NEWSLETTER
NDGS

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CONTENTS

COVER PICTURE

Sand dunes in eastern Ransom County in southeastern North Dakota (see article on page 37). These dunes are located in section 1, Township 135 North, Range 54 West near Anselm (about 145 miles northeast of Lisbon). Relief in the area is from 40 to 50 feet. The dunes are mainly grassed over or wooded, but fresh blowouts do occur in a few places. Since dunes are composed, virtually entirely, of well-sorted sand, the occasional cobble or small rock that is found in the area is usually a Native American artifact (stone hammer, tepee stone, projectile point, butchering tool, etc.).

Photo by John Bluemle.

SURVEY ACTIVITIES

--John Bluemle

Our geologists are involved in a variety of projects that are in varying stages of completion. I am writing a report on the geology of Renville and Ward Counties, which I hope to finish this winter. I'm almost finished with a revised version of a new geologic highway map to replace one that we published ten years ago. We ran out of copies of the 1977 edition, so I decided to compile a new one and include more information than was on the original version. Last summer, with help from two University of North Dakota geology graduate students, Mark Lord and Nate Hunke, I used a backhoe to make some trenches in two of the long, linear drumlins in the Velva area, including the largest one, Hogback Ridge, which extends from near Verendrye to Balfour. The excavations were quite interesting and we'll have more to say about them later.

Tom Heck, who has been doing some work for the NDGS for the past several months, recently completed a map of North Dakota's Precambrian structure that we plan to publish early in 1988; this map was funded by the United States Geological Survey. Tom also has written a short report on the Devonian Dawson Bay Formation in Dolphin Oil Field, Divide County. We will publish that report soon.

Ken Harris recently completed a report: "Documentation for the Data Formats and Programs Used For Computer Assisted Glacial Stratigraphy at the North Dakota Geological Survey" (see the article on page 13 in this Newsletter). We intend to provide the program on diskette with the report to people who are interested. Ken is also continuing his work with the Atlas Series (see article on page 18).

Ed Murphy is involved in our COGEOMAP Project, which will enable us to get a much better understanding of the Middle Cenozoic stratigraphy and eventually the older exposed rock units in western North Dakota. He is working on the project with Nels Forsman, a sedimentary petrologist/geochemist and Richard LeFever, sedimentologist (both with the UND geology department), and John Hoganson, NDGS paleontologist. Ed has been studying several North Dakota landfills, in cooperation with the State Health Department, investigating the geology at each site to determine potential and existing contamination problems. He is also involved in a three-year study of possible groundwater contamination problems from the application of Tordon. Ed's work on the geology of Dunn County continues, and he expects to have a report ready to publish sometime in 1988.

John Hoganson is currently working with Alan Cvancara, professor in the UND geology department, on a study of shark's teeth found in the Cannonball Formation in North Dakota and also on other vertebrates in the Cannonball. John is writing a report on Oligocene stratigraphy and fossils with George Lammers of the Manitoba Museum of Man and Nature. We hope to have that report ready to publish by mid 1988. John is working with Alan Ashworth, geology professor at NDSU, on several papers, including one on the Monte Verde Paleo Indian site and another on insect fossils.

Randy Burke also has a number of projects underway. He is involved in a study of the diagenesis and depositional environments of the Devonian Duperow Formation, especially on the Billings Anticline. He is working on cross sections of the Devonian and isotope analysis of cements in the Duperow. Randy submitted a paper to the International Coral Reef Symposium, which will be held in Australia in August, 1988; whether he will attend the conference depends somewhat on available funding. He expects to present a paper at the meeting of the Rocky Mountain Section, American Association of Petroleum Geologists in Bismarck next August, and he may be involved in the compilation of a field-trip guide for that meeting. Randy will also be involved with the Core Workshop volume for the Bismarck AAPG meeting.

Our engineer, Marv Rygh, plans to begin sampling crude oils from various geologic formations in North Dakota in an attempt to learn more about the source rocks and migration paths of the oil. This is a joint venture with the Canadian Geological Survey; they will perform the laboratory analyses for us in their Calgary office. Marv also plans to begin detailed well-log analyses, along with core analyses, on the Billings Anticline. He has been working with the North Dakota State Land Department, doing reservoir engineering studies of some of the state's oil leases.

Julie LeFever lately has been finishing three manuscripts of preliminary work on the Nesson Anticline. Currently, the data for the Nesson is complete from Beaver Lodge Field to its southernmost extension. Over the next few months the northern portion of the anticline will also be examined in detail, and the study finalized. In addition, preparation is underway for a paper on the Newburg/South Westhope oil fields, co-authored by Richard LeFever, that will be included in the American Association of Petroleum Geologists (AAPG) Atlas of Oil and Gas Fields to be published in 1988. She is also involved in a study with Marv Rygh of the petrophysical properties of the Madison reservoirs of north-central North Dakota. This is a continuation of Report of Investigation 84, which was published in 1986. Work is slowly progressing on her study of the Kisbey Sandstone.

David Brekke is currently working on an assessment of radon potential in North Dakota from a geologic viewpoint (see article on page 24 in this newsletter). This project is in cooperation with the State Department of Health. Another activity is a continuation of his study of the geochemistry of Cretaceous shales in eastern North Dakota. David expects to submit another 40 samples to the USGS for trace-element analysis soon. Evaluation of results from previous analyses is in progress. A spinoff of the project is a cooperative agreement with the USGS-Water Resources Division studying extractable trace elements in soils and shales.

Dave Fischer is in the late stages of preparing a number of manuscripts. Along with Lee Gerhard and Sid Anderson, he is involved in updating a paper on the petroleum geology of the Williston Basin. The paper has been invited to be included in the American Association of Petroleum Geologists (AAPG) Petroleum Basin series. Dave is also cooperating with Lee and Sid in preparing a Williston Basin overview paper to be included in the Rocky Mountain Association of Geologists (RMAG) Carbonate Reservoirs of the Rocky Mountains volume. He is helping to prepare a study on Medicine Pole Hills Field, with Lee Gerhard and Tom Heck, also to be included in the AAPG Atlas. That atlas will also include an updated study on Glenburn Field, authored by Dave, Roger Borchert, Bob Johnson, and Lee Gerhard. A version of the Glenburn Field study will also be included in the RMAG reservoir volume.

Sid Anderson is Acting State Geologist for the North Dakota Geological Survey. It is certainly a full-time job just administering the Survey, but Sid has managed to continue at least some of his research projects. I'll mention just a few of his recent activities.

Sid has been to a number of meetings over the past few months. He attended the meeting of the Interstate Oil Compact Commission (IOCC) in Santa Fe early in December. This is an annual meeting of representatives from the oil-producing states. Several of the governors, including Governor Sinner, also attended this meeting;

Governor Sinner is currently chairman of the Commission. Sid serves on the Geothermal and Research Committees of the IOCC. In September, Sid attended the Rocky Mountain Regional Meeting of the American Association of Petroleum Geologists (AAPG) in Boise. Next year's AAPG meeting will be held in Bismarck in August, and Sid is involved in helping plan for that meeting. Sid (and I) attended the annual Geological Services meeting of the Manitoba Energy and Mines in Winnipeg in late November. We expect to be able to cooperate with the Manitoba Energy Branch in a number of projects that will mutually benefit North Dakota and Manitoba.

Sid is in the process of finishing several reports and articles. They include the following: "Geology of the Williston Basin (United States Portion)" (with Lee Gerhard--this will be part of a Decade of North American Geology volume being published by the Geological Society of America); "Structural History of the Nesson Anticline" (with Lee Gerhard and Julie LeFever--part of a volume entitled Williston Basin: Anatomy of a Cratonic Oil Province published by the Rocky Mountain Association of Geologists). He is also working with Bob Lindsey, Julie LeFever, Richard LeFever, and Lee Gerhard on a paper on the Nesson Anticline, which will be presented at the annual AAPG meeting in Houston next March along with another paper titled "Structural Evolution of the Central and Southern Portions of the Nesson Anticline, North Dakota."

GROUNDWATER SYMPOSIUM TO BE HELD

A Groundwater Symposium is planned for March 29-30 at the Kirkwood Motor Inn, Bismarck. The meeting is being organized by the North Dakota State University Groundwater Task Force with help from a number of state and federal agencies, including the NDGS. Talks that will be presented include topics such as the state's groundwater resource, natural and man-made contamination, health aspects of groundwater contaminants, laws and regulations concerning water quality, reports of ongoing research, and management considerations to minimize contamination.

For additional information, please contact:

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--Sid Anderson

WILLISTON BASIN OIL STUDY

The North Dakota Geological Survey is planning to participate, with the Canadian Geological Survey, in a joint study of the geochemistry and petroleum geology of oils in the Williston Basin. The purpose of the study is to identify families of oils and sources so that the resource potential and prospectivity of this region may be better understood. The study will begin with the examination of the composition of carefully chosen collections of oils from pools characteristic of stratigraphically and structurally distinctive accumulations. In zones where stacked zones occur, such as the Nesson Anticline, we will look at discrete samples from each producing zone.

We expect to report the results

jointly in a medium easily accessible to the oil industry in both Canada and the United States.

The study should be of great interest to the petroleum industry and to researchers working on both sides of the international boundary. We expect the results to be quite useful to explorationists. Recent work in Canada on the Middle Devonian Winnipegosis play has been valuable to active explorers in their evaluation of the limits of the play area.

--John Bluemle

REPRINTS OF ARTICLES AVAILABLE

Many of the articles that appeared in past issues of the NDGS Newsletter have continued relevance. Some of them are essays describing specific aspects of North Dakota geology, some are historical notes, and others deal with particular environmental problems, mineral production procedures, or other topics that really don't become out-of-date as do those articles that deal with current Survey activities. I've compiled a listing of many of these articles, along with a short comment on the content, unless that's obvious from the title. Copies of the articles are available from the North Dakota Geological Survey.

A. Articles describing geologic processes and landforms in North Dakota

North Dakota Scoria (how scoria forms)	Dec., 1976
The Red River Valley (the geologic origin of the Red River Valley)	Dec., 1977
The Glacial Lake Agassiz (origin, history, and characteristics of the lake)	Dec., 1977
The Little Missouri River Badlands (about the origin of the badlands)	June, 1978
A Really Big Souris River Flood? (catastrophic flooding at the end of the Pleistocene)	Dec., 1979
Landslides and the Landslide Problem in North Dakota (why they occur; problem areas in North Dakota)	Dec., 1979
Glacial Thrusting as a Landforming Mechanism in North Dakota (an important glacial process)	Dec., 1979
A Short Sketch of North Dakota's Geologic History (quite generalized)	Dec., 1980
Earthquakes in North Dakota (locations where earthquakes have occurred, etc.)	June, 1981
The Origin of Devils Lake (why the lake formed)	Dec., 1981

Permafrost in Southwestern North Dakota
(evidence for permanently frozen ground during the Pleistocene) — Dec., 1982

Fluctuating Levels of Devils Lake
(geologic reasons for changes in the lake level) — June, 1983

Freckled Land
(unusual land markings in Towner County) — Dec., 1983

Subglacially Molded Surface in McHenry County
(drumlins and other streamlined glacial features) — June, 1984

Deflation Basin Stratigraphy in Southwestern North Dakota
(Late Pleistocene wind erosion) — Dec., 1984

Beaded Shelterbelts
(unusual growth patterns in shelterbelts in the Red River Valley due to salt seepage) — Dec., 1984

Drainage Development in North Dakota
(changes in drainage during the Pleistocene) — June, 1986

North Dakota's Mountainous Areas: The Killdeer Mountains and the Turtle Mountains
(a general discussion of the geology of two areas) — June, 1986

Hummocky Collapsed Glacial Topography in North Dakota
(landforms that resulted from large-scale glacial stagnation at the end of the ice age) — Dec., 1986

B. Articles Dealing with Various Aspects of Paleontology

Fossils in North Dakota
(various fossils that occur) — June, 1977

Fossil Dinosaur Bones Found in Western North Dakota
(a triceratops discovery) — Dec., 1981

Fossil Insect Studies Concerning the Climatic and Environmental Evolution of North Dakota and Adjacent Areas — Dec., 1982

The Fitterer Quarry: An Unusual and Significant Oligocene Mammal Fossil Occurrence in Stark County — Dec., 1984

North Dakota State Fossil — June, 1986

C. Historical Notes about North Dakota Geology

Geography Lesson
(observations by a geologist about life in North Dakota during the 1930s drought years) — Dec., 1977

North Dakota Oil and Gas Development History and Resources
(outlines the growth of the state's oil industry — June, 1981

Excerpts From Early Exploration Efforts
(notes from the early 1900s) — June, 1981

The Promotion of Early Drilling Ventures
(account of oil exploration in the years before it was actually discovered in North Dakota) — Dec., 1984

Gold in North Dakota
(the search for gold in North Dakota over the years) — June, 1985

"Eruptions" on Black Butte (Slide Butte)
(summary of events on Black Butte in the early 1930s) — Dec., 1985

The Geology Building
(the building of Leonard Hall at UND) — June, 1987

D. Articles Dealing Mainly with Mineral Resources

The Origin of Oil and Gas
(a discussion for laymen) — Dec., 1978

North Dakota's Red Wing Creek Field
(discusses the theory that a meteor formed the oil-trapping mechanism at Red Wing Creek) — June, 1975

Production Performance Curves
(what can be learned by studying production records) — June, 1982

The Effect of Oil and Gas Drilling Fluids on Shallow Groundwater in Western North Dakota — Dec., 1981

Potash in North Dakota
(information on potash) — Dec., 1976

Potash Resources
(information on potash) — June, 1978

Groundwater in North Dakota--An Overview
(deals with the occurrence of groundwater) — June, 1979

Cement Rock in North Dakota
(the NDGS's ongoing search for a suitable source) — Dec., 1978

Uranium in North Dakota (history of uranium mining and how it occurs)	June, 1976
North Dakota Lignite--General Geology (how the lignite formed)	Dec., 1976
Oil Production From Kaskaskia Rocks in North Dakota's Williston Basin	June, 1982
Application of Analytical Equipment to the Natural Resources of North Dakota (use of the electron microscope and other equipment)	June, 1983
Evaluating Abandoned Surface-Mined Lands in Western North Dakota	Dec., 1983
Enhanced Oil Discovery (ways of getting more oil of the ground)	Dec., 1983
Protecting North Dakota's Groundwater Resources	June, 1984
What is a Unitized Oil Field?	Dec., 1984
Stripper Wells (explains what stripper wells are)	June, 1985
Gold in North Dakota (known occurrences of gold)	June, 1985
Geochemistry of Shales (composition of North Dakota shales)	Dec., 1985
The Variety of Diversity of Oil Fields in North Dakota (characteristics of some of the larger oil fields)	June, 1986
North Dakota Industrial Mineral Resources (non-fuel mineral resources)	June, 1986

