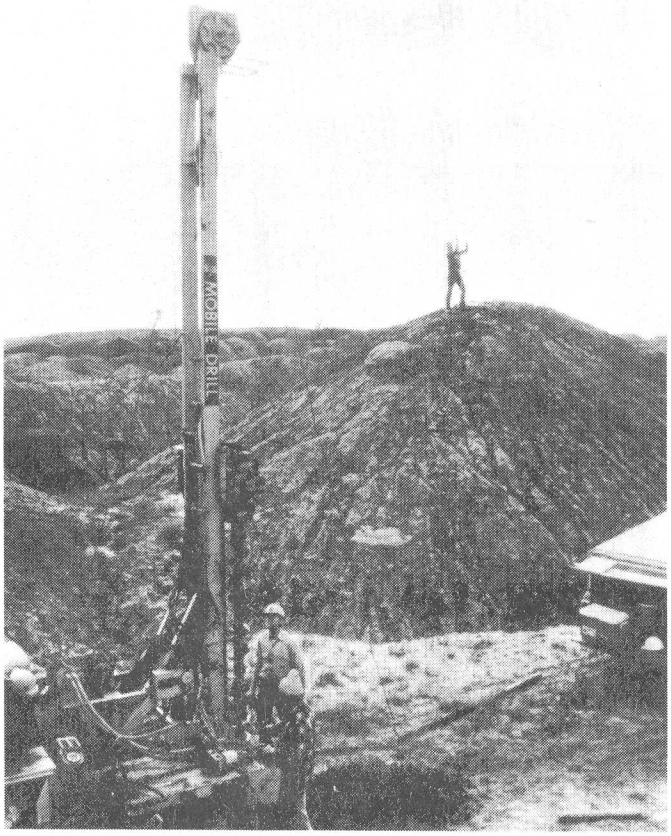
The initial results of the study indicated that the spoil ridge sediments contained high concentrations of soluble salts. This result was verified by our second study, which focused on the spoils within the Noonan Mine in Burke County. In addition, we collected evidence to suggest that these salts would be dissolved and transported to the water table due to increased surface recharge that would result if the spoils were leveled. The increased recharge through the leveled spoils would degrade the groundwater in and around the mine. Furthermore, no topsoil is available to spread on the leveled areas, thereby making it very difficult to reestablish vegetation (see photo).

The Public Service Commission is currently emphasizing the reclamation of underground mines and abandoned high walls in areas where they are a health hazard, and is not presently advocating the leveling of these spoils.



Aerial photograph of the Dishon Oil Exploration Waste Landfill in Williams County (special waste disposal site).

Installing groundwater and porewater monitoring equipment in the Noonan Spoils, Burke County (1982).



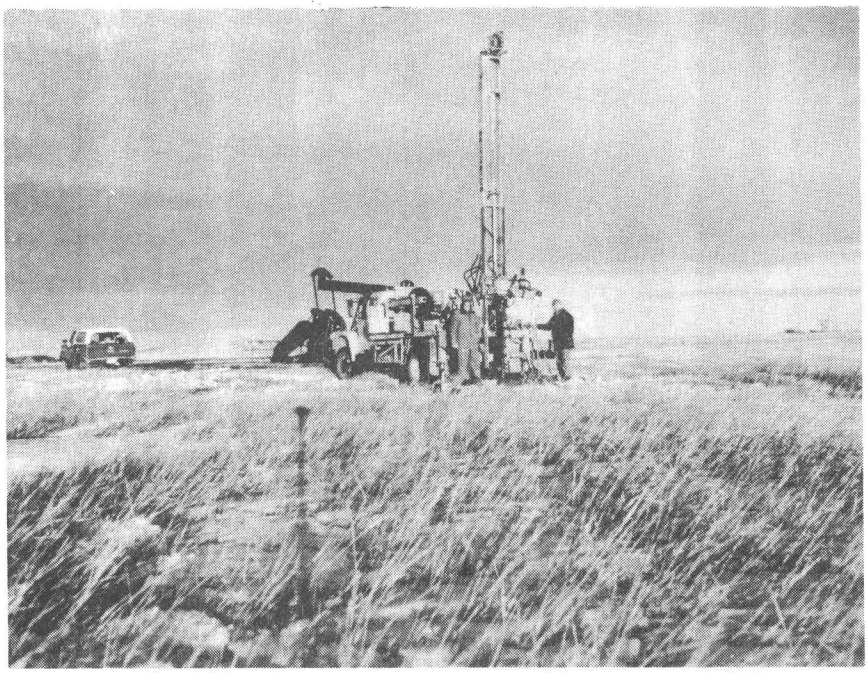
Obtaining sediment samples from both the top of the spoil ridges and from between the ridges in the Noonan Mine, Burke County (1984).

STUDIES OF BURIED DRILLING MUD

--Ed Murphy

One of the mandates of the North Dakota Geological Survey is to promote the safe development of the state's natural resources. Our responsibility to protect the environment is one of the reasons Governor Link, in 1980, asked the Survey and the North Dakota State Health Department to study the effects that buried drilling mud from an oil and gas well has on the surrounding environment (see photo). Our study, which was originally restricted to sites in Billings and McKenzie Counties in western North Dakota, was expandedin 1984 to include sites in Bottineau and Renville Counties in the north-central part of the state. The second study was facilitated by a grant from the North Dakota Water Resources Research Institute, handled through the North Dakota Mining and Minerals Resources and Research Institute.

Very few studies similar to ours have been undertaken in the United States. We have published the results and presented the findings at numerous meetings, both in North Dakota and outside of the state. The studies have made a significant contribution to understanding how to best manage drilling wastes. Equally important, the studies have alerted both state and federal regulatory agencies and



Installing monitoring wells around a reclaimed drilling-mud pit in the Glenburn Field, Renville County (1986).

the oil and gas industry itself to the problems associated with onsite disposal of drilling fluid in North Dakota. We've identified geologic settings that are inappropriate for disposal of drilling mud and, as a result, buried drilling fluids have been removed from some of these sites, either at the request of a government regulator or voluntarily by industry (see photo).

Dave Lechner obtaining a groundwater sample from one of the monitoring wells in the Glenburn Field, Renville County (1986).

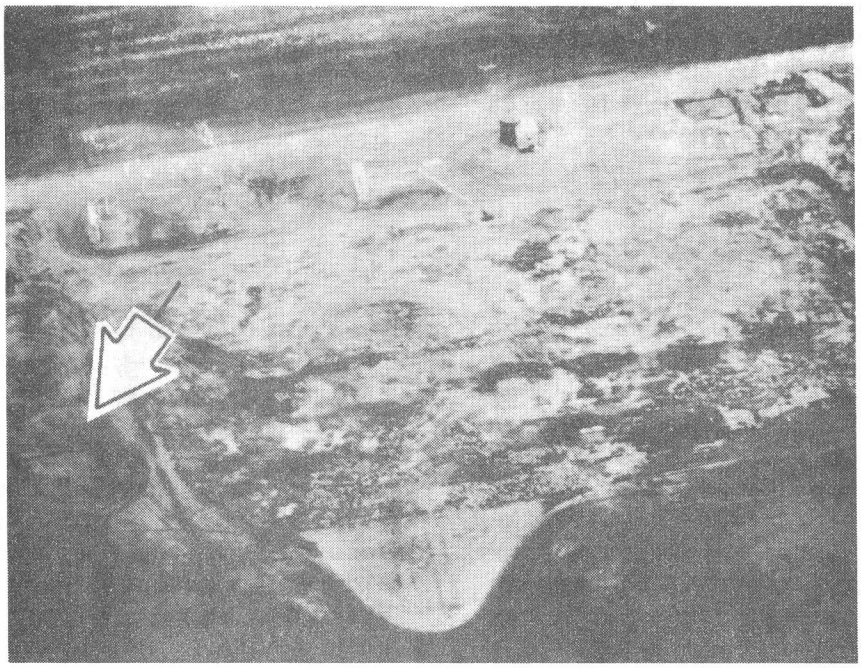
OIL AND GAS BRINE DISPOSAL PIT STUDY

--Ed Murphy

The NDGS took part in a cooperative project with the North Dakota State University, North Dakota Mining and Mineral Resources Research Institute, and the NDSU Land Reclamation Center to study the environmental effects on an area surrounding an abandoned brine pit in the Wylie Field, Bottineau County (see photo). The study was sponsored by a two-year grant (1984, 1985) from the North Dakota Water Resources Research Institute and took place on land owned by North Dakota State University.

Two unlined pits at this site were used for the holding and evaporation of brine produced with oil and gas from 1959 to 1978. No records are available for the amount of salt water that was disposed of in these pits. However, disposal amounts range from one-half to 410 barrels per day in similar pits in the area.

The study determined that a highly saline leachate plume renders the groundwater unusable in an area that extends laterally in a 500-foot radius around the pond and vertically to a depth of 70 feet below the pits (see photo). Even though salt water has not been disposed of in these pits for 8 to 10 years, this area continues to generate brine leachate and will continue to do so for tens and possibly hundreds of years if no



Aerial photograph of the abandoned brine pit study site in the Wylie Field, Bottineau County (Photo by John Foss, 1984).

Installing monitoring wells in the brine pit study site in the Wylie Field, Bottineau County (1984).

action is taken. This continuous saltwater migration has killed trees in a shelterbelt and decreased crop yields in surrounding fields within an area of approximately 10 acres (arrow points to area of crop damage).

Our report suggested three remedial actions, which would decrease the amount of leachate that is spreading laterally at the surface at this site, and at numerous reclaimed brine pits in the area.

COUNTY GEOLOGIC STUDIES

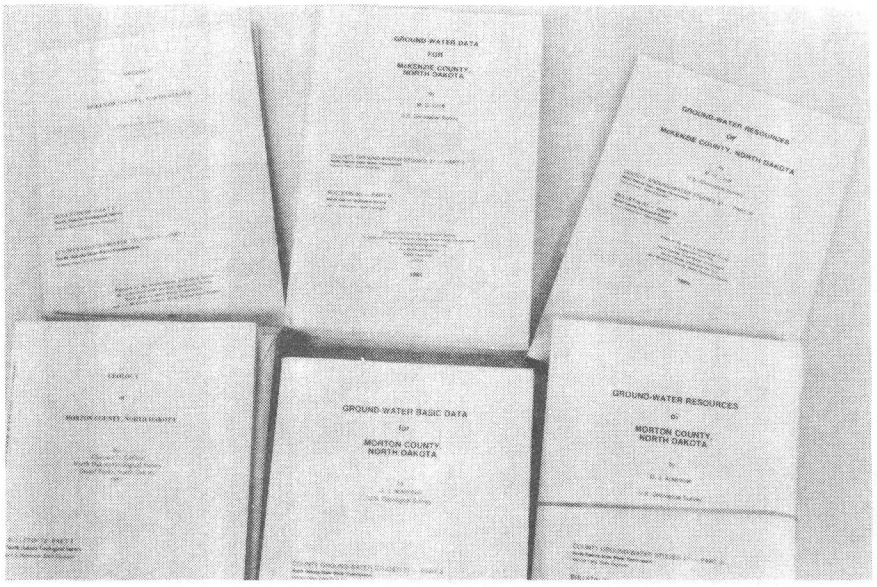
--John Bluemle

Only three reports remain to be published in our series of county studies, which have been underway since 1960. These studies, done in cooperation with the State Water Commission, the U.S. Geological Survey, and the various counties in which the work was done, have resulted in published geologic reports describing the surface geology, groundwater resources, and near-surface mineral deposits of all but four counties (we have a report ready to publish on Ramsey County and some work remains to be done on our studies of Dunn and Ward-Renville Counties). The county reports have generally been published in three parts: geology, which NDGS geologists prepare; basic data, prepared by the USGS and State Water Commission; and hydrology, prepared by the USGS.

