

NDGS

NEWSLETTER



Industrial Commission of North Dakota
North Dakota Geological Survey

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Soldiers making pressed brick at Fort Totten, circa 1870. Throughout North Dakota's history, clay has been used not only for brick making, but also for decorative and functional pottery and ceramics. A new exhibit at the North Dakota Heritage Center features beautiful, early artifacts made of clay, as well as more recent examples of North Dakota ceramics, and examples of the industrial uses of clay. For more information, see article on page 13.

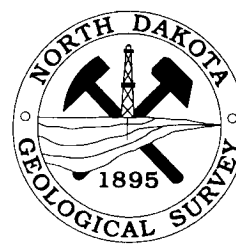
*Photo by Stanley J. Morrow
courtesy of the North Dakota
State Historical Society.*

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Randolph B. Burke • Paul E. Diehl • Ann M.K. Fritz
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Ann M.K. Fritz • Editor
Gina Buchholtz • Layout and Design

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FROM THE STATE GEOLOGIST

By John P. Bluemle



"Geo-Literacy" and Geologic Maps

Most people are naturally interested in the earth and want to understand the science behind land-use issues and hazards such as earthquakes, floods, and landslides. They are curious about, among other things, the landscape and scenery, rocks, minerals, and fossils. Environmental consultants, planners and other

professionals need the knowledge of geologists to make wise land-use decisions.

One way professional geologists share their knowledge and the results of their work is through geologic maps. In the Winter, 1997 issue of the *NDGS Newsletter*, for example, there was a summary of current field investigations of NDGS staff. The results of many of these investigations will be published as geologic maps. Geologic maps contain descriptive information about the sediments and the bedrock materials; they contain structural information about such things as faults and folds in the rocks; and they provide an interpretation of how the different geologic materials are related in time and space. Often, geologic maps are the basis for "hazard maps" which are used in the mitigation of natural disasters such as floods, landslides, earthquakes, and volcanic eruptions (the latter two are not much of a problem in North Dakota!).

Public demand for geologic information is huge, but very often, that geologic information (that is, the geologic map) is not presented in an understandable or interesting manner to people who have never had geologic training. Displaying geologic information so it is understandable to the non-professional geologist is a challenge that we at the NDGS take seriously.

If people are, for all practical purposes, "geo-illiterate," it's not their fault. After all, how many people take geology courses in high school or college? It is our responsibility as professional geologists to provide geologic information in a format the average person can understand so he or she can make intelligent decisions about issues that are affected by geologic factors. Dealing effectively with "geo-illiteracy" is fundamental to effective land-use planning and is a prerequisite for intelligent debate on issues relating to resource management, environmental health, and public safety.

An example of what I am referring to is the current debate about possible new dikes or diversion trenches to deal with the flooding danger in the Grand Forks area. This debate should be taking geology into account. Over 25 years ago, in the 1970's, NDGS geologists mapped the geology of the Grand Forks area in considerable detail and determined the engineering characteristics of the several subsurface formations that underlie the area. Some of the geologic formations they identified have almost no bearing strength; they have a consistency much like soft peanut butter. Placing a massive dike on top of them, or building a deep diversion trench, can cause them to flow into the river or otherwise fail if the design is inappropriate (for a more complete discussion of this problem, see the article in the Summer, 1997 *NDGS Newsletter* by Don Schwert and Mark Peihl about the construction of the Northern Pacific Railroad in the Fargo-Moorhead area at the beginning of the 20th Century).

The North Dakota Geological Survey has always had as one of its fundamental duties the production of accurate and pertinent geologic maps. The earliest geologic map of North Dakota that I know of was produced in 1906 by State Geologist A. G. Leonard. Over the years, NDGS geologists have continued to do a variety of kinds of geologic mapping, providing maps that have become increasingly accurate and sophisticated.