E. Articles Dealing with the Regulation and Production of Mineral Resources

The Separation of Surface Mineral Estates--The Severed Mineral Rights (explains the background of this problem)	June, 1980
A Possible Solution to Rectangular Spacing Units (rectangular units sometimes cause problems)	Dec., 1980
A Brief Review of the History of North Dakota Conservation Law (outlines pertinent legislation)	June, 1981

The Role of the NDGS in the State's Solid Waste Management Program — June, 1983

Termination of Mineral Interest (statement of claim) — June, 1985

F. Articles of General Interest

Rock and Mineral Collecting in North Dakota (the kind of rocks and minerals that occur) — June, 1977

Cracks in the Ground (large desiccation cracks in southeastern North Dakota) — Dec., 1977

Why Do We Have Ice Ages? (speculation on the causes of Ice Ages) — Dec., 1978

The Length of Geologic Time (brief history of methods used to measure geologic time) — June, 1979

The Effect of the Mt. St. Helens' Eruption on North Dakota (very little--but eruptions have been important through geologic time) — June, 1980

A Perspective on Climate Change: the Chilean Connection (climatological research; climate change) — June, 1981

How Geology Affected Where People Settled in North Dakota — June, 1983

Why Do We Save All Those Rocks? (rocks stored in the Survey Core Library) — June, 1983

Some Thoughts About Geologic Maps (how geologic maps work; getting the most out of them) — Dec., 1985

LANDFILL PROJECT

--Ed Murphy

This past summer, the NDGS entered into a cooperative project with the North Dakota State Department of Health (NDSDH) to study the groundwater quality beneath and adjacent to landfills in North Dakota. The Health Department gave us a list of potential landfills they were interested in evaluating; from these we selected six municipal landfills and one industrial dump site. An electrical resistivity survey was run at each of the sites to guide us in the placement of our piezometers (monitoring wells). We augered a total of 2,350 feet in and around these landfills and installed a total of 85 piezometers. Groundwater samples we took this fall are currently being analyzed by the NDSDH Lab.

Our purpose in this study is to determine the extent of groundwater contamination and any associated health risks at each site. We also hope to apply what we learn from these landfill sites to the other 98 landfill sites in North Dakota (70 municipal and 28 private). Municipal and private landfills are permitted by the NDSDH. The permit applications are reviewed internally by the Health Department, by the NDGS, and by the North Dakota State Water Commission. In the future, we will be better-qualified to assess the potential risk for groundwater pollution at proposed landfill sites based upon the results of our study.

Individuals involved in the project are Steve Tillotson (NDSDH), Ken Kary, Rod Reetz, Kim Wehner (NDSDH Lab), Jeff Maletzke, and Eric Graney (graduate students in the UND geology department), and me.

Figure 1. View to the southeast, over the Wishek landfill, located on the edge of a meltwater channel. Town of Wishek in the background. This is one of the landfills we monitored.

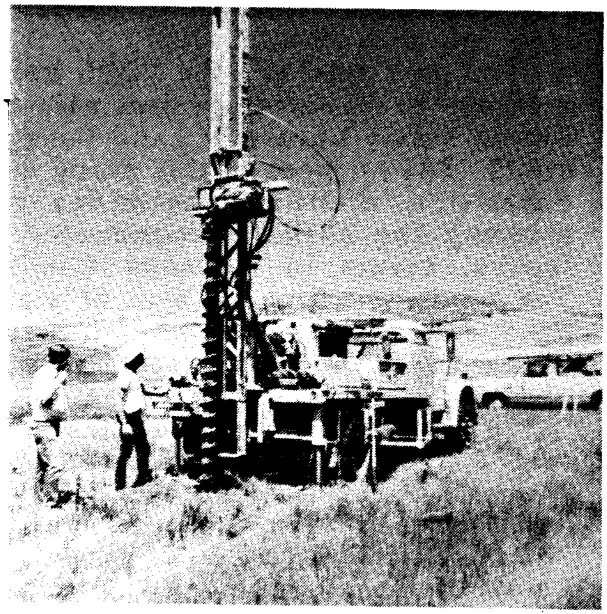


Figure 2. Drilling in the old Williston landfill. Steve Tillotson, North Dakota State Department of Health is on the left, Eric Graney, UND geology graduate student, operating the drill rig.

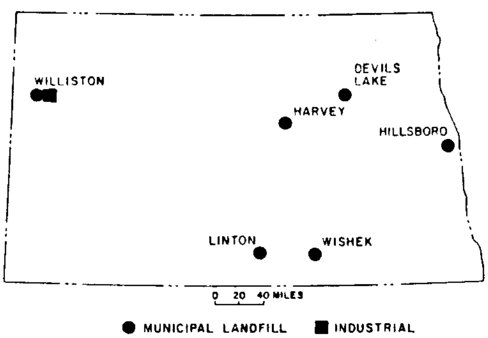


Figure 3. Locations of selected landfills included in this study.

PESTICIDE PROJECT

--Ed Murphy

In recent years, concern has grown that pesticides may be contaminating some of the surface water and groundwater supplies in the United States. This is an important potential problem that needs to be addressed in agricultural states such as North Dakota. To date, I am aware of only a few studies in North Dakota that have tested for these organic compounds in our water supplies (Glatt, 1985; Glatt, 1986; and Lym and Messersmith, 1987).

The past summer, the NDGS began a three- to five-year project with the United States Bureau of Land Management. The purpose of this study is to determine whether pesticides are entering the shallow groundwater on federal tracts in McHenry County. The study is within an area of stabilized eolian dunes known locally as the Denbigh Sand Hills (see article on page 36).

There are areas within the dunes that are heavily infested with leafy spurge. These areas receive heavy applications of the herbicides Tordon (picloram) and 2,4-D (2,4-Dichlorophenoxyacetic acid) to control this weed.

Thirteen piezometers were installed during the initial phase of the study. These monitoring wells were placed both within areas that have been sprayed in the past and will continue to be over the next few years and in areas which have not been and will not be sprayed.

The groundwater samples will be collected semi-annually and analyzed by Mr. Kim Wehner of the North Dakota State Department of Health Laboratory. The project involves Mr. Earl Greene of the U. S. Geological Survey (formerly with the Bureau of Land Management) and me.

References

Glatt, L. D., 1985, Groundwater investigation to determine the occurrence of picloram in selected well sites of Rolette County, North Dakota: Division of Water Supply and Pollution Control, North Dakota State Department of Health, Bismarck, ND, 35 p.

Glatt, L. D., 1986, Pesticide and herbicide survey of selected municipal drinking water systems in North Dakota: Division of Water Supply and Pollution Control, North Dakota State Department of Health, Bismarck, ND, 34 p.

Lym, R. G., and Messersmith, C. G., 1987, Survey for picloram in North Dakota groundwater: North Dakota State University Agricultural Experiment Station, J. Article, No. 1589, 24 p.

Figure 1. Earl Greene, U.S. Geological Survey geologist, taking water samples from one of our piezometers in the sandhills area near Denbigh. Note the dead vegetation from the application of Tordon and 2,4-D.

Figure 2. The left side of this photo shows an area that has been sprayed with Tordon and 2,4-D. The right side, unsprayed, is heavily infested with leafy spurge. Earl Greene, U.S. Geological Survey, is standing by the fence.

COGEOMAP PROJECT **--Ed Murphy**

Of the many buttes scattered throughout western North Dakota, approximately 20 are capped by rocks of questionable age. The majority of the butte caprocks are thought to be of Oligocene age, although a Pliocene age has been suggested for at least one of them.

This past summer, the NDGS entered into a three-year grant project with the United States Geological Survey. The purpose of this COGEOMAP project is to determine the age of these butte-capping rocks. We hope to obtain these answers by a variety of geological methods, including paleontological, geochemical, and paleomagnetic.

The project participants, and their function, include Dr. Richard D. LeFever (sedimentologist) and Dr. Nels F. Forsman (Sedimentary Geochemist) both of the UND geology department; Dr. John P. Bluemle (Project Coordinator), Dr. John W. Hoganson (Paleontologist), and Ed Murphy (Stratigrapher) of the NDGS. This project was initiated when Dr. Forsman determined that volcanic ash within the Killdeer Mountains caprock is datable by geochemical methods and/or fission-track techniques. In addition, Dr. LeFever discovered a potentially datable volcanic ash bed in the South Heart Badlands.

The first phase of this project involved the collection of samples from ash beds and the preparation of samples to be dated by the U. S. Geological Survey. In addition, 22 sections were measured at buttes in western North Dakota. A total of 126 sediment samples were collected and these will be microscopically examined for the presence of distinctive mineralogic components and any microfossils.

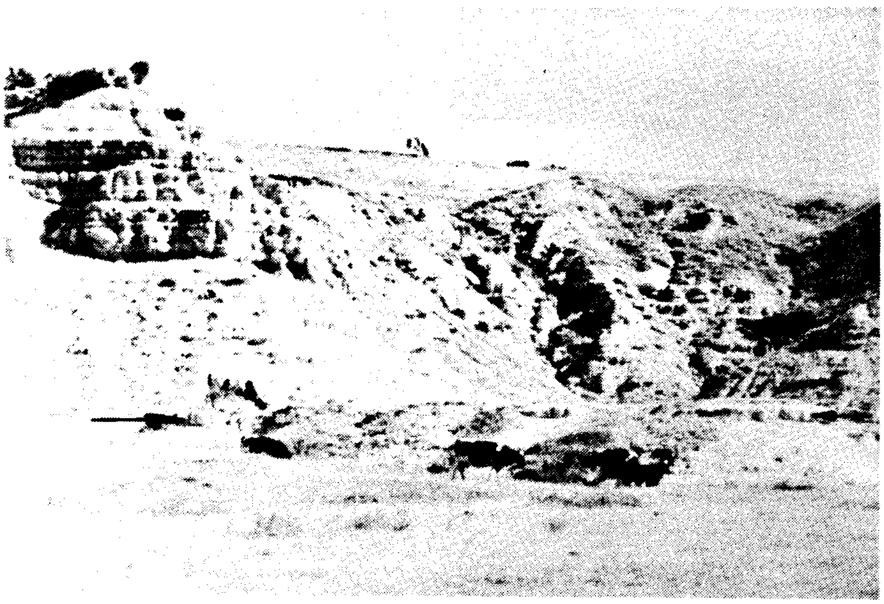


Figure 1. Volcanic ash bed (arrow) in the South Heart Badlands area, Stark County. A sample taken from this ash bed has been sent to the U.S. Geological Survey for dating.

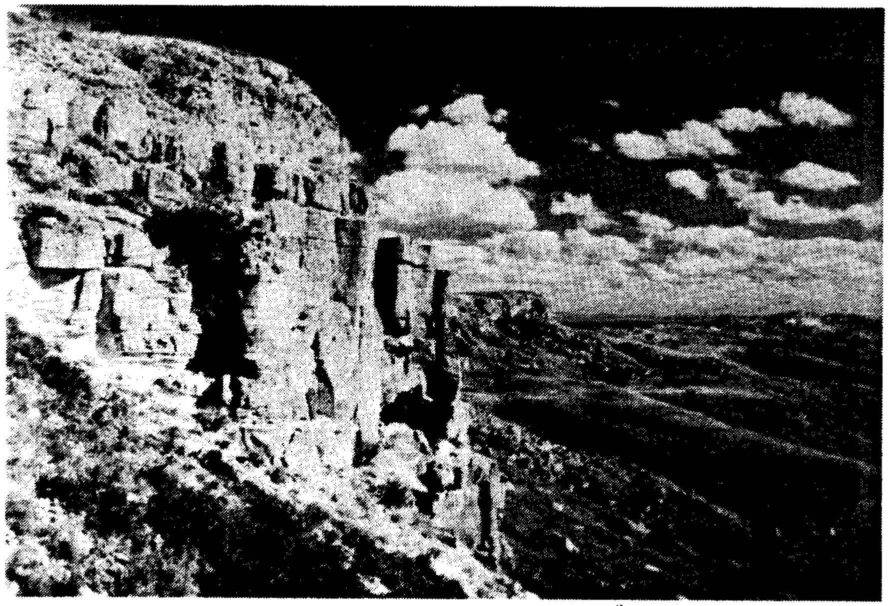


Figure 2. Cap of Oligocene/Miocene (?) sandstone on Bullion Butte, Billings County. Bullion Butte was one of the 22 buttes that we measured this past summer as part of our COGEOMAP study.

COMPUTER-ASSISTED GLACIAL STRATIGRAPHY

--Ken Harris

For about the past year, we have been working on an IBM PC-based system to streamline the handling, interpretation, and correlation of our near-surface stratigraphic data. This data, like all our data, is stored in a database on our IBM System 34. It is used by our geologists as a source of near-surface information for various projects, ranging from environmental evaluations of landfills to glacial stratigraphy. Steve Moran (a former NDGS geologist) started this database in the early 1970s to manage his stratigraphic data. Steve's system has been expanded and modified, and it now contains about 9000 entries. The information in storage was generated, over the years, by Quaternary geologists working in the state. We use the IBM System 34 as a data-storage library. Project files are transferred from it to IBM PC-compatible diskettes for processing at individual work stations.

We have a number of programs to aid in manipulating these project files once they are on diskette. Subfiles can be created that consist of data generated by individual workers or individual projects; or they may contain data sorted by data type or various geographical criteria. Subfiles are routinely created to determine the well control available in a project area; or to identify and locate samples that are stored in the Wilson M. Laird Core and Sample Library.