Our county geologic reports serve as the primary source--in some cases the only source--of geologic data for large parts of North Dakota. In addition to the published reports, our county studies have resulted in a huge store of data, which we maintain in our files and make available to the public. The information in the county reports is especially valuable to water-well drillers and people who need to know something about local gravel deposits. The reports are also widely used by soils scientists who are compiling detailed soils maps and by a variety of citizens who turn to us for answers to problems about their local geology.

The direct field experience our geologists have gained through many years spent mapping counties in all parts of the state is one of the reasons our Survey staff is widely considered to be one of the two or three State Geological Surveys that is notably expert about their local geology. Our geologists can speak from personal experience and knowledge about the geology of mineral resource deposits, engineering constraints, and the geology of specific geologic features in any part of the state because they have actually mapped the counties.

In recent years, the demand for the county geologic reports that we published in the 1960s and early 1970s has increased so much that we have exhausted our supplies of many of the publications. Since those reports were published, we have continued to collect geologic data and, in many instances, we now have considerably more knowledge of the geology of many of the counties than we did when we published the reports. Rather than simply reprinting the old reports, we are incorporating our new data into a "second generation" of studies, the first of which will be released soon (see the following article).



The county geologic studies are published in three parts: geology, geologic basic data, and geohydrology.

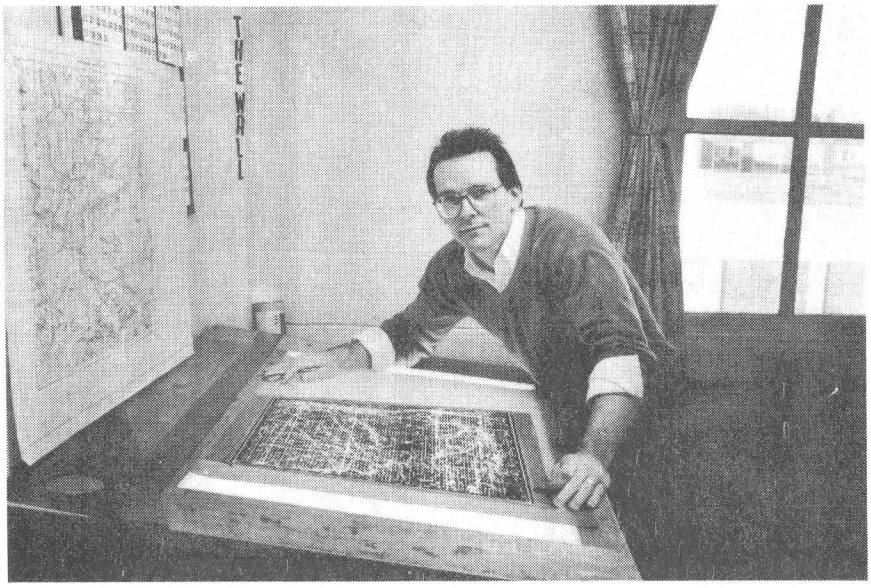
ONE-DEGREE ATLAS SERIES

--John Bluemle

As our county geologic studies program nears completion (see the previous article), we have begun an ambitious new mapping program to replace it (see photo). Our One-Degree Atlas Series will present the surface geology of the state at a scale of 1:250,000 ($\frac{1}{4}$" = 1 mile). At that scale, a total of 21 convenient-sized maps, each measuring approximately 18" x 20", and each including an area measuring one degree of latitude by one degree of longitude, are required to cover the state.

The One-Degree Atlas Series maps will provide a somewhat broader perspective to the geology of the state than did the county geologic studies maps because the new maps include larger areas. Even though the one-degree maps are drawn at a smaller scale than the county maps, we expect to be able to retain as much detail, even provide more information, on the new maps than was included on the county studies maps. We can also "build" the new map series into a true atlas format by adding a variety of derivative maps showing such information as near-surface stratigraphy, bedrock geology, thickness of glacial deposits, availability of various mineral resources, suitability for various types of construction, various engineering constraints, and, as appropriate, other special maps. As field work is completed on the new one-degree areas, and these detailed studies are published, we will gradually accumulate a new, much more complete set of data on the geology of North Dakota than we have now.

The first of our One-Degree Atlas Series maps, which includes a part of southeasternmost North Dakota, is in the process of being drafted. We hope to publish this map sometime in mid-1987.



Our drafting technician, Ken Dorsher, is shown working on the first of our One-Degree Atlas Sheets. This map covers southeasternmost North Dakota.

EVALUATION OF SUBSURFACE ROCK FORMATIONS TO ENCOURAGE OIL & GAS EXPLORATION AND DEVELOPMENT

--Julie LeFever

Several projects currently underway or recently completed at the Survey deal with subsurface rock formations in North Dakota. These projects, which are designed to encourage drilling in North Dakota, are concerned with rocks that either produce or directly affect production of oil and gas. For example, a recent study of Paleozoic salts in northwestern North Dakota resulted in information that led to the discovery of the Gooseneck Oil Field in Divide County. Two other detailed studies of the highly productive Mississippian Madison Formation in north-central North Dakota have helped to identify potential new exploration or development targets with possible source rocks in an otherwise already well-developed area. Other, broader-based studies supply needed information, including electric-log characteristics of potential reservoir rock, water chemistries, and well information. Projects like these enable independent operators with limited resources, land owners, and major oil companies operating in the North Dakota Williston Basin the opportunity to acquire data which often acts as a starting point leading to new drilling prospects.

Subsurface rock evaluation projects highlight areas that are potentially productive and bring them to the attention of the oil industry. These studies almost invariably generate new ideas which encourage wildcatting or build renewed interest in an older productive area; the result is often new drilling and increased revenue to the state. In fact, regardless of whether or not a wildcat well ends up as a producer or a dry hole, there is a strong financial impact upon the state. If a decision to drill a well is made, and if the

well is successful, producing perhaps 125 barrels of oil a day, the direct revenue to the State of North Dakota in taxes from that single well will be about $84,000 a year (assuming oil is worth $16 a barrel). The mineral owner will pay another $4,000 in direct taxes to the state on his share of that same oil, and he will also pay taxes on his income from the well.

A company may spend $80,000 to $750,000 on a dry hole. North Dakota well costs are twice as much as the national average. The most expensive onshore drilling in the lower 48 states is in North Dakota. Even on a dry hole, the state will profit as a result of the jobs associated with the operating rig and by the indirect additional money circulating into the community and then to the state.

ACTIVITY AT THE CORE LIBRARY INCREASES IN 1986

--Rod Stoa

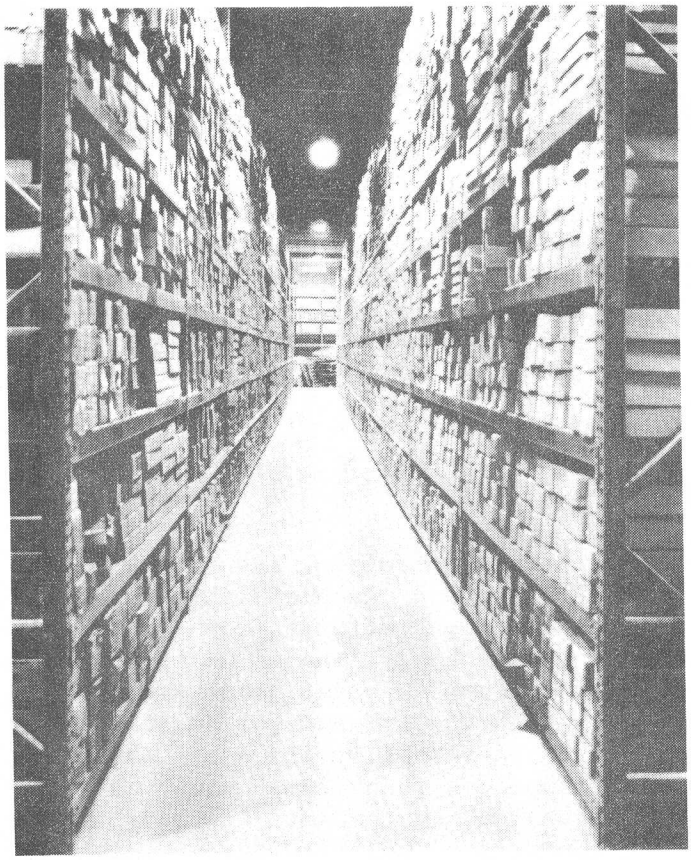
Although activity in the oil patch is definitely in a downturn, the Wilson M. Laird Core and Sample Library has experienced a very busy year. Nearly 700 geologists visited our core library this year, compared with 480 the previous year. The amount of core examined also increased, from 23,455 feet in 1985 to over 48,500 feet so far in 1986 (this was written in mid-December--Ed.). It appears that oil-company geologists, independents and consultants are taking advantage of the slack time to do the research that will enable them to be ready when the next "boom" comes.

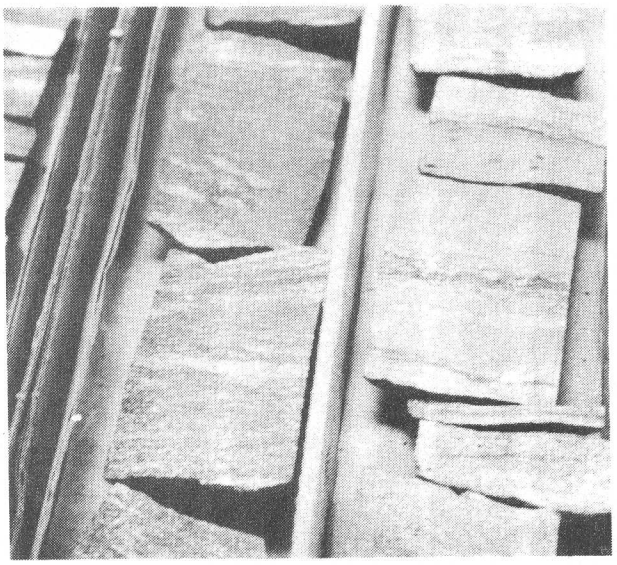
The core library is, perhaps, the least-known aspect of the Geological Survey. However, its importance to the petroleum industry and to the academic sector is of inestimable value. Research is constantly underway, with scientists and students traveling from throughout the U.S. and Canada to gather information, in addition to studies by our own staff geologists. The University of North Dakota geology department currently has several students involved in graduate studies of the subsurface in the Williston Basin, and it is the core library that makes these studies possible.