During the period from about 1958 to 1990, NDGS geologists, working closely with hydrologists with the North Dakota State Water Commission and U.S. Geological Survey, mapped all of the counties of North Dakota at 1:125,000 scale (a half-inch to a mile). These geologic maps have served to provide a sound basis for understanding North Dakota geology. Over the years, a variety of regional and state-wide geologic maps have been produced by the North Dakota Geological Survey. In 1980, Lee Clayton, a University of North Dakota geology professor working in cooperation with the Survey, produced a 1:500,000-scale geologic map of North Dakota.

Since 1993, the North Dakota Geological Survey has undertaken a much more detailed kind of geologic mapping. With the passage of the National Mapping Program in 1992, the NDGS has applied for and received federal funding to help pay for several geologic mapping projects (the program is known as "STATEMAP"). The basic STATEMAP mapping unit is the 7½-minute quadrangle. A 7½-minute quadrangle (a "quad") covers about 50 square miles and is drawn at a scale of about 1" = 2.2 inches. There are 1,464 quads covering North Dakota.

STATEMAP mapping priorities are determined by the State Mapping Advisory Committee. The committee is made up of governmental agencies, including the NDGS, private-sector user groups, and universities. The program has been strongly endorsed by officials who recognize the crucial importance of geologic maps in dealing with a host of land-use and natural-resource issues.

Under the STATEMAP program we have thus far completed detailed geologic maps of the Jamestown and Dickinson areas and of Theodore Roosevelt National Park (although the map of the park has not yet been released). We are currently in the process of mapping the geology in the Bismarck-Mandan area, an area that includes nine 7½-minute quads. NDGS geologists Ed Murphy and Ann Fritz, along with former NDGS geologist Bob Biek, have done most of our STATEMAP geologic mapping. They are now joined by geologist Karen Mitchell, who joined the NDGS staff in February.

The NDGS has also used STATEMAP funds for mapping of a 1:100,000-scale geologic map in the Grafton area in northeastern North Dakota. The Grafton map area contains some of the State's most valuable agricultural, groundwater, and gravel resources. Ann Fritz completed field work in the Grafton 30 x 60 minute quadrangle (covering about 1400 square miles) this past summer. The map will be produced in a digital format. The lithology-based geologic map she produces will be used, in part, to minimize conflicts between competing natural-resource interests and to meet other current and upcoming needs for digital data. The digital format also facilitates use in a geographic information system.

Geologic maps are the basis for a wide range of economic, environmental, and health and safety applications. Maps need to be drawn in a way that makes them intelligible to the people who use them. A fundamental role of the North Dakota Geological Survey is to provide such geologic maps - maps that are accurate and easily understood by the citizens of North Dakota.

NEWS IN BRIEF



Compiled by Ann M.K. Fritz

SURVEY WELCOMES NEW GEOLOGIST

Karen Mitchell has recently joined the ND Geological Survey as a Geologist. Karen grew up on a farm near Breckenridge, Minnesota, a rural community on the Red River about 45 miles south of Moorhead. She received her Bachelor of Arts in Geology from the University of Minnesota-Morris in 1994. While at UMM, Karen participated in the Morris Academic Partners and Undergraduate Research Opportunities Programs studying glacial sedimentology and paleontology.

During the summer of 1994, Karen worked as a geologist with the U.S. Geological Survey in Marlborough, Massachusetts prior to beginning her graduate work at Washington State University (WSU) in Pullman, Washington. Her graduate research at WSU focused on the sedimentology and stratigraphy of the Eocene Springbrook Formation in Southern British Columbia, Canada. The Springbrook Formation is a coarse, clastic deposit that records the onset of Eocene Cordilleran extension. She received her Master of Science in Geology from WSU in December, 1997. Karen will work primarily with the surficial mapping program. If you stop by the NDGS offices in Bismarck, be sure to give a warm welcome to Karen!



EARTHQUAKE IN HAGUE?