The Correlation Parameters

In order to identify different units of glacial sediment, we have to identify some characteristics, or combination of characteristics, of the glacial sediment that are internally consistent; but which differ from unit to unit. We have found six correlation parameters to be useful for correlating glacial sediment in North Dakota. These parameters are based on the textural analysis of the sediment and the lithologic analysis of the coarse-sand fraction (1-2 mm). The textural analysis gives us the percentage composition of sand (SD), silt (SLT), and clay (CLY). The lithologic analysis of the coarse-sand fraction gives us the percentage composition of crystalline and metamorphic rock fragments (XTAL), limestone and dolostone rock fragments (CO3), and shale rock fragments (SH). In order to simplify data manipulation and display, these six parameters are reduced to four. The silt and clay textural parameters are normalized:

NSLT=((SLT/(SLT+CLY))*100);

and the crystalline and carbonate lithologic parameters are normalized:

NXTAL=((XTAL/(XTAL+CO3))*100)

The correlation parameters that are used for the graphical analysis and correlation of glacial sediment are:

1) the percentage content of sand (SD),

2) the percentage content of normalized silt (NSLT),

3) the percentage content of normalized crystalline and metamorphic rock fragments (NXTAL),

4) the percentage content of shale rock fragments (SH).

Defining a Till

Two programs we developed this past year have proved to be useful tools in defining lithostratigraphic units (tills) in the glacial sediment, and then correlating these tills between work areas (fig. 1). The first one (TILSRCH) will identify and define modal tendencies in a dataset (tills). The second one (DISCORT) will display, compare, and assist in the correlation of the definitions (tills) developed by TILSRCH. I would like to briefly describe these two programs and show you how they are used.

TILSRCH Program

Modal groups in a dataset can be located by interpreting crossplots of the correlation parameters in the dataset (fig. 2). These coordinates are then used as input for TILSRCH. An interactive, iterative process is used to refine the definition of a modal group (a till), retrieve all of its member-samples, and statistically evaluate the quality of that definition. This procedure is repeated as often as necessary, until a good definition of the modal group is achieved. When a satisfactory definition is achieved, the program will label all member-samples of that group in the dataset. This procedure is repeated until all modal groups in the dataset have been defined and labeled. The output of the program can take three forms:

1) A list of the member-samples of a specific modal group (a till),

2) A list of the entire dataset identifying all member-samples of all modal groups (the correlated dataset),

3) A list of all of those samples that do not meet the definition of any modal group.

The correlated dataset lists all testholes in order of their location, and all samples at each location in order of increasing depth (fig. 3). This provides the geologist with a mappable summary of the correlated data, which can then be interpreted stratigraphically.

DISCORT Program

This program displays the definitions developed in TILSRCH graphically and checks for overlap between the definitions. The input required is the value of the correlation parameters for each definition

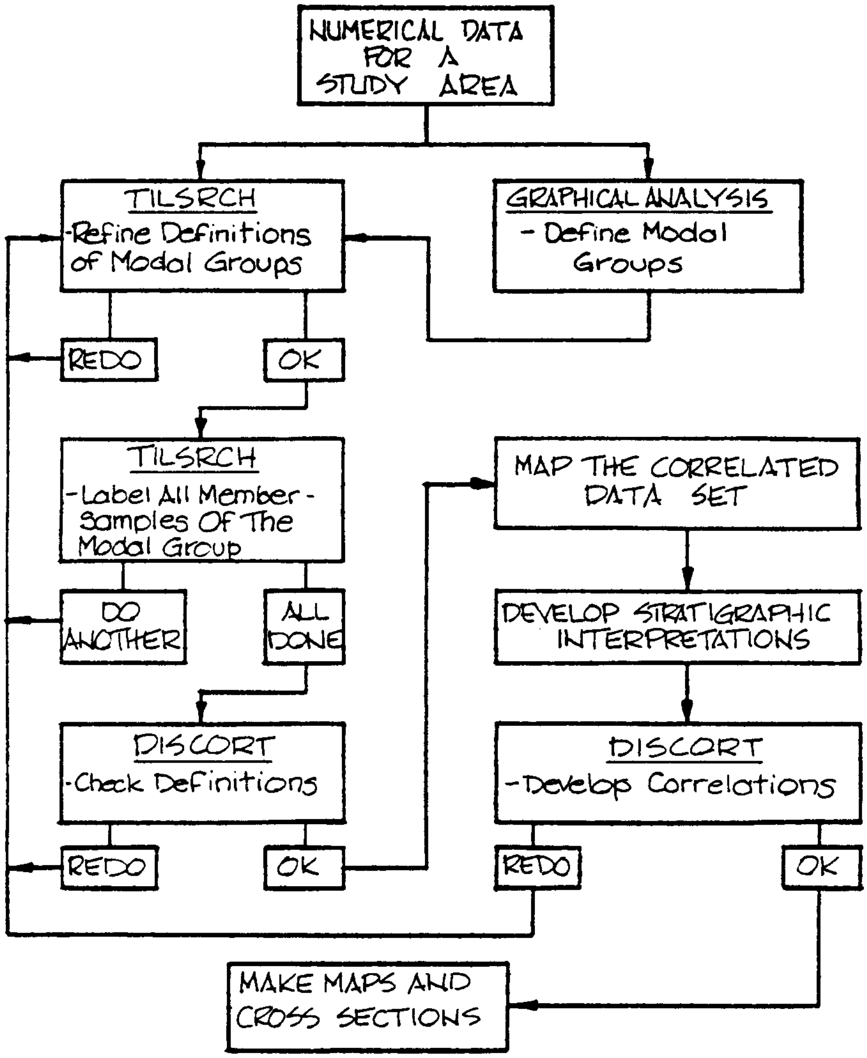


Figure 1. This flow chart shows the steps involved in the computer-assisted definition and interpretation of lithostratigraphic units in glacial sediment.

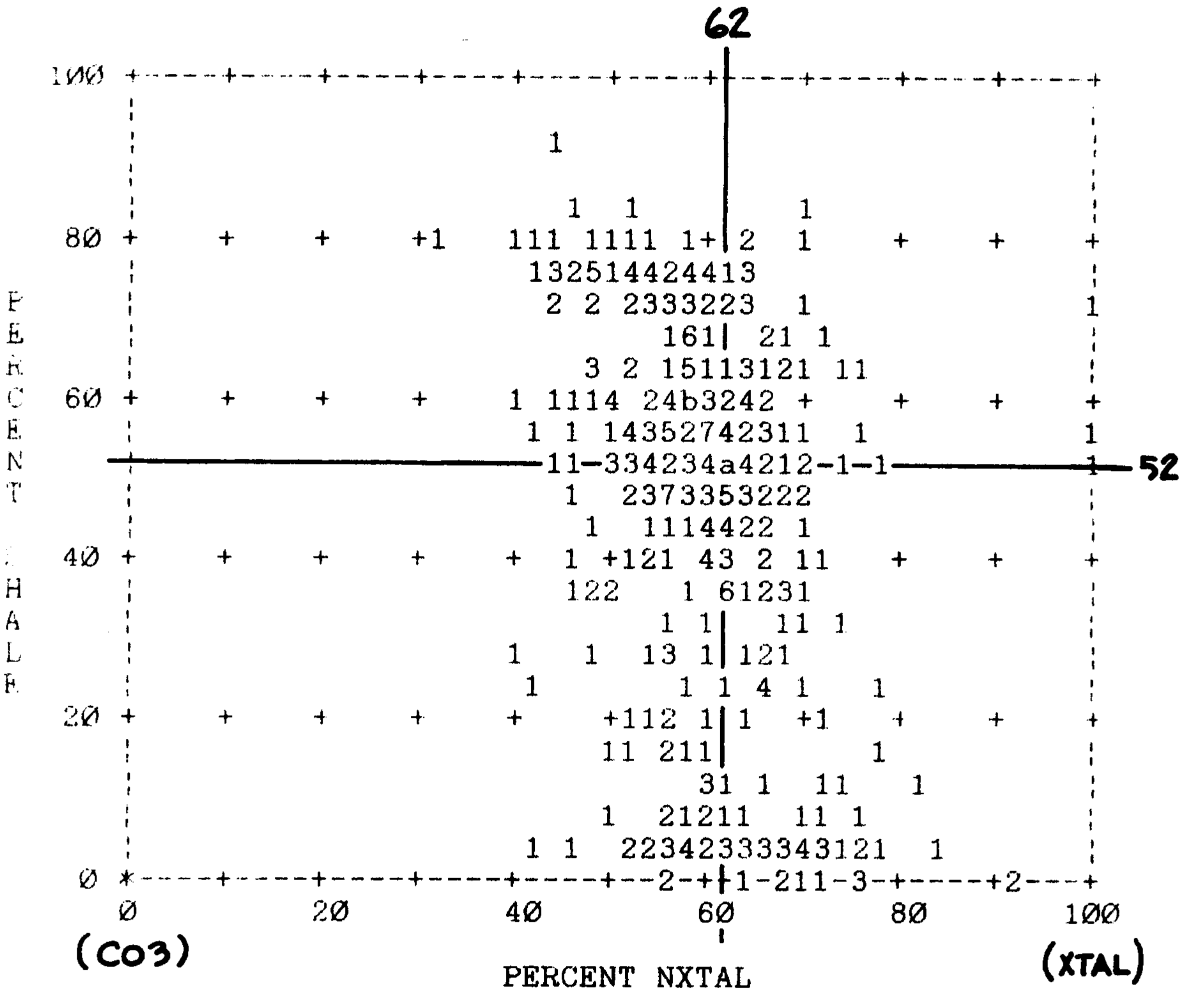


Figure 2. This is a crossplot of NXTAL vs SH from Atlas Series Map Area 15 (Sheyenne River Map Area; N=483). Some crossplots are more useful than others in identifying the coordinates of modal groups. In this case the NXTAL vs SH crossplot is used to identify a modal group at 62,52. TILSRCH will identify the value of the other parameters associated with this modal group.

N = 517Ø LOCATION = 133 - 56 - 25 BBB ELEVATION = 1247

SUBSURFACE SAMPLES COLLECTED BY KLH (Ø15)

DEPTH	ELEV	SD	SLT	CLY	XTAL	CO3	SH	SD	NSLT	NXTAL	SH	TILL
3	1247	34	35	31	55	41	4	34	53	57	4	2
8	1247	32	35	33	58	36	6	32	51	62	6	2
13	1247	33	35	32	53	43	5	33	52	55	5	2
18	1247	33	35	32	55	39	6	33	52	59	6	2
23	1247	32	35	33	59	36	5	32	51	62	5	2
28	1247	32	35	32	55	36	9	32	52	6Ø	9	2
33	1247	33	36	32	58	4Ø	5	33	53	59	5	2
38	1247	3Ø	4Ø	3Ø	41	25	34	3Ø	57	62	34	5
43	1247	31	38	32	51	35	14	31	54	59	14	3
45	1247	31	38	31	44	39	17	31	55	53	17	3

Figure 3. This is an example of the information listed for a sample site in the correlated dataset. Notice that this borehole penetrates tills (definitions) 2, 5, and 3.

(till), and the number of member-samples in that till. This has proved to be a very useful program and can be used in at least three ways:

1) It will display the definitions as bar-charts (fig. 4). It can be instructed to display these charts using various arrangements of the correlation parameters in ascending or descending order.

2) It can perform a check of the quality of the definitions we developed in the dataset. Each definition can be checked against each other definition to find the degree of overlap that exists. The level of precision of that check (allowable variation between compared parameters) can be specified, so that a judgment can be made on the quality of the definitions. In this case we do not want the definitions to overlap. So, the poorer the indicated correlation is, the better our definitions are. The results of the comparison are shown in figure 4.

3) It can be used as a correlation tool. Each definition in a dataset can be compared with each definition in another dataset or datasets. The level of precision of the comparison can be specified, and the quality of the indicated correlations can be judged. In this case we are looking for overlap between compared definitions. So, the better the indicated comparison is, the more likely we are to have a good correlation. The results of the comparisons are shown in figure 4.

Conclusions

Computer-assisted techniques and desktop computers have provided a new perspective to the problems of defining and correlating near-surface stratigraphic units. Previously, progress was very slow in developing any sense of regional cohesiveness in glacial stratigraphy. The use of these programs and our large, near-surface database has provided us with a means of rapidly developing preliminary lithostratigraphic interpretations that are regional in scope. This gives our Quaternary stratigraphy a new, broader

```
************************************************************************
------------------------------------------------------------------------
     A POSSIBLE CORRELATION FROM AS-14 (TOP) AND AS-15 (BOTTOM)
                    GATE WIDTH USED WAS +/- 3
                      12-15-1987 (12:55:46)
------------------------------------------------------------------------
T  SD NS NX SH N        SAND         SHALE         NSLT         NXTAL
------------------------------------------------------------------------
3  42 62 64 28 4  |     XXXXXXXX!XXXXXX      |     XXXXXXXXXXXX!XXXXXXXXXXXX     |
4  42 62 67 25 8  |     XXXXXXXX!XXXXX       |     XXXXXXXXXXXXX!XXXXXXXXXXXX    |
------------------------------------------------------------------------
                 CORRELATION COEFFICIENT =  3 / 2
************************************************************************
```

Figure 4. This is an example of a comparison of two tills. DISCORT indicates a possible correlation between a till in AS-14 (Goose River Map Area) and one in AS-15 (Sheyenne River Map Area). The correlation coefficient indicates the maximum allowable variation between parameters over the average variation.

based perspective, which should provide valuable base line stratigraphic information for a number of applications. We hope to move ahead with this program as quickly as possible. Additional drilling is planned for upcoming field seasons, and we hope to coordinate the development of our Atlas Series surface geologic maps and our Atlas Series Quaternary stratigraphic maps.

ATLAS SERIES MAPPING PROJECT UPDATE

--Ken Harris

We've made considerable progress in our Atlas Series mapping program since the last newsletter was published. Mark Lord, a Ph.D. candidate in geology at UND, has just completed the final revisions on "The Surface Geology of the Souris River Map Area" (fig. 1; AS-4). Mark's dissertation deals with the sedimentology, stratigraphy, and drainage history of glacial Lake Souris. He worked with us this past year to make a surface geologic map of his study area. Mark did a fine job on his map, and it is now in the final stages of drafting. We expect that it will be published in early 1988, and anticipate that it will be one of our most popular maps.

Ed Murphy, NDGS geologist, is continuing to make progress mapping the surface geology of Dunn County. Ed's work will be presented as a report on the geology of Dunn County and also as an Atlas Series map entitled "The Surface Geology of the Charging Eagle Bay Map Area" (fig. 1; AS-9). Ed says he expects to be finished in late 1988.