The petroleum industry utilizes our core and sample library in its exploration efforts on a nearly constant basis. The value of the core and samples is underscored in exploration efforts for stratigraphic traps, especially in cases where the trapping mechanism may not be revealed by seismic methods or by electric well logs. This is illustrated by the recent discovery of a field in the Devonian Duperow Formation in northwestern North Dakota. Extensive studies of core from our library by Conoco, Inc. was a deciding factor in the discovery of Gooseneck Field in Divide County in 1984. Gooseneck Field features a trapping mechanism of salt plugging of porosity.

The discovery of Gooseneck Field has already resulted in tax revenues to the state of more than $600,000. It is easily seen from this single example that our core library is extremely valuable to the State of North Dakota.

The core library, with its unequaled collection of subsurface materials from a single basin in the United States, and its great utilization rate, is certainly a facility of which the NDGS and the State of North Dakota can be proud.





Above left: storage area in Wilson M. Laird Core and Sample Library is nearly full. Lower left: boxes of rock core laid out on tables for study in lab. Above right: closer view of core samples.

COMPUTER MANAGEMENT OF SURVEY DATA

--Kathy Miller and Ken Harris

The Survey is responsible for the storage and distribution of a huge amount of geologic data (we currently have about 20 million bytes--characters--in storage). Since all of our data is public information (proprietary data is maintained separately), we receive frequent requests for copies of all or parts of our data files. We are usually able to respond to these requests in a timely manner.

The geologic data that we have in storage is basic data that is derived from investigations conducted by the Survey, industry activity in the state, academic studies, and studies conducted by other agencies. Table 1 lists some of the data sets we maintain.

Our computer system consists of a central storage device with satellite reference terminals and work stations (fig. 1). The central storage device is an IBM System 34. This device acts as a closed-stack library containing the various data sets. The System 34 uses cartridges of diskettes for data back-up and consequently not all of our data sets need be in residence at any one time. Six dedicated terminals offer reference only or input-output functions needed in the office on a daily basis.

Four IBM Personal Computers function as read-only work stations and as stand-alone units, allowing manipulation of the data and manuscript preparation.

Our computer system includes a high-quality LED printer that produces camera-ready copies necessary for the preparation of documents for publication.

Our system allows for the management of our data bases, provides the necessary security for proprietary data, and interfaces with the Higher Education Computer Network.

In the near future we plan to publish timely summaries of some of the data we manage. The exact form and format, as well as the content, will be determined by the users of the data, but the summaries will be similar to our recently published well schedule.

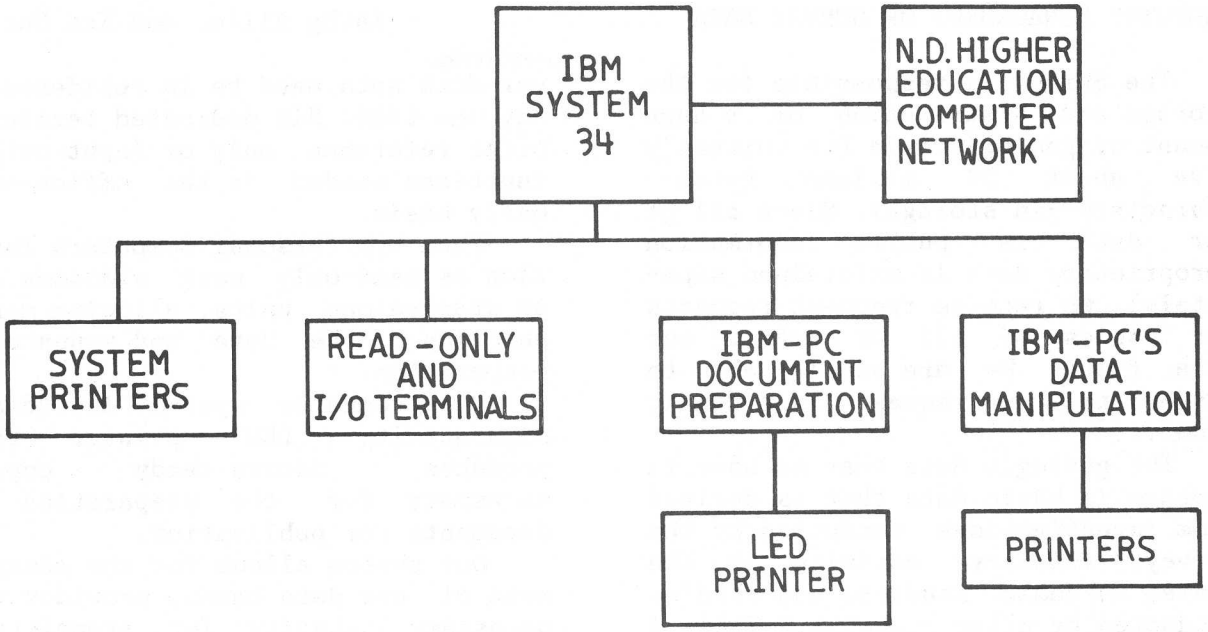


Figure 1. Current hardware configuration used by the NDGS for computer data management.

Our computer programmer/analyst, Kathy Miller, at work in the NDGS computer area.

TABLE 1. A Listing of Some of Our Larger Files and the Types of Data We Have in Each.

GS LEGAL FILE

This file contains legal descriptions and other basic information on all the oil and gas wells in the state. Data in the file include:

1. Well number
2. Operator
3. Well name (current and original)
4. Location (surface and bottomhole)
5. API number
6. County
7. Field name
8. Well status
9. Cancellation, completion & plugging data
10. Ground level and kelly bushing elevation
11. Total depth
12. Total depth
13. Top and bottom of logged interval
14. Bottom-hole temperature
15. Deepest formation penetrated
16. Casings

GS COMP

GS Comp file is an extension of GS Legal. It includes the initial production for wells that have produced. Data in the file include:

1. Formation
2. Perforated interval
3. Barrels of oil daily
4. Condensate
5. Gas-oil ratio
6. Water
7. Size of choke
8. Gas
9. Gravity
10. Whether well is a discovery well

GS CORE AND DRILLING SAMPLES

This file is basically a catalog of our core library. Data in the file include:

1. Whether we have received a core analysis or geologic report
2. Description of core cut; intervals we have in library
3. Type of core
4. Formation cored
5. Interval cored
6. Storage location in core library
7. Drilling Samples

GS CHEM

This is a water-chemistry analysis file that includes data obtained mainly from drill-stem tests. Data in the file include:

1. Formation tested
2. Type of test
3. Interval tested
4. Concentrations of selected ions
5. pH of water
6. Resistivity
7. Temperature
8. Sample and date
9. Drill-stem test number
10. Salinities and alkalinities
11. Specific gravity

TABLE 1. A Listing of Our Larger Files and the Types of Data We Have in Each.--Continued

GS STRAT

This file is a catalog of stratigraphic markers used by the Survey. It indicates the depths we use to denote the markers near the top of selected formations.

GS NFILE

This file contains near-surface information obtained mainly from shallow test-hole drilling. Textural and lithologic data are included.

THE AVAILABILITY OF OIL AND GAS INFORMATION (FIELD MAPS, WELL DATA, AND FIELD INFORMATION)

--Marv Rygh

The North Dakota Geological Survey maintains records of all the oil and gas wells in the state. We answer requests every day by landowners and mineral owners who want information about oil and gas drilling activity and production. This type of information ranges from general publications on the oil and gas industry to specific information about individual oil fields and oil wells. We expect that our recently published Well Schedule will be in considerable demand as a ready source of data on wells. Our Oil and Gas Field Maps are particularly useful to many people, including the oil and gas industry, but not restricted to it. Mineral owners often wonder about exploratory drilling, permitting activity, and production figures in the immediate vicinity of their own land. The status of present oil well drilling, projected drilling, the proximity of their own land to producing wells, and the amount of production from those wells are all important facts mineral owners need to know when they are considering leasing their own mineral interests.

All of the information mentioned above is available from the North Dakota Geological Survey and it is relatively inexpensive. In many cases, the only charge is the cost of photocopying or making a blue-line copy. A single field map covers 12 townships and each map is updated weekly so all the information on the maps is current.

The oil and gas records we maintain are open to the public and are accessible to everyone. This important data can be invaluable to individual landowners and mineral owners as well as to oil and gas companies.

THE VALUE OF NORTH DAKOTA'S MINERAL PRODUCTION

--John Bluemle

I recently received a copy of the text of the Presidential Address, delivered to the North Dakota Geological Society in Bismarck on November 17, 1986 by Dr. Eric Clausen. Dr. Clausen, a Professor at the State University of North Dakota in Minot, spoke on the "Status of the Geologic Profession in North Dakota." One of the topics he dealt with in his talk was the value of North Dakota's mineral production. I think that some of the figures he presented help to underscore just how important our

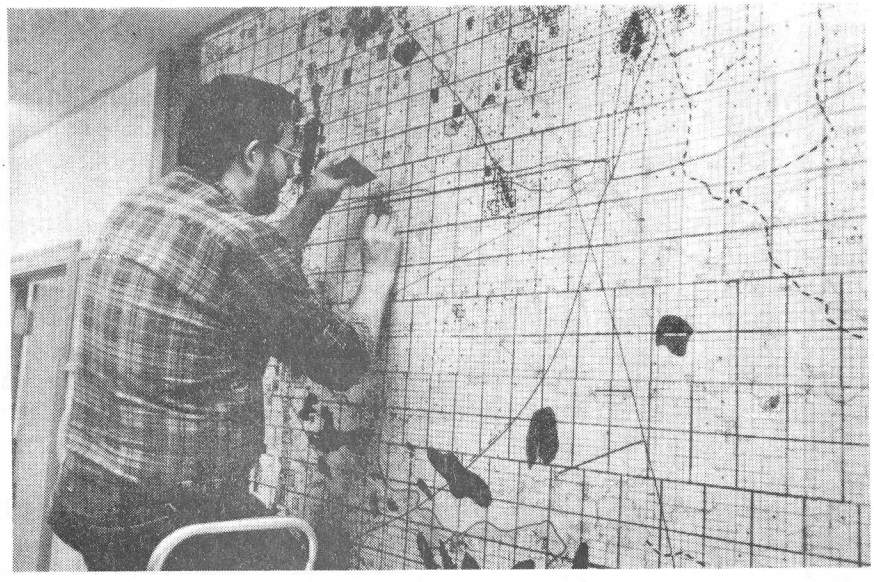
mineral industry is to North Dakota's economy. Dr. Clausen used the term "mineral industry" in a broad sense, including both fuel resources (petroleum, natural gas, and coal) and industrial minerals, which in North Dakota include sand and gravel, salt, clay, sulfur, peat, leonardite, and lime (for more information on North Dakota's industrial mineral resources, please refer to the article in the June, 1986 NDGS Newsletter by David Brekke).