Ann Fritz

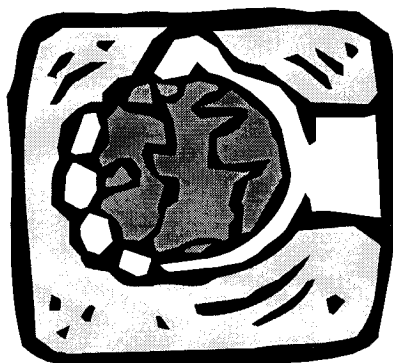
On the afternoon of Sunday, January 4, a loud "boom" was heard near the town of Hague, ND. Ice-fishermen on nearby Rice Lake reported that the ice moved up and down like a wave; the ice cracked and water gushed out of the cracks. Kevin Kocher, a rancher living near Hague, was out feeding his cattle at the time and also heard the boom. "I thought it was loud, but my cattle didn't even look up," Kocher said. Curious, Kocher, as well as Allan Burke, a reporter for the *Emmons County Record*, called the NDGS office to see if the loud noise was due to an earthquake.

Both Ann Fritz and Ed Murphy, NDGS geologists, contacted the U.S. Geological Survey National Earthquake Information Center (NEIC) for more information. According to Bruce Presgrave, NEIC geologist, no earthquake was recorded on January 4 in North Dakota. The evidence seems to suggest that the loud noise was caused by ice-heave on Rice Lake. The air temperature over the weekend was beginning to drop, possibly causing changes in the ice. The men who reported the shaking were out on the ice, which would tend to buckle and move during ice-heave. Further evidence that it was not an earthquake is that Kocher, who was outside at the time, reported that he did not notice that the ground was shaking or moving at all.

However, it should be noted that there are no active seismograph stations in North Dakota with which to measure micro-quakes. The nearest seismograph station to Hague is located just west of Rapid City, South Dakota. Presgrave

reports that even with the sparse seismograph station coverage for North Dakota, the NEIC would normally be able to see some indication of an earthquake as low as a magnitude 3.0 to 3.5. If it was an earthquake near Hague, it was magnitude 3.0 or smaller. An earthquake of magnitude 3.0 would have been felt by persons indoors, hanging objects would swing and vibrations like that of a passing truck would have been felt.

At one time, three seismograph stations were located in North Dakota: one near Hannah in Cavalier County, one in Ryder in Ward County, and one near Trotters in northern Golden Valley County. These stations were part of the Long Range Seismic Monitoring (LRSM) Network based in Garland, Texas. Presgrave states that the LRSM stations were temporary stations operated for short intervals to record signals from nuclear tests during the 1960s. They were used to study crustal structure of North America from known sources (nuclear explosions) and also to provide data for the explosions themselves.



For more information about earthquakes in North Dakota, check out North Dakota Notes #4 at the NDGS website, <http://www.state.nd.us/ndgs/Ndn4.html>, or the article in the Spring, 1996 NDGS Newsletter, "Earthquakes in North Dakota" by Bob Biek (Volume 23, No. 1, pp. 17-23). The National Earthquake Information Center home page is also an excellent source of information about earthquakes all over the world. Their URL address is: <http://wwwneic.cr.usgs.gov/>.

"MERCURY AND THE ENVIRONMENT"

Contributed by John Dwyer, Lignite Energy Council

A new brochure, entitled "Mercury and the Environment," was recently published by the Industrial Commission of North Dakota/Lignite Research Council. Members of the Partners for Affordable Energy coordinated copy and production of the brochure. The purpose of the brochure is to help educate the general public, legislators, public officials, and the media about mercury in our environment and the impact of mercury emissions from coal-fired power-plants. For example, the brochure cites a recent study by the Minnesota Pollution Control Agency that found mercury levels in Minnesota are 25 percent lower than peak rates in the 1960s and 1970s. If you are interested in receiving copies of this publication, please contact Renee Walz of the Lignite Energy Council at (701) 258-7117.

NORTH DAKOTA FOSSILS EXHIBITED AT THE U.S. FOREST SERVICE HEADQUARTERS IN WASHINGTON, D.C.