I am still working on the surface geology of the Goose River and Pembina River map areas (fig. 1; AS-14, AS-1). Airphoto interpretations and compilation should be completed this winter, and I hope to field check the maps next summer. I expect to complete the "Surface Geology of the Goose River Map Area" by late 1988, and the Pembina River sheet in early 1989.

ATLAS SERIES MAP AREAS

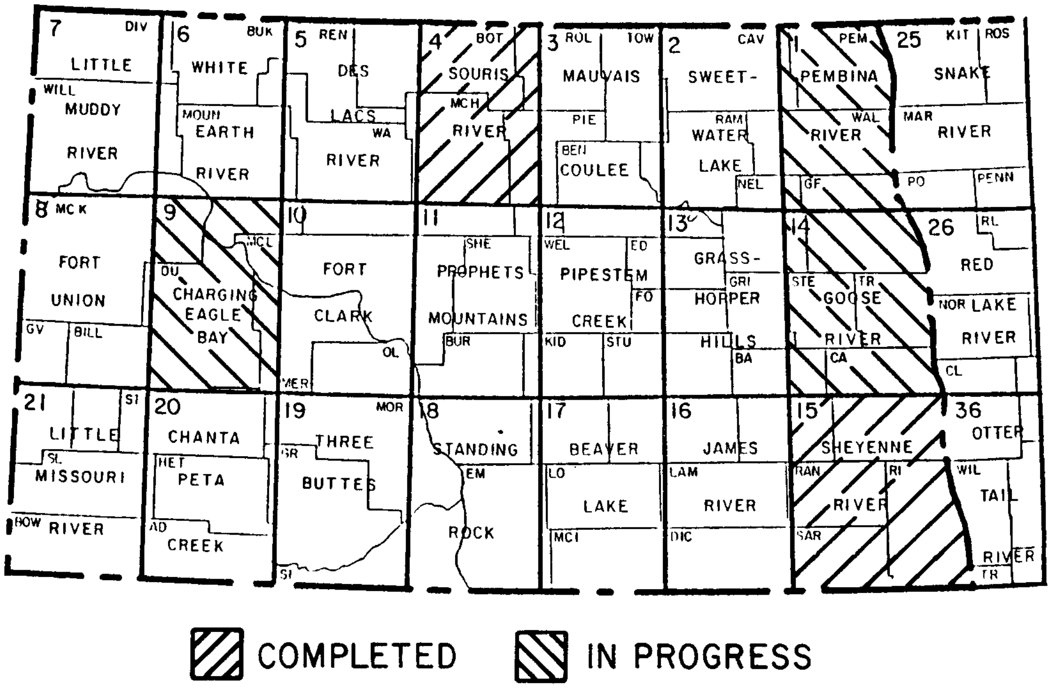


FIGURE 1. STATUS OF ATLAS SERIES SURFACE GEOLOGY MAPS

ATLAS SERIES MAP AREAS

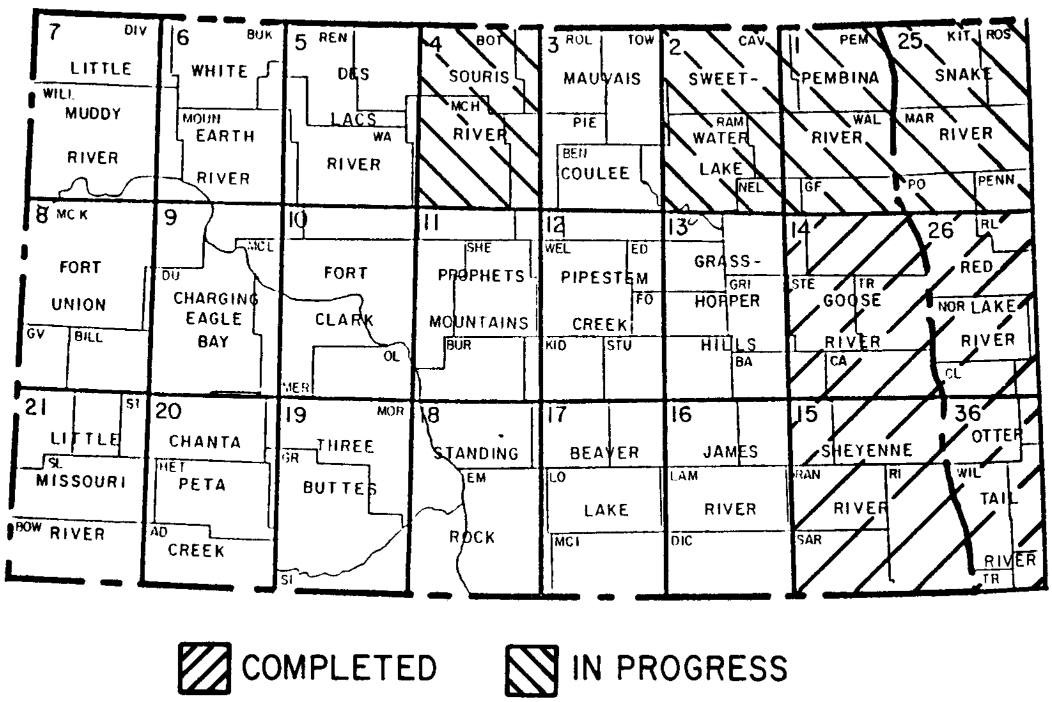


FIGURE 2. STATUS OF PRELIMINARY LITHOSTRATIGRAPHIC MAPS

In the near future we hope to start publishing Atlas Series maps that summarize our interpretations of the Quaternary stratigraphy in each map area. Preliminary lithostratigraphic maps have been compiled for some map sheets in eastern North Dakota and in the adjacent parts of Minnesota (fig. 2). These preliminary interpretations were reached using an interactive, computer-assisted technique that we developed during the last year. This approach allows us to rapidly make correlations and stratigraphic interpretations using all of the near-surface data that we have stored in our digital database. We plan to be busy this coming field season drilling additional test holes to extend our subsurface data into those areas with sparse well control. To insure consistency in our interpretations, we plan to develop preliminary lithostratigraphic maps of most of eastern North Dakota before we publish any of these map sheets in final form. Working copies of the maps will be maintained on an open-file basis.

HORIZONTAL OIL WELL DRILLING IN NORTH DAKOTA

--Marvin Rygh

An innovative technique is being tested in North Dakota by Meridian Oil Inc., which has initiated a program involving the drilling of a number of wells that will horizontally penetrate an oil reservoir. Meridian's objective is the Bakken Formation in the Billings anticline area. The Bakken Formation is a thin black shale which produces from naturally fractured zones in the Williston Basin. Matrix permeability is extremely low, and the occurrence of vertical fractures is necessary for a productive well.

The plans for Meridian's first horizontal well included taking an oriented core through the Bakken by drilling a normal vertical hole. Observation of the fractures in the core will indicate the regional trend of the fractures in the formation. If previous well density is sufficient, this coring process might not be necessary. The next step in the drilling process would be to begin slanting away from the vertical position starting 400 feet above the top of the Bakken. The objective is to directionally drill out to a horizontal position into the Bakken and continue drilling horizontally as far as 2500 feet. The direction of the borehole will be such that the well bore is perpendicular to the vertical fractures in the formation. A schematic drawing showing approximate depth relationships is given in figure 1.

Using state-of-the-art drilling tools, the transition from a vertical position to a completely horizontal position will occur within a 400-foot radius. This is substantially different from most deviated wells, which usually do not trend more than 20 to 30 degrees from vertical, and in which the curvature of the well bore is more gradual compared to the new technique.

The purpose for drilling a horizontal well is also substantially different than for drilling a normal deviated well. A horizontal well is drilled into the reservoir so it will penetrate much more pay zone than would be penetrated under normal vertical drilling procedures. Ideally, the reservoir will be more efficiently drained with the horizontal drilling procedure, particularly in rocks which have low permeability or are considered "tight."

The more common deviated well bore is usually drilled as a result of restricted surface locations. In much

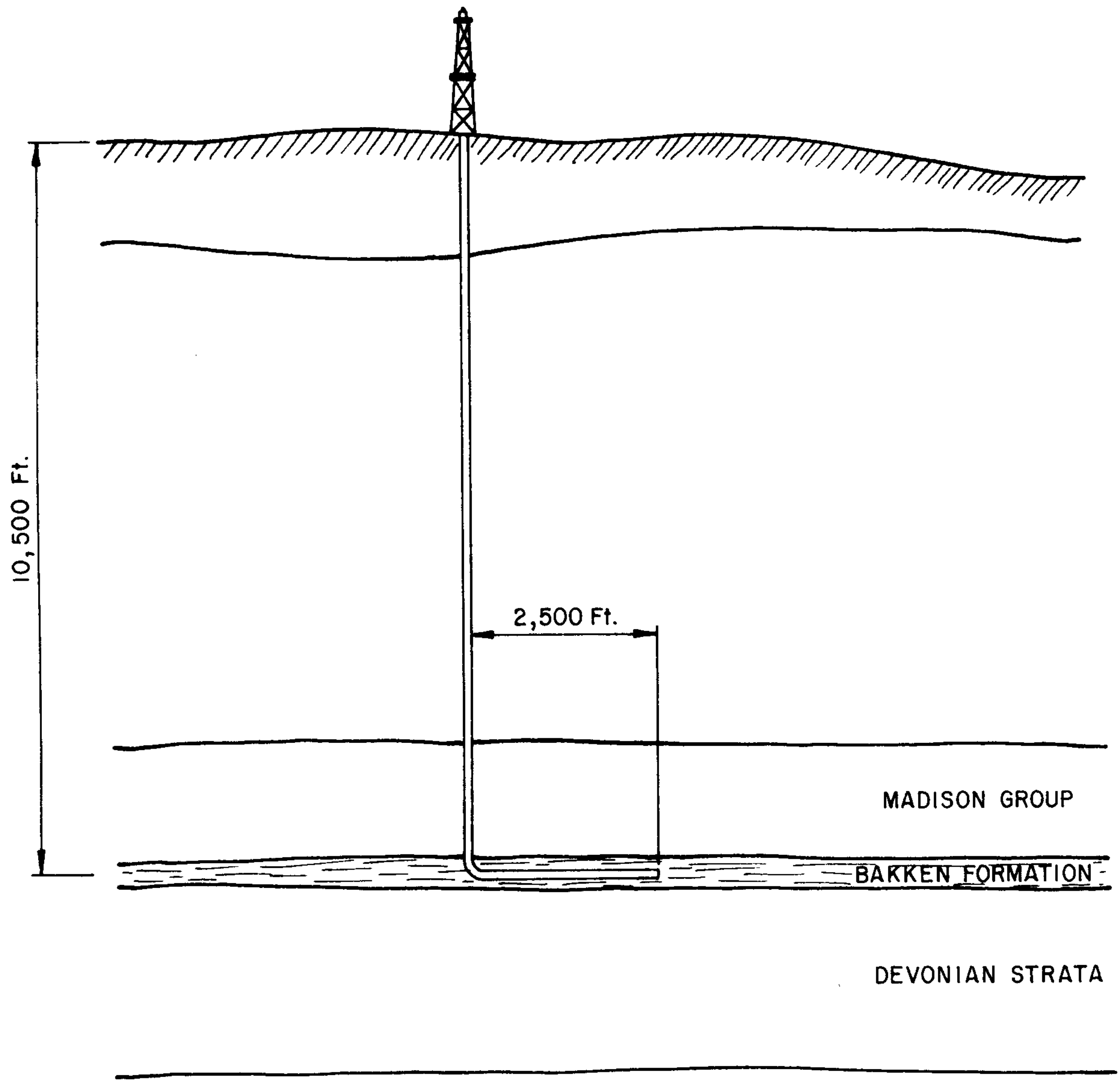


Figure 1. Diagram showing horizontal well bore penetrating the Bakken Fm. Vertical and horizontal distances are approximately to scale.

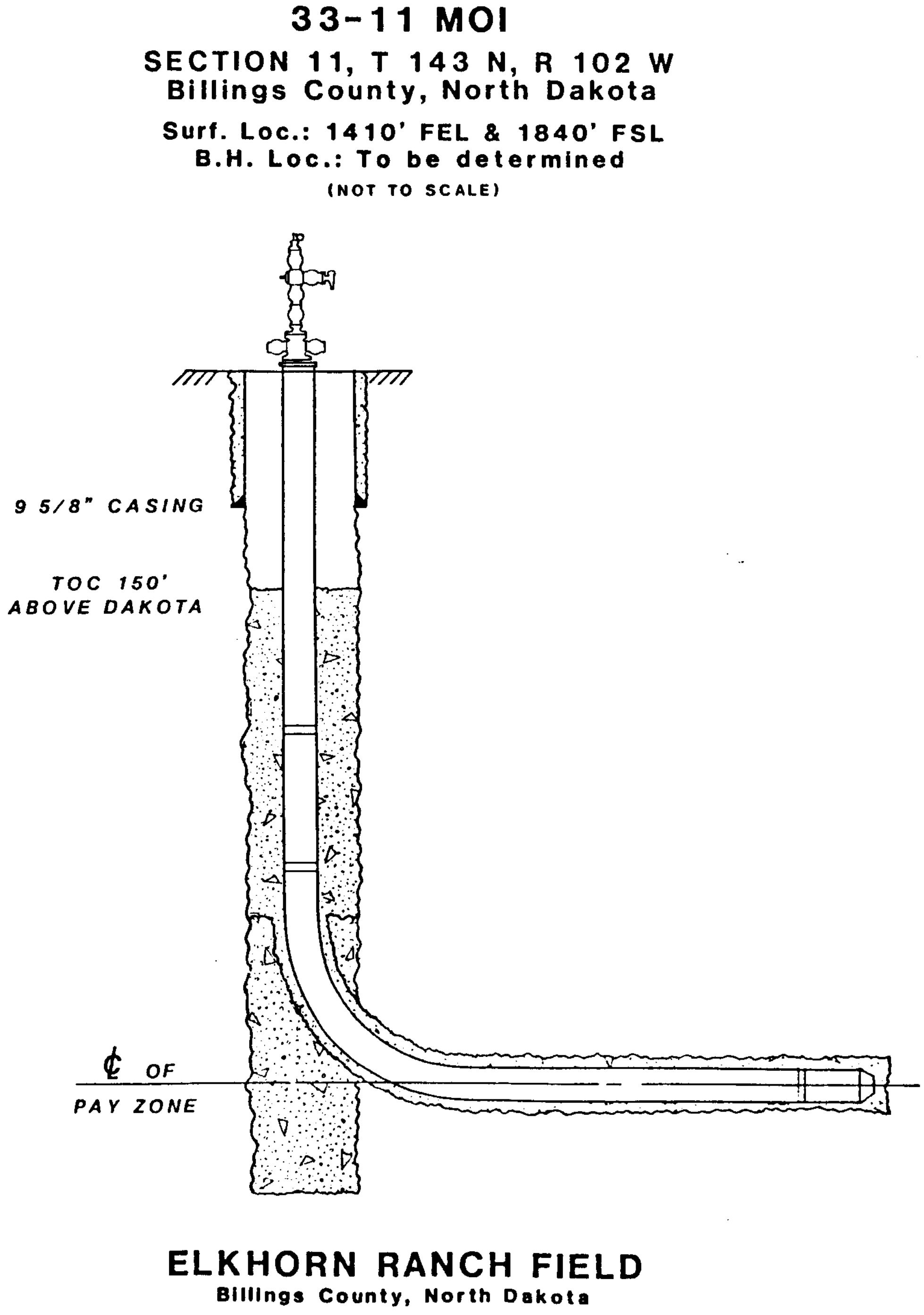


Figure 2. Schematic of completed horizontal well bore from N.D. Industrial Commission hearing #4296.

of western North Dakota, the badlands topography determines where a drill site can be feasibly located. The surface location does not always coincide with the legal location allowed by North Dakota spacing rules. The well is directionally drilled so it will penetrate the producing zone at what would be a legal location. A normal directionally drilled well does not enhance the productivity beyond that of a normal vertical well. This is because the well bore inclination in a deviated well is usually not great enough to substantially increase the amount of reservoir rock penetrated.