According to U.S. Bureau of Mines and Department of Energy Data, which Dr. Clausen used in researching his speech, North Dakota ranked 18th in the nation in terms of total value for all mineral commodities produced in 1983, the last year for which data was available for all commodities for all of the states. North Dakota ranks higher than 18th for certain mineral commodities, such as petroleum (we ranked 9th in the nation in petroleum production), but since we don't have any iron mines, copper mines, or gold mines and, since those and other mineral commodities are included in the totals, our overall ranking is pulled down. The value of all the minerals produced in North Dakota in 1983 was slightly over 1.8 billion dollars (table 1). That's a huge amount of money for a state with an overall economy as small as North Dakota's.

I took some of the same data Dr. Clausen used to arrive at his figures and did some additional calculations. Figured on a per-capita basis, North Dakota's 1.8 billion mineral commodity dollars amounts to over $3,000 per person. Only five states produced minerals with a higher per-capita value in 1983 (table 2). North Dakota's most important mineral resources are oil and gas, followed by lignite coal. The value of North Dakota's oil and gas production in 1983 (I chose that year so I would be able to make valid comparisons with earlier figures) was 1.4 billion dollars (of the total 1.8 billion dollars noted above). That's more than $2,200 for each person in the state (table 3). Only three states, Alaska, Wyoming, and Louisiana, had greater per-capita incomes from oil and gas.

I suppose this article could end here, because I think I've shown that North Dakota's mineral industry constitutes an extremely important part of the State's economy. But I do want to make at least one more point, and that has to do with the monetary value of geological research. Just how valuable is the time and money we (the NDGS) spend learning more about North Dakota's mineral resources? How can we evaluate the value of that effort? It's difficult, maybe impossible, to quantify. Money spent by the State Tax Department to collect taxes probably yields the State one of the best-documented immediate returns for its investment. In fact, the Tax Department has calculated that, during the 1983-1984 biennium, it spent less than a penny for every dollar it collected. That's certainly a worthwhile investment. I'd like to be able to say something comparable--what the return is for every dollar we spend--but it's much more difficult to determine the direct and immediate benefit the State realizes from the Survey's investment in studying the occurrence of mineral resources. If I were an economist and willing to spend some time juggling numbers in various ways, I think I could make a valid case for the idea that the dollars spent by the NDGS yield an even better return than those spent by the Tax Department. We know, for example, that over the past 6 or 7 years, during the recent oil "boom," several companies became interested, began exploration, and were successful in North Dakota as a direct consequence of things they learned from our publications or advice they obtained from our geologists. It's certainly safe to say that, in that way, several tens--probably several hundreds--of millions of mineral revenue dollars were realized by the State that wouldn't have ever materialized had

Petroleum engineer, Marv Rygh, at work in his office on the NDGS Oil & Gas Field Maps.



Dave Lechner, our laboratory technician, is shown here at work on our large map of North Dakota, changing the boundaries on an oil field.

Table 1. Value of all Mineral Production by State.*

State	Value of all Mineral Production-1983
1. Texas	42,805,000,000
2. Louisiana	28,938,000,000
3. California	12,203,000,000
4. Alaska	11,489,000,000
5. Oklahoma	9,946,000,000
6. Wyoming	6,549,000,000
7. New Mexico	5,619,000,000
8. Kentucky	4,711,000,000
9. West Virginia	4,612,000,000
10. Pennsylvania	3,508,000,000
11. Illinois	3,071,000,000
12. Kansas	2,957,000,000
13. Michigan	2,709,000,000
14. Ohio	2,453,000,000
15. Alabama	2,410,000,000
16. Colorado	2,236,000,000
17. Utah	1,924,000,000
18. North Dakota	1,822,000,000
19. Arizona	1,800,000,000
20. Minnesota	1,676,000,000
21. Montana	1,549,000,000
22. Mississippi	1,494,000,000
23. Virginia	1,442,000,000
24. Florida	1,410,000,000
25. Arkansas	1,273,000,000
26. Indiana	1,253,000,000
27. Georgia	1,140,000,000
28. Missouri	832,000,000
29. New York	712,000,000
30. Tennessee	708,000,000
31. Nevada	616,000,000
32. North Carolina	451,000,000
33. Idaho	412,000,000
34. Washington	403,000,000
35. Maryland	341,000,000
36. Iowa	322,000,000
37. Nebraska	300,000,000
38. South Carolina	276,000,000
39. Maine	242,000,000
40. South Dakota	232,000,000
41. New Jersey	156,000,000
42. Wisconsin	129,000,000
43. Oregon	120,000,000
44. Massachusetts	107,000,000
45. Connecticut	80,000,000
46. Hawaii	51,000,000
47. Vermont	45,000,000
48. New Hampshire	23,000,000
49. Rhode Island	12,000,000
50. Delaware	3,000,000

* Data is compiled for 1983, the last year for which figures are available for all mineral commodities for all states.

Table 2. Value Per Capita of all Mineral Production for the Top Ten States (in 1983).

State	Value per capita
1. Alaska	$28,722
2. Wyoming	14,236
3. Louisiana	6,890
4. New Mexico	4,322
5. Oklahoma	3,315
6. North Dakota	3,036
7. Texas	3,014
8. West Virginia	2,427
9. Montana	1,960
10. Utah	1,282

Table 3. Value Per Capita of Oil and Gas Production for the Top Ten States (in 1983).

State	Value per capita
1. Alaska	*
2. Wyoming	7,405
3. Louisiana	3,435
4. North Dakota	2,268
5. Texas	1,780
6. New Mexico	1,709
7. Oklahoma	1,558
8. Montana	1,060
9. Kansas	883
10. Utah	665

* I couldn't obtain an exact figure for Alaska, although I can estimate that the value per capita to each Alaskan for the state's oil and gas production exceeded $20,000 per person.

it not been for NDGS and industry research efforts. So, while it's true that, in some cases, it takes a long time to realize a return on basic research, that's certainly not true with respect to our geologic studies; the return on our investment has been, and continues to be, spectacular.

THE NDGS COMPARED TO OTHER STATE GEOLOGICAL SURVEYS

--John Bluemle

How does the North Dakota Geological Survey stack up against the other state geological surveys? Is our survey comparable to others with respect to projects, personnel, etc.? I've been looking through several past issues of the Journal of the Association of State Geologists to determine the type of projects geologists at other surveys are working on and I was able to get a general idea of some trends.

One way to determine how important geology is, or should be, in each state is to consider how valuable the mineral production is in that state. Another way might be to try to evaluate the relative severity of the various environmental problems with which each state has to contend. In some states, for example, the availability of water is a major concern of the geological surveys. In other states, landslides or earthquakes are a concern. All of these issues are the kinds of things with which geologists deal. Some of the larger state surveys concern themselves mainly with their extensive energy resources, but others, like Illinois and California, have extremely diverse programs. California, for example, lists programs in landslide and earthquake hazards, marine geology, geothermal resources, mined-land reclamation, minerals, mapping, and others. Many of these topics are not problems in North Dakota.

Let's start by comparing the sizes of the various state surveys (or the equivalent agency for that state--Department of Natural Resources, Geologic Branch; Bureau of Mines; Bureau of Economic Geology; etc.). Table 1 shows that the North Dakota Geological Survey is one of the smaller ones. Ours ranks 43rd in size, with eight full-time geologists, one full-time petroleum engineer, and two half-time geologists.

In the previous article (page 18), I discussed the importance of mineral resource production to the North Dakota economy. As I pointed out there, North Dakota ranks 18th in terms of value of its mineral production, 6th in terms of value per capita of minerals to our citizens. Yet, our Survey is 43rd largest among all the state geological surveys. Only Arizona, with almost the same mineral production value as ours, has a comparably small geological survey. Possibly, since most of Arizona's mineral production is from mines that have been producing for a long time, basic geologic research is less vital there than here in North Dakota where continual exploration is required to keep our petroleum industry going. In any case, I've learned recently that the Arizona Survey is in a state of transition and may be expanded in the near future.

Let's look at another aspect of the North Dakota Geological Survey: the number of reports we publish on the state's geology. Table 2 lists the total number of publications for each of the state geological surveys (between 1963 and 1980). Illinois, the largest geological survey in the country, published the most reports during that time, 294. With only one exception, the ten geological surveys that were most effective in making the results of their studies available to the public--those with the most publications, were also among the largest surveys. The single exception is North Dakota. Our

TABLE 1. Number of Professionals Employed by State Geological Surveys
(Geologists, hydrogeologists, engineers, etc.)

This table is a composite of information from several sources and some of the totals may not be accurate and up-to-date. Because of organizational differences from state to state, some states have geologists working for geological surveys, bureaus of mines, oil and gas boards, etc.), there is probably a tendency for the totals here, if they are incorrect, to be on the low side.

State	Full-Time	Part-Time	Total
+ Illinois	106	0	106
+ Texas	68	29	97
+ Kansas	39	30	69
+ California	68	0	68
+ Michigan	63	0	63
- New Jersey	56	6	62
- Missouri	40	4	44
+ Georgia	41	0	41
+ Kentucky	35	4	39
+ Pennsylvania	29	10	39
+ Alabama	37	0	37
+ Ohio	37	0	37
- Nebraska	31	5	36
+ Alaska	35	0	35
+ New Mexico	35	0	35
+ Utah	29	5	34
+ West Virginia	30	3	33
+ Indiana	30	2	32
+ Montana	27	0	27
+ Virginia	26	0	26
- Iowa	24	1	25
- South Dakota	21	4	25
+ Louisiana	24	0	24
+ Minnesota	20	4	24
+ Florida	15	8	23
- Maryland	22	0	22
- Tennessee	18	0	18
- Wisconsin	17	1	18
- Oregon	15	3	18
+ Colorado	15	2	17
+ Oklahoma	13	4	17
- Washington	13	4	17
+ Wyoming	9	7	16
- South Carolina	7	9	16
- New York	15	0	15
- Connecticut	6	9	15
- Massachusetts	14	0	14
+ Mississippi	14	0	14
- Nevada	13	0	13
- Delaware	10	3	13
- North Carolina	1	11	12
+ Arkansas	11	0	11
+ North Dakota	9	2	11
- Maine	8	0	8
- Idaho	5	1	6
+ Arizona	4	0	4
- Hawaii	3	0	3
- Vermont	2	1	3
- Rhode Island	1	0	1
- New Hampshire	0	0	0

+ Produced over 1 billion dollars worth of minerals in 1983.
- Produced less than 1 billion dollars worth of minerals in 1983.