John W. Hoganson

In 1986, the NDGS and the U.S. Forest Service (USFS) signed an agreement to cooperatively manage paleontological resources on lands administered by Custer National Forest in North Dakota. Custer National Forest has the responsibility to manage fossils on large tracts of public land in the Little Missouri National Grassland area of western North Dakota. As a result of this agreement, several hundred fossil sites in the Little Missouri National Grassland have been discovered, many of which have been determined to be significant scientific and educational sites. Two fossil exhibits have been established at the North Dakota Heritage Center in Bismarck as a result of the NDGS - Forest Service partnership. One of the exhibits is a restored skull of a *Triceratops* dinosaur found in the Cretaceous Hell Creek Formation north of Marmarth, Slope County. The other display is a nearly complete, restored skeleton of a champsosaur, a crocodile-like animal that lived in ponds in western North Dakota during the Paleocene. It was recovered from the Sentinel Butte Formation at the Tracy Mountain fossil site near Belfield, Billings County. The USFS administers the Tracy Mountain fossil site and provided funds for the exhibits.

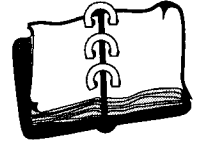
A second exceptionally well preserved skeleton of a champsosaur was collected at the Tracy Mountain site in 1993. The Forest Service decided that an exhibit of North Dakota fossils at their headquarters in Washington, D.C. would demonstrate their commitment to effective management of fossil resources on lands administered by them. Johnathan Campbell, the NDGS's fossil preparator, restored the champsosaur skeleton and other fossils for the exhibit. The Forest Service believes that this exhibit will help bring attention to the need for effective management strategies of fossils on public lands administered by federal land managing agencies. To help accomplish that goal, the USFS will soon be hiring a paleontologist to develop fossil resource management policy for USFS lands in this country.

Johnathan Campbell and I installed the exhibit with the help of Barbara Beaseley, USGS paleontologist from Chadron, Nebraska, and Carol McCoy Brown, Custer National Forest geologist from Billings, Montana, on January 27 and 28. A dedication ceremony was held on January 29. Mike Dombeck, USFS Chief, Larry Gadt, USFS Director for Mineral and Geology Management, Larry Dawson, USFS District Ranger, Little Missouri National Grassland, and I gave short presentations expressing the need for effective fossil resource management on federal and state administered public lands in this country and the importance of cooperative fossil resource management programs such as the one between the NDGS and the USFS-Custer National Forest.



Champsosaur exhibit at the U.S. Forest Service headquarters. Pictured left to right: Johnathan Campbell, John Hoganson, Barbara Beaseley, and Ken Johnson, USFS Assistant Director for Geology & Mineral Management.

MEETINGS & CONFERENCES



★★ INVITATION ★★

The North Dakota Geological Survey and Saskatchewan Energy and Mines are pleased to announce the upcoming **Sixth International Williston Basin Horizontal Well Workshop** to be held in Bismarck, North Dakota, May 3-5, 1998. We invite your participation!

As before, the workshop will provide an informal setting to exchange information on horizontal drilling in the Williston Basin, make contacts, and identify future opportunities. The workshop is co-sponsored by the North Dakota Geological Survey and Saskatchewan Energy and Mines and focuses on the specific area of the Williston Basin. The Basin continues to experience a great deal of horizontal drilling activity with growing interest in deeper horizons. Horizontal wells have been used very successfully in old fields to revive production and in newly discovered fields to improve production rates and recoveries.

The Sixth International Workshop will concentrate on specific topics of interest to operators who are active, or would like to become active, in further oil-development projects in the Basin on both sides of the border. As a participant, you are encouraged to play an active part in making this endeavor a success and we hope that you will come away from the workshop with an improved understanding of the technical opportunities for horizontal wells in North Dakota, South Dakota, Montana, southeast Saskatchewan, and Manitoba. In addition, this is an opportunity for you to develop and/or renew contacts with other Williston Basin production companies, consultants, and service companies active in horizontal drilling.