Drilling a horizontal well is technically difficult and costly. Meridian Oil Inc. estimates that a horizontal well drilled and completed in the Bakken Formation will cost an additional $600,000 compared to a conventionally drilled well. A schematic drawing of a completed horizontal well is given in figure 2. There is also a substantial risk involved as the difficulty of horizontal drilling increases the chances of failure in the well. However, if Meridian is successful and the horizontal wells prove to be economically attractive, more operators may consider using this technique.

NEW PUBLICATIONS

Report of Investigation 86--"Migration of Contaminants from Buried Oil-and-Gas Drilling Fluids Within the Glacial Sediments of North-Central North Dakota," was written by William A. Beal, Edward C. Murphy, and Alan E. Kehew. This 43-page report is an expanded version of Mr. Beal's Master's thesis at the University of North Dakota.

The authors studied two reclaimed oil and gas well sites, one in Renville County and the other in Bottineau County. At the Renville County site, the drilling fluids were disposed of in a shallow pit excavated in Pleistocene glaciofluvial deposits (gravel), and at the other site they were disposed of in trenches in the Pleistocene glacial till. The results of chemical analyses of porewater, groundwater, saturated-paste extracts, and earth resistivity surveys indicate that leachate is being generated from the buried drilling fluids and that the contaminants have migrated away from the sites.

The authors recommend that drilling fluids not be disposed of in glaciofluvial sediments. Problems involved with disposing of drilling muds in glacial till depend on the geological setting. For this reason, a subsurface investigation should be conducted at any potential disposal sites in till. The authors believe that, in many cases, disposal of drilling fluid wastes at properly chosen central locations is more effective than disposing of them at each drilling site.

Report of Investigation 86 can be obtained for $2.00 from the North Dakota Geological Survey.

Miscellaneous Series 69--"Core Workshop Volume-Fifth International Williston Basin Symposium," was edited by David W. Fischer. It was prepared as a guide to the proceedings of a core workshop held at the Wilson M. Laird Core Library in Grand Forks in conjunction with the Fifth International Williston Basin Symposium in June, 1987.

The volume includes four separate papers: "Silurian Interlake Group, A Sequence of Cyclic Marine and Freshwater Carbonate Deposits in the Central Williston Basin," by Esther R. Magathan; "Winnipegosis Platform Margin and Pinnacle Reef Reservoirs, Northwestern North Dakota," by James R. Ehrets and Don L. Kissling; "Lower Ratcliffe Interval (Mississippian) in Williams and McKenzie Counties," by Michael Hendricks; and "Coteau and Dale Intervals of the Mississippian Mission Canyon," by Nels Voldseth.

The volume is intended to be not only a guide to the proceedings of the core workshop, but also a formal discussion and documentation of the interpretations and theories presented. Miscellaneous Series 69 is 113 pages long and can be obtained from the Survey for $3.00.

We also have a new List of Publications available. We will provide the List without charge to anyone who requests it.

Open-File Reports--Even though they are not formal publications, we do occasionally prepare reports and maintain them on open-file status. This means the material is all compiled and ready for examination by anyone interested. In some cases, these are maps or other materials that we are updating continually and any published version would be out-of-date almost immediately. Other reports are of limited interest and we did not want to spend the money on a formal publication; even so, the information may be of great interest to some people.

Two recent reports by Ken Harris have been added to our open-file series. The first is designated OF-87-1 and is titled: "The Quaternary Geology Of The Grand Forks-Red Lake Falls Area, North Dakota-Minnesota." Ken originally compiled it for the 1987 Minnesota Association of Professional Soil Scientists' field trip. It is intended to serve as a field trip guide to the Quaternary geology of the area and includes summaries of the surface geology and near-surface stratigraphy. The second report, designated OF-87-2, is titled: "Documentation For The Data Formats and Programs Used For Computer-Assisted Glacial Stratigraphy At The North Dakota Geological Survey." This report describes the computer techniques Ken has devised in his work with Quaternary stratigraphic units. It includes a computer diskette with the applicable programs.

Both of these open-file reports may be obtained by contacting our office.

THE OCCURRENCE OF RADON IN NORTH DAKOTA

--David Brekke

Radon is a colorless, odorless, inert, radioactive gas. It is a decay product of uranium and is undetectable without special instruments. Recent studies have shown that it is present in almost all houses and buildings, sometimes in hazardous concentrations. Measurements in a home in eastern Pennsylvania showed an indoor radiation level 100 times the maximum allowable radiation levels permitted in uranium mines. Although most of the radon we inhale is expelled, the inhalation of the radioactive decay products of radon may be hazardous since high radon levels in underground mines are a known cause of lung cancer among miners. If a radon atom, or its daughter product, becomes attached to a smoke or dust particle and is inhaled, it may become lodged in the lungs and stay there longer than the half-life of the atom. A potential for cell damage occurs when the radon or daughter products undergo radioactive decay and emit relatively large and heavy alpha particles (fig. 1). Radon can be considered a geologic hazard since the source and transport of the element is in geologic materials. This article emphasizes the geologic aspects of radon occurrence in North Dakota.

The geology of radon is essentially the geology of uranium and its

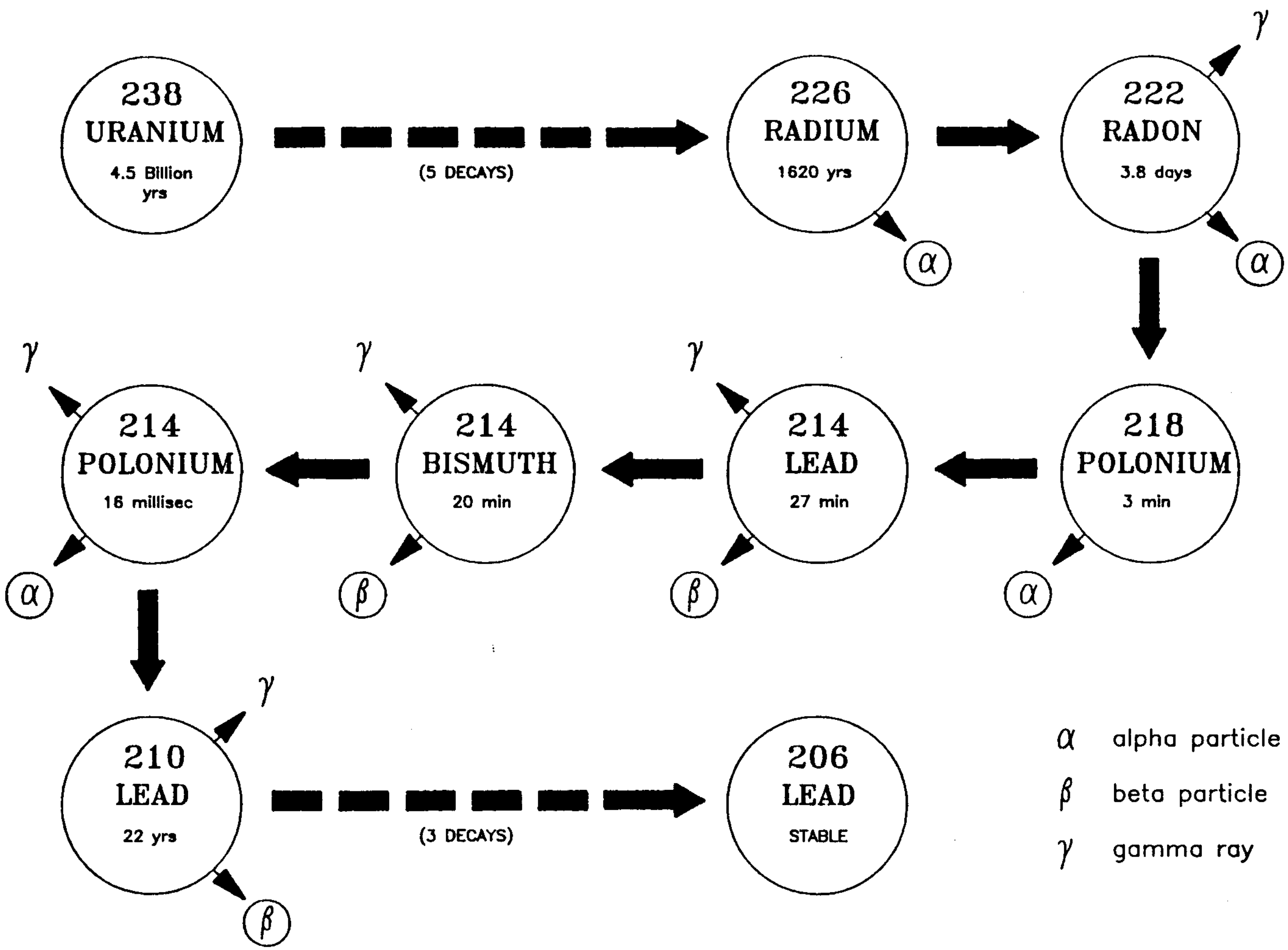


Figure 1. SIMPLIFIED URANIUM-238 DECAY SERIES. Note that the four immediate decay products of radon (middle row) decay rapidly and produce two alpha particles. These decay events are the ones responsible for cell damage in the lungs. The top number in each atom symbol is the atomic weight of the isotope and the bottom number is its half-life.

occurrence. Uranium is found in a variety of rocks such as granites, gneisses derived from uranium-bearing sediments, phosphatic rocks, and highly organic shales. Although none of these rocks are exposed at the surface in North Dakota, we do have an abundance of coal in the western part of the state. Groundwater has leached uranium from the volcanic ash deposits that overlie the coal. The uranium-bearing groundwater then flowed through adjacent sandstone aquifers. Subsequently the uranium was deposited in adjacent lignite beds. Enough uranium can accumulate to form a low grade ore deposit. In the 60s, lignite was burned in pits to concentrate the uranium in the resulting ash. This ash concentrate was shipped as ore to mills in other states for further processing. The mining and burning of lignite as a means of uranium extraction ended in 1967.

Lignite occurs over the entire western half of the state, and the potential for localized uranium concentrations in lignite exists anywhere in that area. However, proven deposits of uranium are limited to the area southwest of the Missouri River in North Dakota. Therefore, the highest potential for radon is in these areas. Other regions of the state have geologic materials at the surface or in the near-surface that contain variable amounts of organic matter and thus may be potential uranium sources. These materials include Lake Agassiz silt in the Red River Valley and the Pierre, Carlile, and Greenhorn Formations in the eastern third of the state. Also, glacial till and gravel in North Dakota is composed partly of variable amounts of granite pebbles and boulders.

An important factor to consider in understanding radon distribution is transport of the gas through geologic materials. The half-life of radon is relatively short at 3.8 days. This means that 90 percent of it will decay in 13 days and no longer be a hazard. Thus a radon atom cannot move great distances from its original uranium parent atom. The range of movement has been estimated from a few feet to tens of feet under favorable conditions. The ability of radon to migrate through soil or rock depends on the porosity and permeability of the material. Coarse materials, such as glacially derived sand and gravel, are excellent pathways for gas transport, especially if they are dry. Poor materials for gas migration are clays and clay-rich glacial till, especially if wet. However, if these low-permeable materials are highly fractured, radon gas can travel long distances through them. The fracture system may act as a collection network to gather a large quantity of radon gas from rocks or sediments that originally contain low concentrations of uranium.

In several parts of North Dakota, highly permeable sediments or soils exist at the surface. Most of these are derived from glacial processes. They include: sandy beach ridges and delta deposits along the western margin of the Red River Valley, sand dunes and density current sand deposits (see article on dunes in this issue) near the Souris River, and meltwater stream gravel deposits. The Tertiary sediments southwest of the Missouri River, in addition to containing lignite, are composed of sandstone, siltstone, and shale. The more permeable sandstone units can act as pathways for gas migration. If water is present in any of the geologic materials, radon will be dissolved in the water and either transported away or released again when the water evaporates.