TABLE 2. Number of State Geological Survey Publications, 1963-1980. Data Compiled by Eric Clausen.

State	State Geological Survey Publications
1. Illinois	294
2. Kentucky	233
3. Kansas	227
4. Alabama	208
5. New Mexico	193
6. North Dakota	189
7. Pennsylvania	182
8. California	180
9. Texas	178
10. Montana	166
11. Florida	154
12. Hawaii	145
13. New Jersey	144
14. Alaska	134
15. Indiana	133
16. Utah	131
17. Missouri	129
18. Ohio	114
19. South Dakota	112
20. Virginia	100
21. Mississippi	99
22. Maryland	88
23. West Virginia	86
24. Georgia	84
25. Nevada	83
26. Oklahoma	81
27. Oregon	80
28. Wisconsin	72
29. Michigan	70
30. Idaho	70
31. Washington	68
32. Minnesota	66
33. Louisiana	64
34. Colorado	63
35. Wyoming	60
36. Iowa	59
37. Connecticut	55
38. Tennessee	52
39. Arizona	43
40. South Carolina	34
41. Delaware	33
42. North Carolina	27
43. Vermont	24
44. Maine	20
45. Arkansas	20
46. Nebraska	13
47. Rhode Island	0
48. New Hampshire	0
49. Massachusetts	0
50. New York	0

TABLE 3. Productivity Index
(Publications/No. of Staff Persons)

1.	North Dakota	17.2
2.	Kentucky	6.6
3.	Montana	5.7
4.	Alabama	5.6
5.	New Mexico	5.5
6.	Pennsylvania	4.7
7.	Kansas	3.3
8.	Illinois	2.7
9.	California	2.6
10.	Texas	1.8

geologists published 189 reports during that period, more than 43 of the other surveys. While it is true that, during most of that 17-year period, the NDGS had a somewhat larger staff than we do now, about 14 professionals (geologists and engineers), even since 1981, when our oil and gas regulatory duties, and several staff persons, were transferred to Bismarck, we have managed to publish 57 reports.

Just for fun, I calculated a "productivity index" for the top ten states on table 2, dividing the total number of publications by each Survey during the 17-year period by the current number of staff persons. Each NDGS professional, during that period of time, produced 17.2 publications, about one a year. That's more than any other state geological survey (table 3).

Incidentally, our recent publication record would be even better were it not for the fact that, over the past six years, our budget has been cut back more than 30 percent. That, plus the fact that printing costs have risen considerably, have made it impossible for me to print some of the things I'd like (I'm stating this personally because, as editor for the NDGS, I am responsible for seeing to the printing of our reports). Last month, for example, I had to reject bids on our recently completed report on the geology of Ramsey County; our printing budget just couldn't stand the cost. That's particularly unfortunate, I think, in view of the fact that many of the geologic concerns in Ramsey County bear directly on certain aspects of the Garrison Diversion Project, and could prove useful to people working on that project.

Finally, another way to compare the NDGS to other surveys might be in terms of the number of inquiries handled by our staff. We responded to about 8,000 calls for advice or information last year--phone calls, letters, etc. Unfortunately, my source of information about the other states, the Journal of the Association of State Geologists, includes comparable figures from only 3 other geological surveys: Georgia, with 2,600 calls; Kentucky, with 4,000; and Ohio, with 50,000. That's certainly not a "statistically valid" comparison, but, considering the fact that all three of those states are much more populous than North Dakota, and all three have considerably larger surveys, we made a respectable showing.

All of the comparisons I've just made between the NDGS and other state geological surveys deal only with a few numbers, some of which don't necessarily mean a great deal. The most important measure of our effectiveness--the quality of the work we do--simply can't be measured and compared in this way. I know that

our geologists, and the geologists employed by the other state surveys, are, by and large, extremely competent and dedicated people. They tend to be a relatively stable group who stay in their respective states long enough to become extremely knowledgeable about local problems.

As a group, geologists and engineers working for state geological surveys are paid somewhat less than their counterparts in industry, but this is compensated somewhat by the fact that, in most cases, they enjoy greater job stability. During the recent--the current--"bust" in the oil industry, for example, many geologists working for oil companies lost their jobs, but most of those in state government continued in their positions. That's probably as it should be (at least the last part of the sentence), because it would be extremely shortsighted for a state to base its long-term geologic studies--its potential future mineral wealth--on short-term economic conditions.

NEW PUBLICATIONS

The following publications were issued recently by the Survey:

Report of Investigation 84--"Structure and Stratigraphy of the Frobisher-Alida and Ratcliffe Intervals, Mississippian Madison Group, North-Central North Dakota," was written by Julie A. LeFever, Sidney B. Anderson, and Clarence G. Carlson. The 17-page report deals with a portion of the Mississippian Madison Group along the northeastern margin of the Williston Basin in Bottineau, Renville, and Ward Counties, north-central North Dakota. This study of the Frobisher-Alida and Ratcliffe Intervals of the Madison includes a series of 12 detailed isopach and structural maps of important horizons in the area, as well as several cross sections. The text includes discussions of the various structural and stratigraphic features found in the area along with explanations and interpretations of the maps themselves.

Report of Investigation 84 is available from the Survey for $3.00.

Report of Investigation 85--"Madison Subcrop--North Central North Dakota," was authored by Julie A. LeFever and Sidney B. Anderson. The report deals with parts of Bottineau, Burke, Renville, and Ward Counties, and consists of one sheet, showing a colored map, a typical log with the stratigraphic breakdown of the Mississippian Madison Formation, and a short explanatory text.

Report of Investigation 85 is a revised version of a similar map published in 1965. All available well control has been used in updating the new map. The report should be valuable for the exploration geologist concerned with the location of potential pay zones within the Madison Formation and/or location of potential areas where the Madison may supply the overlying Spearfish Formation with oil.

Report of Investigation 85 is drawn at a scale of 1 mile to a half inch (1:125,000). It can be obtained for $3.00 from the Survey.

North Dakota Well Schedule, Volumes 1 and 2 was compiled by E. Kathleen Miller. The well schedule is a compilation of producing oil and gas wells and exploratory wells in North Dakota. It includes information on every location that has been permitted in the state, about 12,000 entries. We hope to update the directory annually as new locations are added and as changes in the status of existing wells occur. The well schedule is organized according to loca-

tion, by township and range, and by sections within townships. Information on each well includes the NDGS well number, the location, elevation, original and current operator, lease owner, total depth, API number, field (if the well is a producer), status (producing, dry, abandoned, etc.), plugging date, deepest horizon penetrated, bottom hole temperature, logs available, whether the well is a discovery well, producing interval, date of completion, initial production, and other information.

The two volumes of the North Dakota Well Schedule are 383 and 367 pages long. Volume 1 covers the area from Township 129 North, Range 58 West through Township 155 North, Range 104 West. Volume 2 covers the area from Township 156 North, Range 56 West through Township 164 North, Range 103 West. The Well Schedule is available from the NDGS for $15.00 for each volume.

Miscellaneous Series 66 -- "North Dakota Stratigraphic Column," by John P. Bluemle, Sidney B. Anderson, John A. Andrew, David W. Fischer, and Julie A. LeFever, consists of three sheets. Sheet 1 is a colored stratigraphic column that shows all major North Dakota Williston Basin geologic units. It includes descriptions of each formation, group, and member, and columns for mineral resources, maximum thickness, and other information. Sheets 2 and 3 show sample wireline logs at a scale of 200 feet to the inch, and a small portion of a seismic line to illustrate log characteristics of the subsurface rock units included on the Stratigraphic Column. Logs for ten representative wells in various parts of the state are included. Tops for formations, members, and log markers are indicated on the logs where they are readily recognized.

This new North Dakota Stratigraphic Column replaces one that was published by the Survey in 1980, which is now exhausted. The stratigraphic column (sheet 1) measures 28" x 42" and the log sheets (sheets 2 and 3) measure 31" x 42" and 24" x 42". Miscellaneous Series 66 is available from the Survey at a cost of $7.00 for all three sheets, or $3.00 for Sheet 1 alone.

Miscellaneous Series 67 -- "Oil Exploration and Development in the North Dakota Williston Basin: 1984-1985 Update," was written by David W. Fischer and John P. Bluemle. This 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 authors analyze current conditions and offer their best prognosis of future possibilities.

The report includes 19 illustrations and 4 tables to help the reader better understand the role of oil and gas in North Dakota's economy. Graphs of wildcat wells drilled annually since oil was discovered, the number of new oil pools discovered each year, annual crude oil production, average number of drilling rigs operating in the state, and the amount of oil and gas tax revenues collected by the state are included along with many other illustrations. Tables are included detailing all the new-pool discovery wells for 1984 and 1985.

This 40-page report is available from the Survey for $3.00.

NICHOLAS KOHANOWSKI--1905-1986 --Bob Seidel

This past fall, a respected and long-time member of the North Dakota geologic community passed away. Nicholas N. Kohanowski, emeritus associate professor of geology at the University of North Dakota, died at his home on September 18, 1986. During his 26-year association with the University of North Dakota, he was also employed at various times by the North Dakota Geological Survey.

Kohanowski was born aboard a refugee train near the Ural Mountains in Russia on February 27, 1905, during the Russo-Japanese war. After the war, the family returned to Vladivostok where he grew up. At 18, along with his father, he fought on the side of the czar during the Russian Revolution. Following the defeat of the czar, he learned the Bolsheviks were looking for him so he fled to China and finally to Japan in 1923. While there, he obtained a visa to come to the United States. He returned to the Soviet Union for a 17-day visit in 1963.

While a student at the Colorado School of Mines, he met Mercedes Tafoya, and they were married October, 1931, in Golden, Colorado. In 1935, they moved to Bolivia, South America where they lived for 14 years and he worked for the Aramayo Mining Co.

Nicholas Kohanowski began his association with the University of North Dakota in 1949. During one of his periods of employment by the North Dakota Geological Survey, while he was acting as State Geologist in the absence of Wilson M. Laird, he signed the drilling permit for the Amerada Petroleum Corporation's #1

Clarence Iverson well, drilled in Williams County. The permit was issued on August 4, 1950, and the well was to become the first major oil discovery in North Dakota. During his tenure at the University of North Dakota, Nick taught geological engineering and designed many courses in geology, mining engineering, and Russian. From 1961 to 1963, he lived in Tripoli, Libya, where he helped organize the geology department at the University of Libya.

Nick was also a major force in incorporating the geological engineering department into the Geology Department at the University of North Dakota, and he was instrumental in starting the extensive mineral collection housed there. He retired from the University in 1975. Following his retirement, he remained active in the University community, teaching part-time, translating foreign publications using his knowledge of five languages, and attending a variety of scientific meetings and social gatherings on campus.