Format

To achieve the above format, we propose to have plenary sessions which will combine a number of presentations from companies and individuals with experience in the Williston Basin along with time for examination of notice board displays. There will also be plenty of opportunity for informal discussions of topics "one-on-one".

The workshop begins on Sunday, May 3, with registration and an informal "ice-breaker". Monday and Tuesday's focus will be on engineering and geology and, for those interested, there will be a display of core on Tuesday afternoon. We will also be offering a pre-workshop tour of coal country facilities on Sunday, May 3. The tour will cover reclamation areas, lignite mines, and energy conversion facilities in Mercer County. It will include the Great Plains Synfuels Plant, Basin Electric Power Cooperative's Antelope Valley Station, and the Coteau Properties Company's Freedom Mine. This tour is limited to 95 people and cost is \$15 per person.

Informal Posters

One of the features of the workshop is that any participant who wishes may put up a visual technical display. *We will provide notice board and/or table space at NO CHARGE to registrants who would like to do this.* The tone of the meeting is informal, as are the poster presentations. Poster displays can consist of maps, logs, drilling reports, or whatever you think will allow for a focused discussion. The notice boards have been a popular focus for discussion at the first five workshops and we believe this aspect is consistent with the workshop's aim of encouraging greater individual contact and opportunity development across the border. You may also include a one- or two-page summary of your display in the workshop preprint.

Registration

The workshop will be held at the Radisson Inn, Bismarck, North Dakota. Cost is \$60 (\$90 Canadian). To register for the Sixth International Williston Basin Horizontal Well Workshop, or for more information, please contact Gina Buchholtz at (701) 328-8000.

North Dakota
Geological Survey



Saskatchewan
Energy and Mines

FIFTH CONFERENCE ON FOSSIL RESOURCES

You are invited to participate in the Fifth Conference on Fossil Resources to be held October 13-16, 1998, at the Rushmore Plaza Holiday Inn in Rapid City, South Dakota. The 3-day conference is being co-hosted by the National Park Service, USDA - Forest Service, the Bureau of Land Management, South Dakota School of Mines and Technology, South Dakota Discovery Center and Aquarium, and the North Dakota Geological Survey. Seven theme sessions will revolve around the title of this year's conference, *Partners Preserving Our Past, Protecting Our Future*. The theme sessions are as follows:

- **Education and Outreach.** This theme will be divided into three different sections: Museum, Paleontological Curricula, and Interpretation. Various case studies involving paleontology curricula developed by three fossil parks for grades 2 through 8 will be presented.
- **Science and Research on Public Lands.** Highlights of on-going paleontological research on public lands will be presented. Researchers who work on Federal, State and Tribal lands are invited to present. Presentations will include technical themes along with discussions on building ties between land management agencies and the academic community.
- **Paleontology and the Public Trust** will explore some of the basic philosophy underlying the concepts of public trust. A series of panel discussions will be set up to pursue the status of paleontological legislation of Federal, State and Tribal lands. Dr. Joseph L. Sax, leading scholar of the public trust doctrine, will participate.
- **Technology and Paleontology.** These sessions will include both a symposium and discussion panel on the use of GIS and computer databases to document paleontological resources. There will be a demonstration using paleontological and geological data layers integrating research and resource management issues.

- **Paleontological Resource Management.** All levels of resource managers from various agencies will discuss proactive and collaborative management of paleontological resources.
- **Curation, Preparation and Conservation** of fossil resources. The themes include: fossils and collections care, significant museum and federal government partnerships, and basic field collection standards.
- **Partnerships.** Amateur and volunteer programs, as well as cooperative agreements between agencies will be highlighted. The symposia will also include panel sessions and open discussion.

As an added bonus, field trips are included in the registration fee and will be scheduled for Thursday, October 15. Conference participants can choose to attend one of seven field trips in the Black Hills, Badlands or Rapid City area.