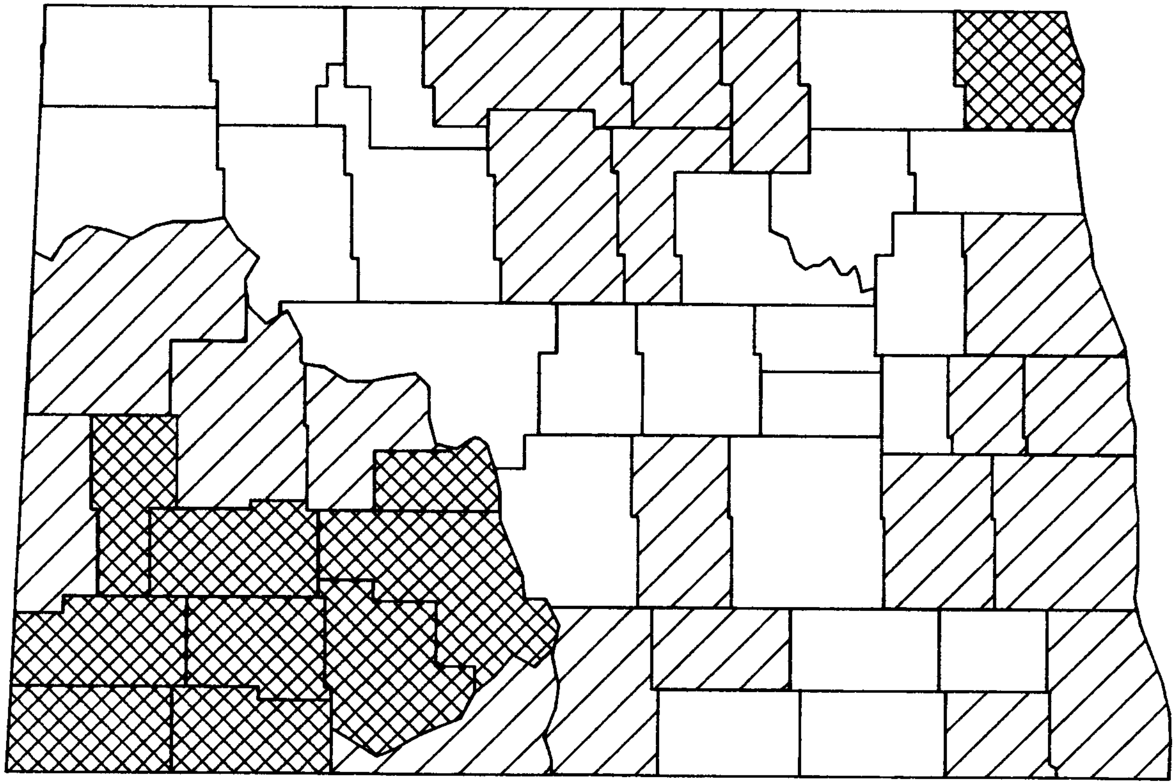
Since the half-life of radon is so short, we need to evaluate only those geological factors affecting uranium distribution and radon gas transport in the top dozen feet or so. A general map of radon potential can be constructed based on geologic materials, soil permeability, and information obtained from federal NURE data (fig. 2). This map does not imply that radon problems will occur in all buildings in those counties labelled as "high." Conversely, high radon levels could be found in buildings in counties labelled as "low." The map does show relative potential for radon occurrence on a county-wide average of many factors. However, the only way to find out if radon is actually present at hazardous levels in any building is to measure the air for a reasonable length of time, usually several months.

Radon is rapidly dispersed in outdoor air and therefore represents no health hazard there. It is in indoor air that concentrations may become hazardous. A house can act as an air pump, drawing soil gas into the basement. One of the constituents of soil gas is radon. This can happen when indoor air is heated and the heated air rises to upper levels in the house, creating lower pressure in the basement. The relative difference in air pressure between the indoor air and outdoor air causes soil gas to be drawn into the house through cracks, seams, sumps, and holes. Fortunately, simple methods such as sealing basement walls and floors and improved ventilation are available to help reduce radon levels.

The North Dakota State Department of Health is conducting a statewide monitoring study this winter. They are monitoring selected buildings in cooperation with the federal Environmental Protection Agency. The EPA has many informative pamphlets concerning radon and measures that can be taken to reduce exposure. For more information about possible danger from radon, contact the North Dakota State Department of Health, Environmental Health Section, in Bismarck.

POTENTIAL FOR RADON OCCURRENCE

by David Brekke, North Dakota Geological Survey



NOTE: Potential for radon occurrence in any county is based on an average of geological factors. The rankings are relative and any particular area within a county can be higher or lower.

Figure 2. MAP OF POTENTIAL RADON OCCURRENCE IN NORTH DAKOTA.

GEOLOGIC FIELDWORK IN THE EARLY 1900s

--David Brekke

We recently came across a box of old glass photographic plates that depict Survey geologists at work over 80 years ago. I think the four photos here are interesting, especially for the way they show the conditions under which those early geologists worked. If anyone knows the names of any of the unidentified people in the photos we would like to hear from you.

Figure 1. Photo of Dr. A. G. Leonard near Kern's ranch, western North Dakota, in 1906. Leonard was State Geologist from 1903 to 1932 and spent many summers on horseback or in horse-drawn wagons investigating the geology of North Dakota. Note geologists' essential field equipment such as the rock hammer tied to the saddle and binoculars and a compass or altimeter slung over the shoulders.

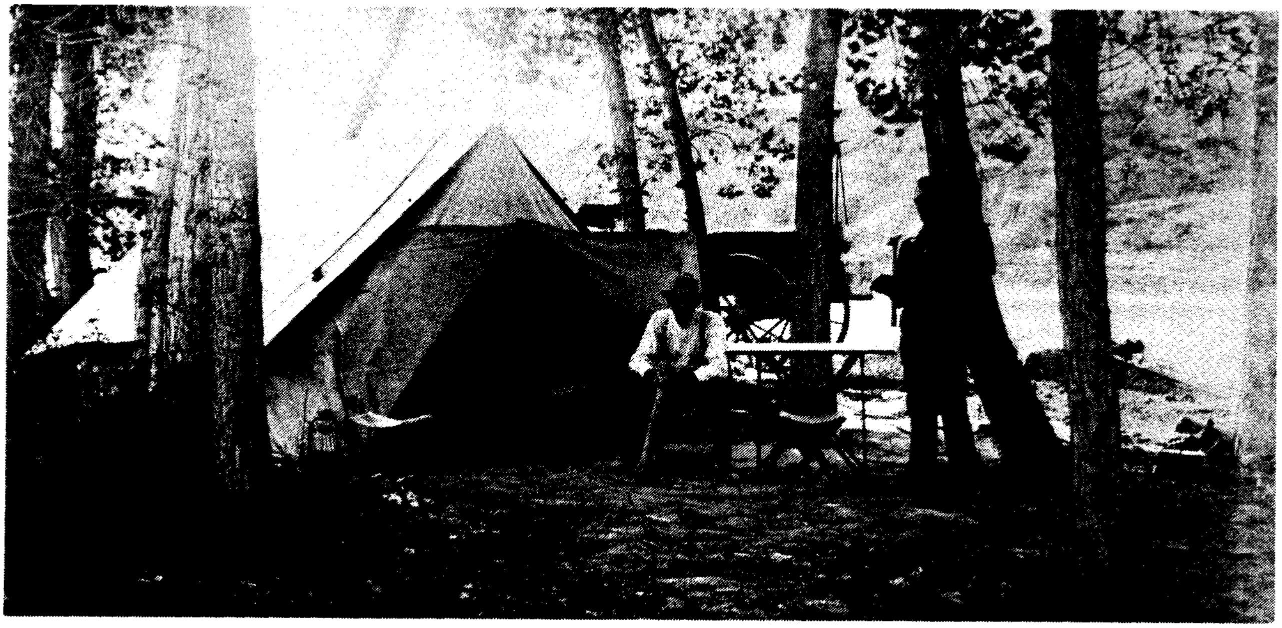


Figure 2. Camp at Miles City, MT, on the Yellowstone River. Dr. Leonard led a field party for the U.S. Geological Survey during the summers of 1905 and 1906. The objective of the work was to study the lignite deposits in western North Dakota and eastern Montana. Note that camping gear hasn't changed much in eighty years! The unidentified geologist at right appears to be demonstrating the proper technique for splitting rocks with his hammer.

Figure 3. Camp on North Dakota prairie circa 1905-1908. The field party is unidentified, but the NDGS had one or two field geologists on staff and hired a few students for the summer. Judging by shadow length, photo was taken around evening meal time. The fellow at left must have appropriated firewood from some other area.

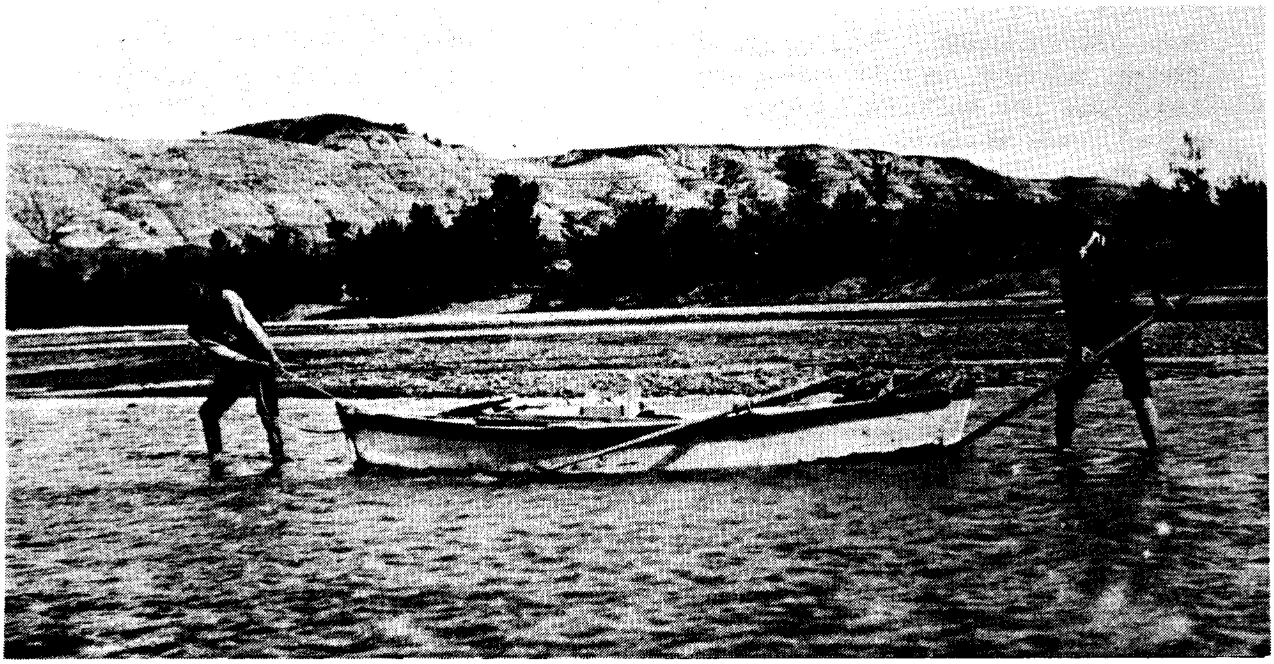


Figure 4. Hauling boat over rapids in the Little Missouri River below Johnson ranch, 1903. The field party included L. H. Wood, party chief, and UND students Harry Pease and Herbert Goodall, who was also the photographer. This group started at Medora and followed the river to its mouth at the Missouri River, north of present-day Halliday, where they met Dr. Frank A. Wilder (State Geologist 1902-1903) and his party. Wood's party then travelled up the Knife River by wagon while Wilder continued down the Missouri River to the mouth of the Cannonball River.

BRICKMAKING IN GRAND FORKS

--David Brekke

The clay industry in North Dakota has been limited almost exclusively to common brick manufacture. Earliest production of brick at Fargo dates to the 1870s. By 1906 there were eighteen plants operating in the state, all producing common brick. Only one plant remains in operation today, at Hebron. The low population of the state and surrounding areas combined with high freight costs are not favorable for increased economic development of brick products.

The Grand Forks brick industry started in the early 1880s with the opening of two plants, one by William Budge and another by W.P. Alsip. Up to four plants were operating at one time in Grand Forks. The photographs accompanying this article are from glass negatives exposed during that era. The account of brick manufacturing in Grand Forks that follows is by C.H. Clapp and E.J. Babcock. It appeared in the North Dakota Geological Survey 4th Biennial Report written in 1906.

> The chief center for the common brick industry is Grand Forks, where the Red River Valley Brick company operates four plants, one of them, however, being located on the Minnesota side of the river. The Grand Forks Brick, Tile and Cement company opened up a

new plant in 1906. The brick is cream colored and is manufactured by the soft-mud process, dried in pallet racks, and burned in scove kilns with wood fuel.

The clay underlying the black surface loam is used. From eight inches to a foot of loam is scraped off and the underlying three feet of yellow clay and about a foot of blue and yellow "joint clay" is shoveled directly into two-wheeled dump carts, which take the clay to the pug mill. The pits are broad and shallow, and are worked sometimes in two benches for convenience in handling. The clay is fed directly into the pug mill, from which it goes to the brick machine. All of the plants at Grand Forks use the Wellington Quaker soft brick machine, with a capacity of 45,000 brick per day. The brick are dried in very large yards with covered pallet racks, each yard having a capacity of about 300,000 brick. The latter are dried from six to seven days, and then burned in scove kilns with wood for fuel. At the Alsip yard four down-draft kilns were built during the past season but were not successful. The clay dries and burns readily, giving a hard, cream brick, which is very porous but is very good for common structural purposes. About thirty men are employed at each plant, and they are in operation from the first of May to the first of September.

Figure 1. View of a brickyard located east of the University of North Dakota. The city of Grand Forks can be seen in the distant background. The Great Northern railroad is visible in front of the brickyard, parallel to the line of poles. The photograph was probably taken from an upper floor of Budge Hall, looking southeast.