Kohanowski was a member of the American Institution of Mining Engineers, North Dakota Society of Professional Engineers, Sigma Xi, GEM Club, Greek Orthodox Church, and the Elks.

Nick Kohanowski is survived by his wife, Mercedes (Babe) Grand Forks; sons, Frank Igor, Wauwatosa, Wisconsin, and Nicholas Maurice, Cullman, Alabama; daughter, Tamara Ann McDermott, Tacoma, Washington; 13 grandchildren; and 2 great-grandchildren. Nick is missed by his many friends and former students.

GROUNDWATER FLOW MODEL AVAILABLE

--John Bluemle

Some of the earth science teachers who receive this Newsletter may be interested in a groundwater flow model available for loan from the State Water Commission. Groundwater flow models are used to demonstrate groundwater movement principles. The model, which was described in the November issue of The Oxbow Newsletter, the North Dakota State Water Commission's monthly newsletter, has a clear plexiglass front, which allows observers to watch how the water that is introduced into the system moves and how the water is affected by obstacles such as a pumping well.

The State Water Commission's model is relatively small, measuring 24 inches long, 12 inches high, and 1 inch thick. Associated pumping and recharge apparatuses for the model are stored in a small trunk. The whole package weighs less than 45 pounds and can easily be shipped by UPS or bus service to interested users.

The groundwater flow model demonstrates two types of aquifers: an unconfined aquifer of white sand located just below the surface, and a confined aquifer of gravel located near the bottom. The aquifers are separated by a semi-impervious clay/sand layer.

The model features a leaky lagoon, two wells that actually pump water, three injection wells, a river, a lake, several observation wells, and an artesian well. Water is introduced into the model through two inverted quart jars located at each end. Blue, green, yellow, and red dyes are added to enhance water movement patterns. The dyes also serve as visual tracers to show how contaminated water migrates.

A surprising number of physical and chemical groundwater concepts can be demonstrated with the model. A manual that accompanies the model describes 28 concepts that a teacher can demonstrate. People interested in learning more about the groundwater-

flow model or in purchasing a model for their own educational program should contact Dennis Nelson at 701-224-4833 at the Water Commission.

Incidentally, many of our readers may not be familiar with the Water Commission's newsletter. The Oxbow Newsletter always includes several interesting items and I'd encourage anyone interested in North Dakota's water-related issues to subscribe to it. The editor is Melissa Miller, the address is State Water Commission, 900 East Boulevard, Bismarck, ND 58505, and the phone number is 701-224-2750.

THE NORTH DAKOTA GEOLOGICAL SURVEY'S FOSSIL STUDIES PROGRAM

--John W. Hoganson

The State Legislature gave the North Dakota Geological Survey the statutory responsibility to "effect a complete account of the State's paleontological resources." Recently, there has been a renewed interest in the state's fossils. This has been prompted by the realization that many specimens have been taken out of North Dakota by non-resident collectors and that many important fossil sites were being destroyed by untrained collectors and by industrial activities before the sites and specimens could be adequately studied. In response to these concerns and to address the need to learn more about the organisms that inhabited North Dakota in the past, the NDGS inaugurated a Fossil Studies Program in 1983. The objectives of the program include five primary goals, each of which I will discuss briefly.

I. Monitoring paleontological activities in North Dakota.

Because North Dakota has many important fossil sites and potentially productive fossil areas, our state has been the focus of fossil studies by many non-resident scientific groups. Last summer alone, at least five such groups (Milwaukee Public Museum, University of California-Berkeley, Minnesota Museum-St. Paul, Cleveland Museum, and Yale University) were actively exploring for and collecting fossils in southwestern North Dakota. Before our Fossil Studies Program was developed it was unlikely that state officials would have even known that these groups were working in North Dakota.

One mechanism by which the NDGS is now monitoring fossil studies in North Dakota is through Memoranda of Agreements with the U.S. Forest Service and the North Dakota Historical Society. The U.S. Forest Service issues permits for fossil studies on federal lands in North Dakota. The State Historical Society is the permit-granting agency for fossil studies on state-owned lands (because, by law, fossils are considered to be cultural resources in North Dakota). Through these agreements the NDGS now plays an active role in the permitting process by evaluating the permit applications and recommending to the Forest Service and the Historical Society whether permits should or should not be granted. All three agencies have a mutual interest in the management of the state's paleontological resources and the agreements provide a tight network of communication between the agencies. The agreement with the Historical Society is cost-effective management of the state's personnel because paleontological expertise, not available at the Historical Society, is provided by the NDGS to fulfill one of that agency's mandates. The agreements allow the NDGS to keep track of paleontological activities on federal and state-owned lands in North Dakota. We are currently in the process of working out a similar agreement with the Bureau of Land Manage-

ment, the other federal agency that has jurisdiction of some federal lands in North Dakota.

II. Identifying, mapping, and assessing the significance of North Dakota's fossil sites and computerizing of that information.

The ultimate objective of this phase of our Fossil Studies Program is to identify, map, and assess the importance of all fossil sites in North Dakota. We are accomplishing this through literature review and field studies. We obtain additional site information through our agreements with the U.S. Forest Service and the State Historical Society. Individuals who have federal or state permits are required to provide information to the NDGS about the sites they discover. Data sheets are compiled for each site. The locations of the sites are plotted on county maps (scale ½" to a mile) and information is compiled on location, type, and age of fossils, etc. The maps and files are continually updated as new sites are discovered or more information about a particular site is obtained. We are in the process of entering these data into our computer for ease in recovery. One of the purposes of this aspect of our program is to enable us to supply information to other state and federal agencies so they can take the state's paleontological resources into consideration in their resource management plans. We have provided this information to the Bureau of Land Management and we are currently working on a similar report for the U.S. Forest Service. This information is considered confidential, however, and is provided only to qualified individuals or agencies.

III. Conservation and preservation of significant fossil sites and specimens.

One of the Survey's mandates is to collect and care for North Dakota fossil specimens. Over the years this has been accomplished through a cooperative effort with the faculty in the University of North Dakota Geology Department. Until recently the NDGS did not have a paleontologist on staff and the fossil collection was curated mostly by faculty members in the Geology Department. At times the NDGS provided stipends to curate North Dakota fossils. Consequently, the fossil collection here in Leonard Hall on the UND campus is the largest and best curated collection in the state.

The NDGS and UND Geology Department have recently reconfirmed our mutual commitment to care for North Dakota fossils and have designated our facility as the State Fossil Repository. Such a facility is needed in North Dakota to prompt non-resident scientists to leave some specimens in state. As a result of the agreement with the U.S. Forest Service, researchers on federal lands under their jurisdiction will be required to deposit a representative sample of the fossils they collect with the NDGS to be curated into the State Fossil Repository.

Another goal of the Fossil Studies Program is to seek protection for significant sites that contain unique or rare fossil specimens. To this end, the NDGS has entered into a formal agreement with the North Dakota Parks and Recreation Department to assure effective protection of the state's significant fossil sites. The North Dakota Parks and Recreation Department is the state agency responsible for securing an adequate system of nature preserves and natural areas in North Dakota. This includes areas of paleontological significance. The NDGS recommends sites to be nominated for natural-areas status because of their paleontological importance and assists Parks and Recreation with land-owner contact, etc. We also provide information about fossil sites in existing nature preserves and natural areas and tracts being considered for nomination to protected status for other than paleontological reasons. So far only one area in

North Dakota has been designated as a nature preserve because it is an important fossil site, but our program with Parks and Recreation was only recently initiated and we hope to nominate at least two fossil sites for natural-areas status in 1987.

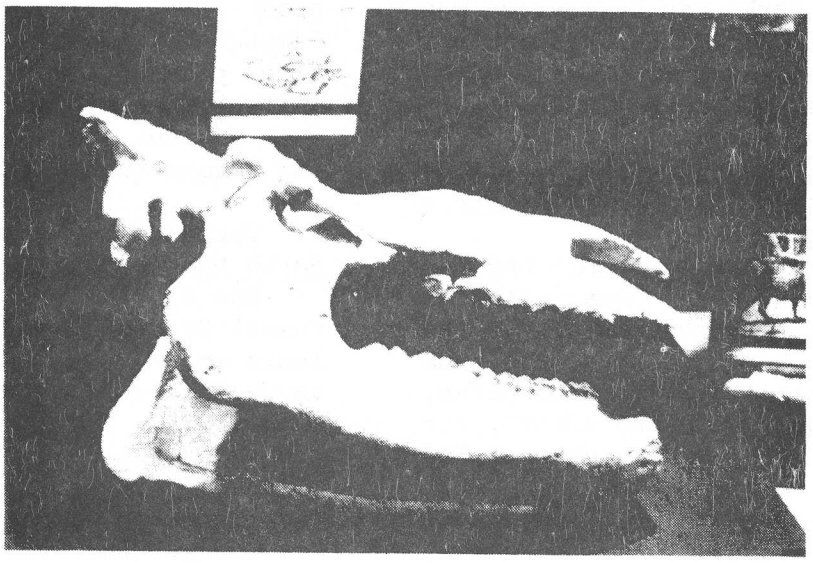
IV. Education and promoting awareness of the importance of North Dakota's paleontological resources.

One of the most enjoyable and rewarding aspects of the Fossil Studies Program is contact we have with the citizens of North Dakota. Numerous inquiries, especially from children, but also from interested adults, are received by the NDGS each year for information pertaining to North Dakota fossils. Information about North Dakota fossils is also requested by people from other states and countries. In addition, many fossil specimens are either brought or sent to us for identification. Answering these inquiries is an important function of the program.

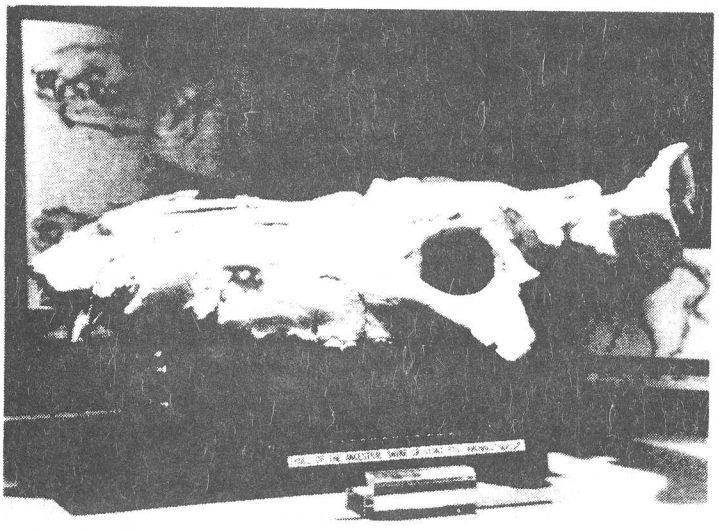
The educational aspect of the program also includes presenting lectures to the public (I recently talked to the North Dakota Geological Society in Bismarck about Oligocene fossils) and writing newsletter articles such as this. The display of North Dakota Oligocene fossils, including an exquisite saber-toothed cat skull, that we recently put on exhibit here in the museum area of Leonard Hall, will be viewed by hundreds of people each year. The display illustrates our commitment to provide the public with information about the ancient life of North Dakota. In addition, the NDGS will also provide assistance to other state groups planning fossil displays such as the one being considered by the Bowman County Historical Society.