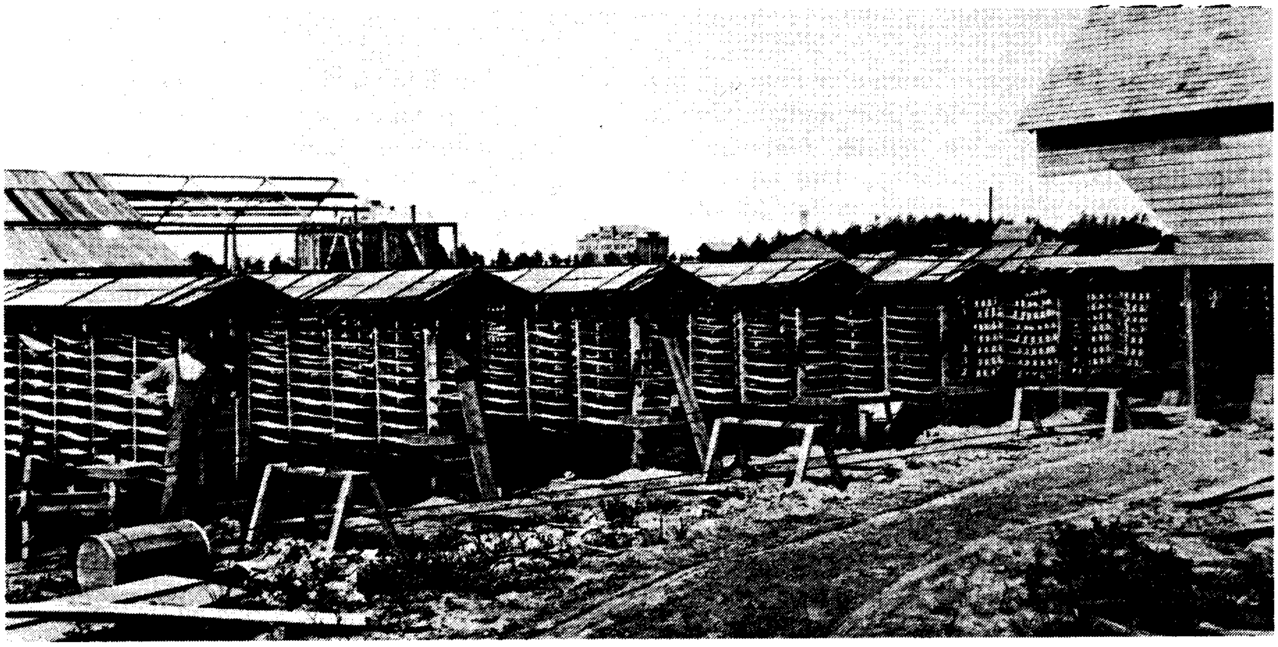


Figure 2. View of drying racks in another brickyard southwest of the University. The dual-cable carrying device can be seen in operation carrying pallets of six bricks at a time, one pallet every ten feet, out to the covered racks for air drying. The buildings in the background are Old Main, left, and Budge Hall, center. Both buildings have been demolished.

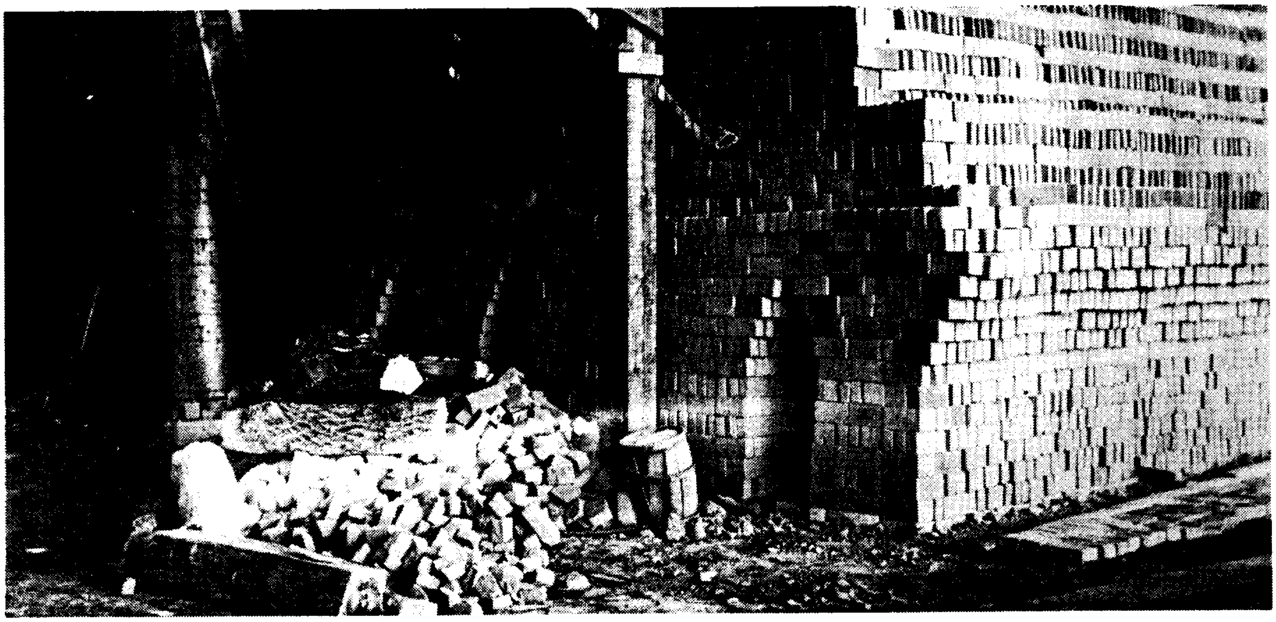


Figure 3. View of up-draft type scove kiln. Wood fires are built in ends of the arches and pushed in toward center until entire archway is filled. The kiln itself is made up of green brick to be fired. After firing, the kiln is dismantled. This type of kiln was cheap and handled large quantities of brick. However, since temperature was difficult to control, some bricks were overburned at the arches and some were left soft and unburned at the top.

WATER WITCHING

--John Bluemle

The practice of "water witching" or "dowsing"--searching for water with a "divining rod"--is quite common in North Dakota. In fact, the use of a forked twig or a pendulum for locating minerals or groundwater has been a common practice for hundreds, even thousands, of years. Maybe the first divining rod was the one mentioned in the Bible incident in which Moses struck a rock with a rod and water gushed forth (Num:20:9-11). Divining rods were used by the Scythians, Persians, and Medes. However, most accounts by the Greek and Roman naturalists and scientists do not mention the use of a magic rod, although some of them give hints and directions for finding water.

The exact origin of the divining rod in Europe apparently is not known. The first detailed description of it is in Johannes Agricola's "De Re Metallica," published in 1556. This was a description of German mines and mining methods. The divining rod was apparently introduced into England during the reign of Elizabeth I, to locate mineral deposits, and very soon after that it was widely used as a water finder over the rest of Europe.

People who practice or believe in water witching or dowsing generally try to explain it as a kind of "empathy" or "attraction and repulsion." People who don't believe in it usually condemn it as superstition. In the past, some people have held that the twig (if a twig was used) was moved by a satanic influence; others said that the dowser received the power from God. In 1518, Martin Luther proclaimed that the use of the rod violated the First Commandment. About 1660, Jesuit Father Gaspard Schott denounced the divining rod as an instrument of the Devil, thereby identifying it with witchcraft and bringing it within the jurisdiction of the Catholic Church.

As I noted, water witching seems to have developed as a European practice. It was apparently unknown to the Native Americans and Eskimos, and was not practiced by Asians. It crossed the Atlantic in the 18th century with settlers from England and Germany. After 1775, it began to be mentioned in newspapers in connection with witches and witchcraft. Articles condemning it appeared in the 1821 and 1826 issues of the American Journal of Science. Even though very few geologists and engineers accept it (or, if they do, would be willing to admit it), the practice of water witching continues, especially in rural areas such as North Dakota.

It is interesting watching a dowser locate groundwater with his or her divining rod. Most commonly, he holds a forked stick, one fork in each hand, palms upward. The bottom of the "Y" points skyward at an angle of about 45 degrees. The diviner walks back and forth over the area he is testing. When he passes over a place underlain by groundwater, the butt end of the twig is supposed to be attracted downward, or somehow rotate downward. I was with a man once when he was witching, and at one point, it appeared that the willow stick he was using twisted so hard that the bark actually came off in his hands.

Most dowsers use a forked twig from a willow tree, at least in North Dakota, but in other places many different plants may be used; peach trees are commonly used in the south, or any of several different plants called <u>witch hazels.</u> Some dowsers use straight sticks or metal rods, and still others used keys, wire coat hangers, pliers, pendulums, or various kinds of elaborate boxes with batteries, electrical instruments, and lights. Once when I was working near Minot, a man showed me how he used a garden rake to find water; he balanced the rake in his hand and as he walked over the "water vein," the metal end of the rake dipped downward (I don't know if the location was ever drilled, so I don't know if he was actually successful).

Water is only one of the many substances dowsers or diviners claim they can find. They may attempt to locate gold, silver, lead, uranium, coal, and of course, oil. Dowsers are often asked to locate a buried pipeline or sewer line. Some even claim the ability to diagnose disease or to determine the sex of an unborn child. According to a reference I have in front of me as I am writing this, dowsers have attempted to discover buried or hidden treasure, to find criminals, to analyze personal character, to cure disease, and to find lost dogs.

Normally, dowsing for water is done at the actual spot where water is needed, but some dowsers have claimed to be able to locate water from maps alone, simply by passing the stick or whatever instrument over the map. I was once shown where to drill for oil in Traill County by a dowser who used a coat hanger to point to a spot on a geologic map of the area (it was a map I had drawn, but I had shown only surface materials so I'm not sure how he was able to use it to find oil!).

Generally, dowsers operate in communities where the location of an adequate water supply is uncertain and expensive to find using conventional methods. People sometimes turn to them for information when they are doubtful whether a particular well site will yield enough water. And I should add that most of the people I have known who claim to have witching ability are quite sincere in their belief; many of them perform their service without charge, simply as a hobby.

A variety of researchers, through controlled experiments, have concluded that water witching is not a reliable method of locating groundwater. Even so, a truly astonishing number of books and pamphlets are available on the subject.

Most dowsers I have met have told me that groundwater flows in veins, or underground rivers and what they are doing is locating these rivers. Actually, groundwater is the water filling pores or cracks in the rock or sediment. It is replenished by precipitation and occurs in a variety of geologic situations. Groundwater is variable in both quantity and quality.

The best explanation why many dowsers are often successful is that, in some areas, water would be hard to miss. The site indicated by the rod is not necessarily the only one where water could be found. In areas of adequate rainfall, especially in the eastern United States, and where the geology is favorable, it may be difficult <u>not</u> to find water, and the fact that some groundwater exists almost everywhere helps explain why so many dowsers appear to be successful. However, to locate groundwater accurately, a number of geologic, geophysical, and hydrological techniques must be used. Geologic and geophysical knowledge is needed to determine the depth and extent of water-bearing layers, and the quantity and quality of water that may occur in them. In North Dakota, the NDGS, along with the State Water Commission, have been studying the geology and hydrology of the counties for the past 30 years, and most of the major aquifers in the state have now been identified and studied. Even so, it still is often difficult to accurately predict whether a successful well can be drilled in a particular location.

So, if you want to drill a water well should you hire a water witch? It is my <u>opinion</u> that you'd be better off contacting the State Water Commission or a reputable driller in your community. Even so, I realize that there are many people who are convinced that witching works and I know too that nothing I can say will ever convince them otherwise. Finally, if any of you reading this have had personal experience with water witching, or know of methods of witching I didn't mention, I'd like to hear from you.

DUNES

--John Bluemle

No, I'm not going to write a sequel to Frank Herbert's classic science fiction novel <u>Dune</u>. However, some people do have a hard time taking me seriously when I start telling them about North Dakota's sand dunes; perhaps they think I'm talking fiction. You find dunes in the desert, right? Yes, you may, but you also find them in North Dakota. Our dunes are real too, not a topic for a science fiction article. North Dakota has several areas of fairly good-sized sand dunes (fig. 1), none remotely like the ones described by Herbert on the planet Dune, or the massive dunes found near Alamosa, Colorado in Great Sand Dunes National Monument, or the widespread dunes in the sand hills of western Nebraska. Even so, our dunes are interesting features and a pleasant place to spend an afternoon roaming around (but in the summertime; dunes are about the easiest place I know of to get lost in during a snowstorm).

All of the larger areas of dunes in North Dakota are associated with sand that was originally deposited by glacial-related processes. Most of the dunes in North Dakota probably formed during the Middle Holocene, between about 7,500 and 5,000 years ago, during a time geologists refer to as the "Altithermal Interval." The Altithermal Interval was the warmest and driest time since the end of the Ice Age. It is sometimes defined as a time when most of the world experienced mean annual temperatures higher than those at present. During much of that time, conditions were probably similar to those during the 1930s, when the cover of vegetation became so sparse it was no longer effective in controlling wind erosion. Many people still remember the terrible dust storms we had over the plains during the so-called "dirty thirties."

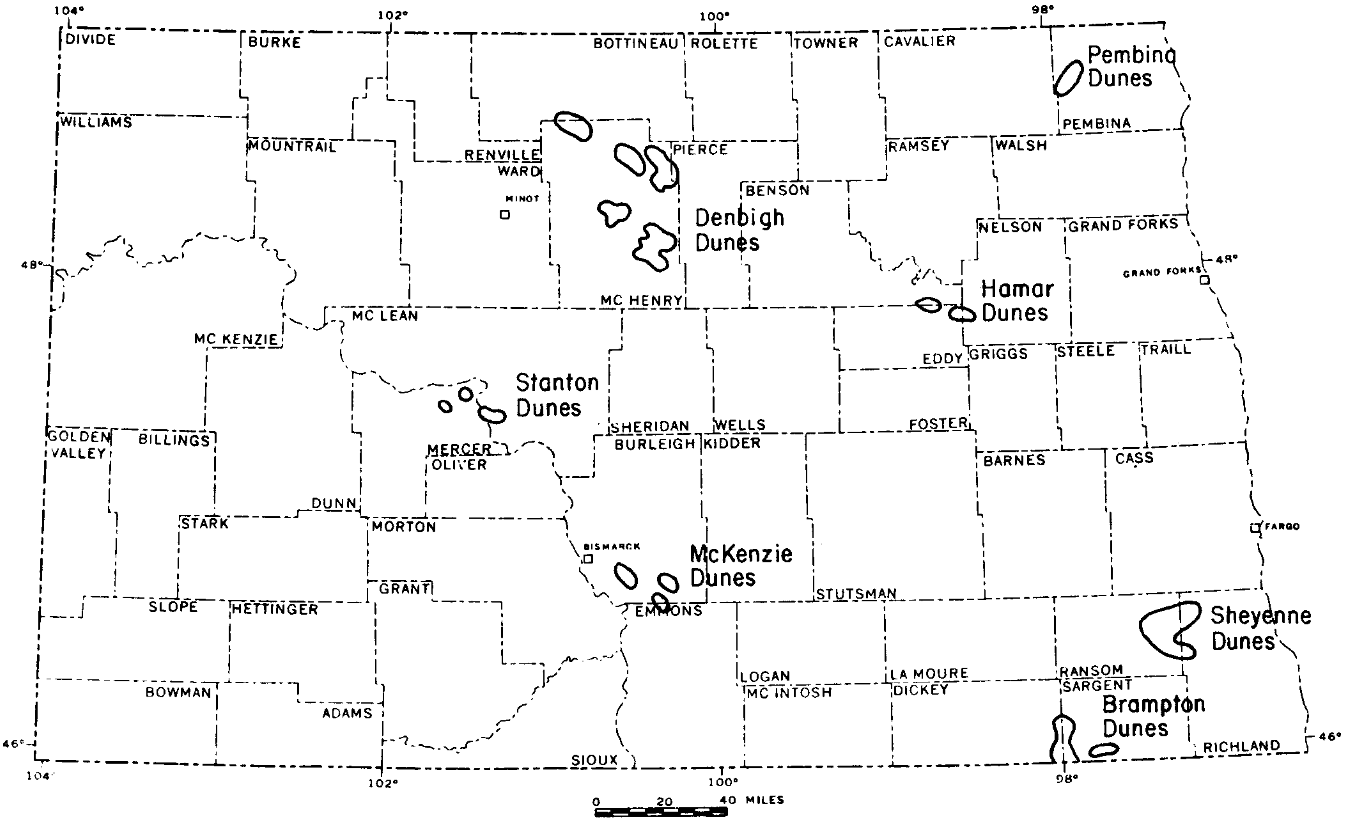


Figure 1. Areas in North Dakota where sand dunes can be found. All of these dune fields are associated with glaciolacustrine deposits, places where rivers emptied into proglacial lakes. Some small areas of dunes southwest of the Missouri River occur in association with Paleocene bedrock sands. These are not shown on the map.