V. Technical studies concerning North Dakota fossils.

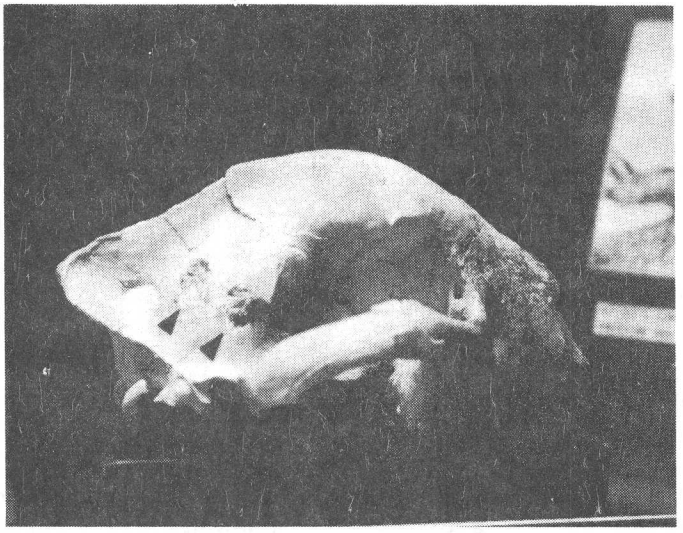
One of the major goals of the Fossil Studies Program is simply to learn more about North Dakota fossils through detailed investigations. Two such studies are currently being conducted by the NDGS. The study of the Oligocene fossils of North Dakota (see December 1984 Newsletter) with Dr. George Lammers of the Manitoba Museum of Man and Nature is near completion and the report will be available from the NDGS next year.
Dr. Alan Cvancara, UND Geology Department, and I are investigating the vertebrate fossils (primarily sharks teeth) from the Cannonball Formation. Preliminary results of that study will be presented at the North Dakota Academy of Science meeting in April. The objectives of these and future investigations are to find out what kinds of organisms inhabited North Dakota at different times in the past and the types of environments and climates in which they lived.



Skull and lower jaw of the hornless, running rhinoceros Caenopus. This animal was about the size of and similar in proportion to the American tapir.



Skull of the ancestral swine or giant pig, Archaeotherium.



Skull of Dinictis, an early saber-tooth cat or tiger. Dinictis was one of the few beasts of prey that existed in southwestern North Dakota in the Oligocene.

Fossils from near Dickinson, North Dakota. All the specimens shown here are of animals that lived during Oligocene time, about 32 million years ago. The fossils are on display in the lobby of Leonard Hall on the University of North Dakota campus. This display was put together through the combined efforts of John Hoganson of the NDGS and George Lammers, of the Manitoba Museum of Man and Nature in Winnipeg.

OLD NDGS RECORDS NOW AVAILABLE

--John Bluemle

I was told recently, by Sandra Beidler, an archivist in the Department of Special Collections at Chester Fritz Library here at UND, that certain historical records of the NDGS were recently accessioned into the University of North Dakota Archives and are now available for research. The Survey records consist primarily of Dr. Arthur G. Leonard's field notebooks and the photographs he took to illustrate his survey work in western North Dakota. Leonard's handwritten field observations date from 1905 to 1922 and delineate his survey investigations in his capacity as State Geologist of North Dakota. Leonard surveyed lignite beds in North Dakota and eastern Montana and topographically mapped several areas in cooperation with the U.S. Geological Survey. He also studied the glacial deposits and resultant drainage changes, he collected fossil specimens to determine the age of lignite-bearing strata, and he surveyed for oil and gas possibilities and for deposits of gravel and clinker, building stone, cement rock, and brick clays. The results of Dr. Leonard's investigations are described in several bulletins and articles.

The NDGS records also include Howard E. Simpson's field notes of the Mohall gas survey, in addition to his survey work on oil shale activity and groundwater resources. Biennial Reports from 1901 to 1936 and a paper entitled, "Work of the North Dakota

Geological Survey, 1899-1936" give a complete general account of the accomplishments of the survey as well as a picture of its difficulties in securing adequate funding appropriations from the state legislature. Finally, the new records contain Wilson M. Laird's reports, which he did for the American Year Book, 1943-1949, material on the Martin River Glacier expedition, 1962-1963, and the transcript of Hearing: Amerada Petroleum Corporation Application for Well Spacing, 1952.

HUMMOCKY COLLAPSED GLACIAL TOPOGRAPHY IN NORTH DAKOTA

--John Bluemle

In past Newsletters I've discussed a variety of landforms that are found in North Dakota. This issue I'll deal with one of the more interesting and widespread glacial landforms, collapsed glacial topography ("dead-ice moraine"), which formed at the end of the Ice Age, in Late Wisconsinan time as the last glaciers were melting, about 12,000 years ago. I'll start by saying a little about how glaciers move and the materials they deposit, then I'll explain how the collapsed topography formed.

When the glaciers advanced over North Dakota, they carried great amounts of debris and, when they stopped advancing, they deposited thick layers of sediment. The glaciers plowed up the soil and loose rock as they moved over the land, plucking and gouging boulders from outcrops, carrying this material forward, and grinding it into a mixture that ranges from clay-size particles through sand, gravel and boulders. This mixture of materials, which constitutes glacial sediment, is commonly referred to as "till." Typically, in North Dakota the clayey fraction of the till forms a sort of stiff matrix that contains the larger particles of sand, gravel, and boulders. The way in which the till was deposited, and the amount of it that was available to be deposited, are the two main factors that determine the type of glacial topography that formed in any given area. When the glaciers advanced over North Dakota, they shaped a variety of landforms.

In some places, as the glacier advanced, it abraded the surface, smoothing and planing it, much as sandpaper is used to smooth wood. In other places though, as the ice passed over irregular topography, it plastered a thin layer of till on the surface, more in the depressions, less on the hills, so that the resulting landscape was more subdued than was the surface prior to glaciation.

In certain glaciated areas southwest of the Missouri River in North Dakota, only thin patches of glacial sediment lie on the bedrock surface. Some of these places were glaciated so long ago that, even if thick layers of glacial sediment were once present, they were removed by erosion in the long period of time since then. In some other places, the glaciers may have deposited only small amounts of sediment. Wherever the amount of till is too thin to greatly modify the shape of the underlying preglacial surface, the topography is essentially non-glacial. In some of these areas of thin glacial sediment, the only evidence of glaciation is an occasional boulder or a patch of till or gravel.

Over much of northern and eastern North Dakota, moderate to large amounts of till were deposited from the glacial ice when it melted. These thick layers of glacial sediment formed a rolling, in some places rugged, landscape that geologists refer to as "hummocky, collapsed glacial topography." Much of eastern and northern North Dakota is dominated by this glacial landform.

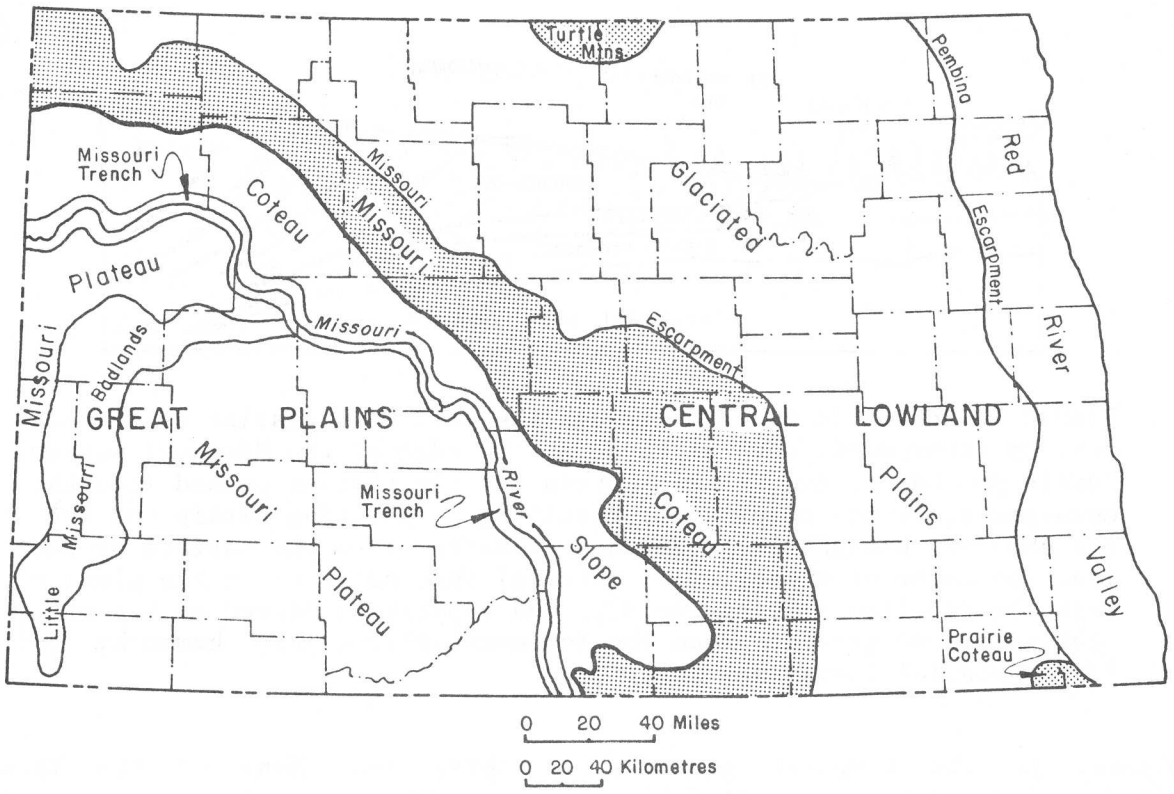


Figure 1. The shaded areas are those in which high-relief hummocky collapsed glacial topography occurs. This glacial landform is sometimes called "dead-ice moraine."

The most extensive area of rugged topography that was formed by glaciers in North Dakota is the hummocky collapsed glacial topography found on the Missouri Coteau, which extends from the northwest corner to the south-central part of the state. Other areas are the Turtle Mountains in north-central North Dakota and the Prairie Coteau in the southeast part of the state (fig. 1). The landforms of the Turtle Mountains are similar in most ways to those on the Missouri Coteau and Prairie Coteau, but the Turtle Mountains have a woodland cover, the result of receiving several inches more precipitation each year than the other areas. Even though North Dakota's vast tracts of hummocky collapsed glacial topography are not generally good farmland, they include a lot of excellent rangeland and thousands of undrained depressions--lakes, ponds, and sloughs--wetlands that serve as important nesting and feeding areas for waterfowl.

The landscapes of the three areas formed when the glaciers advanced against and over steep escarpments as they flowed onto the uplands (fig. 2). The land rises as much as 650 feet in little more than a mile along parts of the Missouri Escarpment, which marks the northeastern edge of the Missouri Coteau. Similar prominent escarpments border the Prairie Coteau and the Turtle Mountains. When the glaciers advanced over these escarpments, the internal stress that resulted in the ice caused shearing (fig. 2). Large amounts of rock and sediment beneath the glacier were forced into the ice and to its surface along shear planes in the glacier.

Eventually, the glaciers stopped moving and stagnated over the

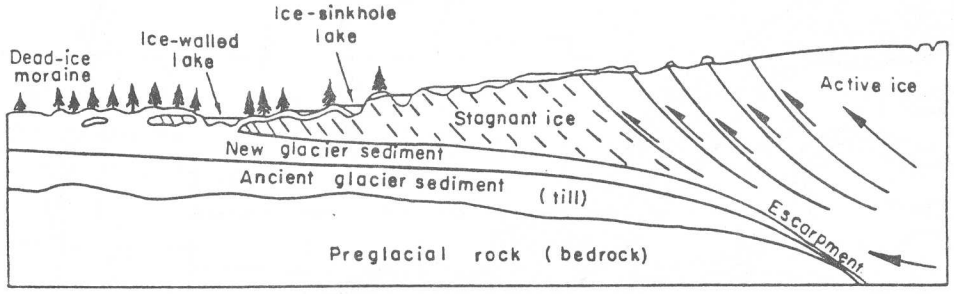


Figure 2. Schematic diagram through the edge of a glacier as it moved over an escarpment, such as those at the edge of the Missouri Coteau, Turtle Mountains, and Prairie Coteau. As the glacier pushed into the escarpment, it was compressed, resulting in shearing within the ice. The shearing brought large amounts of material to the surface of the ice. The cover of superglacial material that built up on the glacier kept the ice from melting rapidly, and vegetation formed on top of the debris-covered glacier. When the ice eventually melted, hummocky, collapsed glacial topography resulted.

uplands. As the stagnant glaciers melted, large amounts of debris (rock, soil, etc.) that had been dispersed through the glacier tended to accumulate on top of the ice. As the clean ice at the top of the glacier melted away first, debris became concentrated at the ice surface. The resulting cover of sediment was quite thick and it helped to insulate the underlying ice so that it took several thousand years for it to melt. In places where the debris on top of the ice was thickest, the glacier melted most slowly. Over nearby areas of the Glaciated Plains (see fig. 1), where little or no insulating debris cover developed on the glaciers, melting was rapid and the land was free of ice in a relatively short time. As the stagnant ice on the uplands slowly melted, and the glacier surface became more and more irregular, the soupy debris on top of the ice slumped and slid, flowing into low areas, forming high-relief, hummocky, collapsed glacial topography, the hilly landscape we see today over the Turtle Mountains, Missouri Coteau, and Prairie Coteau.

Thousands of lakes and sloughs of various sizes are found in these three areas. Many of the lakes and sloughs occur in the depressions, known as prairie potholes, which are located between hummocks that resulted when the highly fluid glacial sediment slid into place as the ice melted. Many more of the prairie potholes formed when buried or partly buried blocks of stagnant glacial ice melted, causing the overlying materials to slump down, forming depressions that are sometimes referred to as potholes. Potholes are also abundant over the less hilly areas of the Glaciated Plains, as well as in areas of hummocky collapsed topography. Figures 3, 4, 5, and 6 are photos of typical hummocky collapsed topography.

In places, the blanket of debris on top of the stagnant glacial ice in areas such as the Turtle Mountains became so thick that the cold temperatures of the ice beneath could no longer affect the surface of the ground. In these areas, trees, grasses, and animals established themselves. As the environment gradually stabilized, water collected in lakes in depressions on the debris-covered glacier. Most of the water in the lakes came from runoff from local

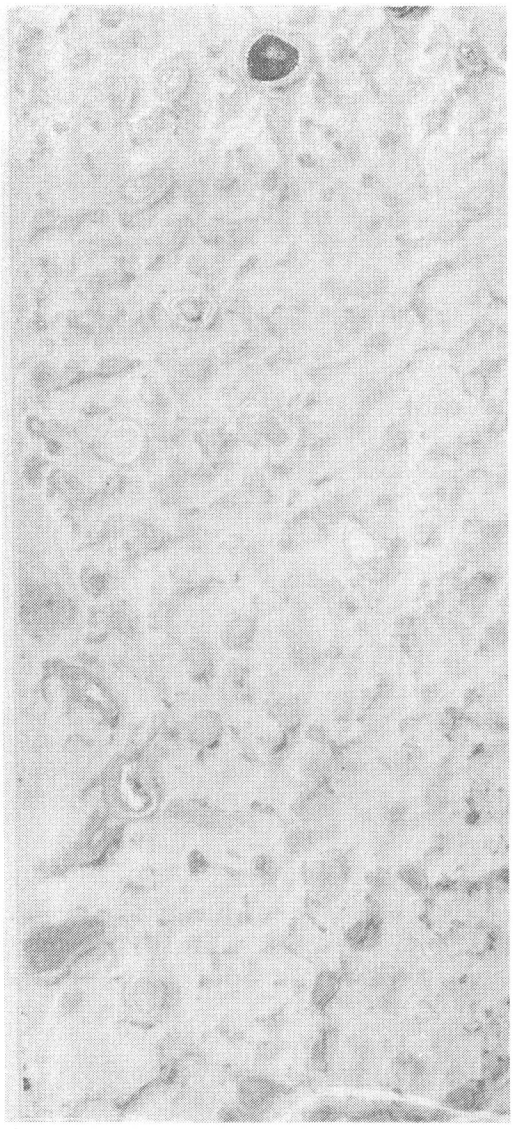


Figure 3. Vertical aerial photo showing simple mound-like hummocks in an area of collapsed glacial topography in Mountrail County. The area shown is 0.8 miles wide. North is to the top of the photo.

precipitation rather than meltwater from the glacier. Precipitation at the time was much greater than it is today, probably between 25 and 50 inches of rainfall a year, and the mean annual temperature was a few degrees cooler than it is today.

Fish and clams and other animals and plants thrived in the lakes. Surrounding the lakes and streams, the debris on top of the stagnant glacier was forested by spruce, tamarack, birch, poplar, aquatic mosses, and other vegetation, much like parts of northern Minnesota today. The stagnant-ice environment in the three areas was in many ways probably similar to stagnant, sediment-covered parts of certain glaciers in south-central Alaska today. It is likely that prehistoric people roamed about on the debris-covered glaciers in North America without realizing that the ice lay only a few feet below

Figure 4. Hummocks (commonly referred to as "doughnuts") in an area of hummocky collapsed glacial topography. This oblique air view is near Denhoff in Sheridan County.

their feet (or, if they did realize it, they accepted it as a normal situation, which, I suppose, it was at that time). It took as long as 3,000 years for the debris-covered ice to melt after the glaciers stagnated about 12,000 years ago, but eventually all of the buried ice melted, and all of the materials on top of the glacier were lowered to their present position, resulting in the hilly areas of hummocky collapsed glacial topography we see today.

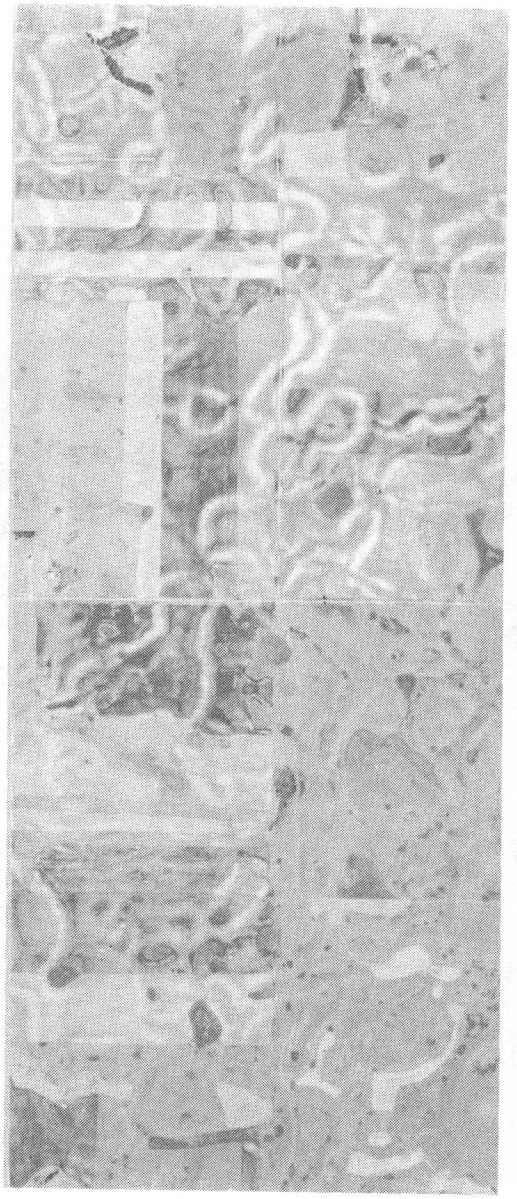


Figure 5. Vertical aerial photo showing ring-shaped hummocks ("doughnuts") in an area of collapsed topography in Mountrail County. The area shown here is 0.8 mile wide and north is to the top of the photo.

Figure 6. Irregular, linear disintegration ridges and depressions in an area of hummocky collapsed moraine ("dead-ice moraine") on the Missouri Coteau in Ward County. This area has relatively low relief and is farmed; other nearby areas are much too hilly for farming and are used mainly for pastureland.

COMMENTS

Do you have questions, comments, or suggestions regarding the Newsletter 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, University Station, Grand Forks, ND 58202-8156.

CHECKLIST FOR NEW PUBLICATIONS

See pages 27-28 of this Newsletter for descriptions of publications.

____RI-84 ($3.00) Structure and Stratigraphy of the Frobisher-Alida and Ratcliffe Intervals, Mississippian Madison Group, North-Central North Dakota

____RI-85 ($3.00) Madison Subcrop--North-Central North Dakota

____($15.00/volume) North Dakota Well Schedule, Volumes 1 and 2

____MS-66 ($7.00) North Dakota Stratigraphic Column; Sheet 1: colored column; Sheets 2 and 3: Sample logs. Cost is $7.00 for all three sheets or $3.00 for Sheet 1 alone

____MS-67 ($3.00) Oil Exploration and Development in the North Dakota Williston Basin: 1984-1985 Update

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(December, 1986)

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