Most of North Dakota's sand dunes are found in places where sand was deposited by rivers flowing into lakes at the end of the Ice Age. A few of the more important areas of dunes in North Dakota are the ones located south of Walhalla in Pembina County, where the Pembina River entered Lake Agassiz; in eastern Ransom and northeastern Richland Counties, where the Sheyenne River flowed into Lake Agassiz; in southwestern Sargent County where the James River flowed into Lake Dakota; and in McHenry County near Towner, where the Souris River flowed into Lake Souris.

In these and other places where rivers flowed into glacier-dammed lakes like Lake Agassiz and Lake Souris, they deposited large amounts of well-sorted sand. By way of explanation, when geologists speak of "well-sorted" sediment, they mean that all of the particles are about the same size; thus, when we speak of poorly sorted sand or gravel, we mean that all sizes of particles--pebbles, sand, cobbles, silt, and clay--are mixed together. Generally, river sediment is poorly sorted because the rapidly flowing water deposits all sizes of materials. By way of contrast, lake sediments were deposited more slowly and settled to the bottom evenly in still water. They therefore tend to be well sorted, fine- to very fine grained deposits. In places where rivers entered lakes, as I noted above, large amounts of fine-grained sand were dropped in the quiet lake water. The sediments were deposited at the mouths of the rivers as density-current fans. The heavy sediment-laden river water stayed near the bottom of the proglacial lake and spread out over a broad area. The coarser materials were either deposited farther upstream, on the river floor itself, or very close to the river mouth; only the finer sand and coarse silt made it into the lake. It was this well-sorted sand that was later blown into dunes. Dunes did not form in areas covered by poorly sorted gravel--glacial outwash, etc.-- because, as soon as the wind began to blow over these materials, it blew away the finer particles, leaving a lag of gravel armor that prevented further wind erosion.

Many of our dunes are from 50 to 80 feet high and a few are nearly 100 feet high. It's hard to visualize by standing on the top of a dune, but many of the dunes have a strong northwest-southeast linearity, parallel to the direction the wind was blowing when it built them. These are known as longitudinal dunes. A few of our dunes are crescent shaped with their convex side pointing toward the northwest or nearly north (upwind), and their ends pointing southeastward (downwind). In North Dakota, the crescent-shaped dunes are not as large as the longitudinal dunes. Geologists generally refer to them as barchan dunes (pronounced bar-con), although they are also known as horseshoe dunes or parabolic dunes.

Sand dunes are certainly our most obvious and spectacular wind-blown landforms, but they are not the only type of deposit in North Dakota formed by the wind. While the wind was shaping the sand into dunes, the finer, silt-sized particles were being blown greater distances and spreading out over much wider areas. In fact, much of North Dakota is veneered by a discontinuous layer of wind-blown silt that geologists call "loess" (rhymes with "puss;" the word translates approximately "loose" from German) (fig. 2). In places along the Missouri River valley in northern Mercer County; just south of Garrison Dam in McLean County; and in parts of Emmons County along the Oahe Reservoir the loess is as much as 20 feet thick. Over much of southwestern North Dakota, the loess cover is from 3 to 6 feet thick. Generally, the relatively flat areas of wind-blown silt, which are essentially the deposits of Middle Holocene dust storms, occur downwind from river flood-plain deposits or downwind from any place the wind could sweep over a broad area of fine-grained sediment. In parts of western Iowa, just east of the Missouri River valley, deposits of loess more than 100 feet thick are found, and in the Gobi Desert in Mongolia the wind-blown silt may be as much as 1000 feet thick. In North Dakota and other plains states during the 1930s, as much as several feet of wind-blown soil collected along fence rows and on buildings; we've all seen pictures of the dust-bowl conditions during the thirties.

The next nice summer day that you happen to be travelling on Highway 2 in the area between Towner and Denbigh, or along Highway 27 east of Lisbon, or in any of a number of places where dunes are easily accessible, stop for a while and walk out into them. The dune area near McLeod in eastern Ransom County is part of the Sheyenne National Grassland and a beautiful place to see undisturbed native prairie. The dunes in the Walhalla area are largely wooded. Wherever you stop among our dunes, I think you'll enjoy them as much as I do.

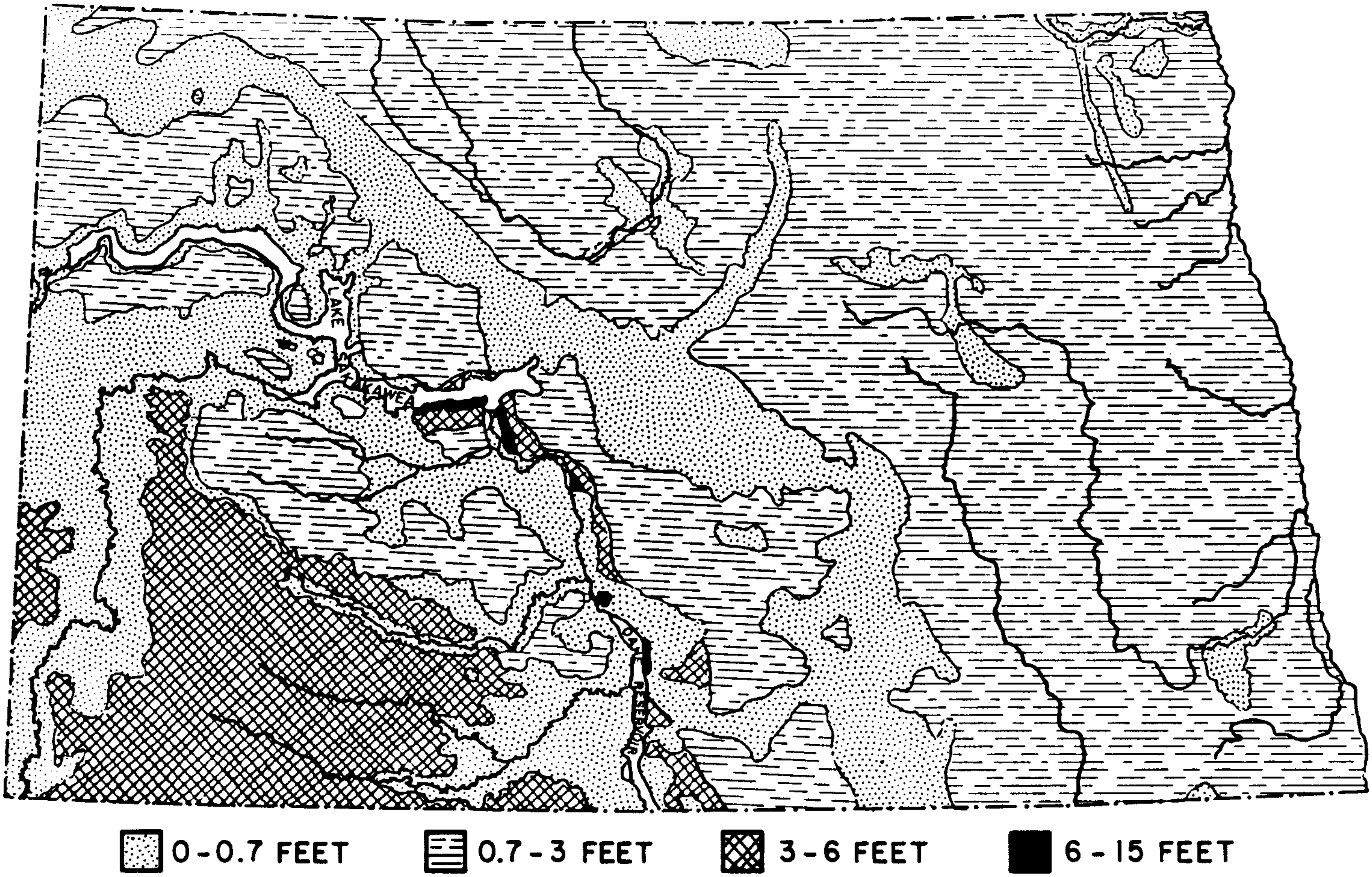


Figure 2. This map is a reproduction of an illustration from a report entitled "Stratigraphy, Origin, and Climatic Implications of Late Quaternary Upland Silt in North Dakota" by Lee Clayton, S. R. Moran, and W. B. Bickley (NDGS Miscellaneous Series 54, published in 1976). The wind-blown silt is thinnest where other Holocene sediment (such as stream sediment and wind-blown sand) had been deposited or where slopes are steep. It is 1 to 3 feet thick on flat to rolling late Wisconsinan surfaces. It is 3 to 6 feet thick downwind from the Missouri River flood plain and on flat to rolling early Wisconsinan or older surfaces. It is 6 to 15 feet thick immediately downwind from the Missouri River flood plain.

Figure 3. This is a vertical air photograph of part of a dune field about two miles northeast of Denbigh in McHenry County (north to the top). The line extending northeastward from the lower left corner of the photo is the Burlington Northern Railroad track. These dunes, which are as much as 50 feet high, were deposited by wind blowing from the northwest (upper left).

Figure 4. Dunes in eastern Ransom County, southeastern North Dakota, near McLeod. This is in the Sheyenne Dunes Field, also a National Grasslands area.

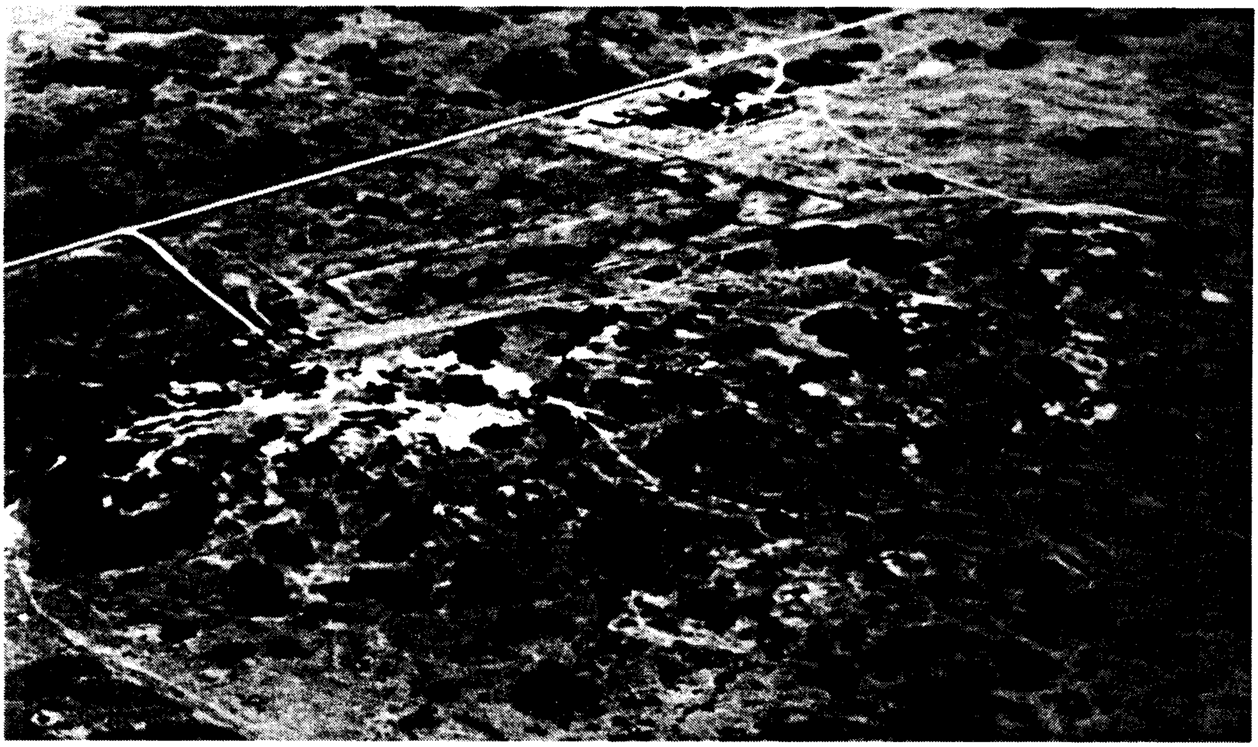


Figure 5. Oblique airphoto of part of a small dune field near Denbigh in McHenry County. The black areas are trees. Lighter areas are places where the sand is bare and may be actively blowing.

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 23 and 24 of this Newsletter for descriptions of publications.

____RI-86 ($2.00) Migration of Contaminants from Buried Oil-and-Gas Drilling Fluids Within the Glacial Sediments of North-Central North Dakota.

____MS-69 ($3.00) Core Workshop Volume--Fifth International Williston Basin Symposium.

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