Call for Papers: If you are interested in submitting an abstract and/or paper, please contact either John Hoganson at the NDGS office at (701) 328-8006 or Rachel Benton of Badlands National Park, P.O. Box 6, Interior, SD 57750 - (605) 433-5361. Submittals will be reviewed by an editorial board before acceptance. All papers must be paleontologically related. *The deadline for submittal of papers and/or abstracts is April 17, 1998.*

Registration Information: The \$150.00 registration fee includes all symposia, a banquet, a field trip of your choice, a luncheon, two socials, coffee breaks and conference proceedings. A one day registration fee of \$50.00 includes one field trip day or one symposia day (does not include banquet or luncheon). An on-site registration fee of \$195.00 can be paid on the first day of the conference. Scholarships and sponsored registrations may be available. For more information, please contact Chris Niewold at (605) 433-5361. Pre-registration is available until August 1, 1998. For general registration information, contact Rachel Benton at (605)433-5361.

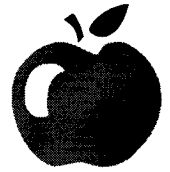
EIGHTH INTERNATIONAL WILLISTON BASIN SYMPOSIUM

The Eighth International Williston Basin Symposium will be held October 19-21, 1998, at the Ramada Renaissance Hotel in Regina, Saskatchewan, Canada. Sponsors of the Symposium are the Saskatchewan, North Dakota, and Montana Geological Societies. The Symposium will include pre-conference field trips, technical sessions, proceedings volume, poster and commercial displays, and a core workshop with manual.

Registration Information: The registration fee amount, as well as other fee amounts, will be announced in the Second Circular, which will be distributed in April, 1998. This can be obtained from Doug Paterson (306) 787-2625 or dpaterson@gov.sk.ca. One fee that has been determined is the student registration fee of \$20. This fee covers admission to all technical sessions and poster and commercial displays. It does

not include a copy of either the Symposium Proceedings or the Workshop Manual, nor admission to social events. For more information about the Eighth International Williston Basin Symposium, you can view the Symposium web site at <http://www.gov.sk.ca/enermine/about/intwilst.htm>. For general inquiries about the conference, please contact Chris Gilboy at (306) 787-2573 or Don Kent (306) 789-7040.

TEACHING TOOLS



THE FOSTER COUNTY TREES PROGRAM

by Ann Fritz

Sometimes I wish I were in 6th grade again. School seems like so much fun these days! Computers in the classrooms, on-line chats with the astronauts in the space shuttle, field trips, and lyceum presentations. Unfortunately, the only lyceum I remember from my grade school years was when Ronald McDonald came to my elementary school during Fire Prevention Week and did the "Stop, Drop, and Roll" dance.

Middle school kids in North Dakota now have an even better lyceum presentation available to them, yes, better than Ronald McDonald (no offense, Ronald). There's Sam Ting. Sam and three other characters are part of the Foster County TREES program. In the Foster County TREES program, laughing and learning go hand in hand.

TREES (The Regional Environmental Education Series) was developed by the Foster County Soil Conservation District (SCD) and is designed to emphasize the need to protect and conserve our natural resources. According to Jill Vigesaa, Program Coordinator for the Foster County SCD, the program began approximately eight years ago, when the SCD wanted an educational program to bring into middle school classrooms. Vigesaa and her colleagues, in coordination with

a professional environmental educator, created a puppet named Sammy Soil Digger that would demonstrate natural resource conservation in a fun and informative manner. Sammy was a hit with both educators and children alike and the program became very popular, so popular that they were unable to cope with the demand for presentations. The Foster County SCD decided to expand the project with seed money from the North Dakota Game and Fish Department and North Dakota State University Extension, and began a pilot program using both puppets and live action characters. The two-year county-wide pilot program was again so popular and successful that they expanded their program statewide.

The characters have evolved over time and Sammy the Soil Digger has since retired. Currently, Tom Gibson, an environmental educator, portrays a variety of characters: Darin Ewe, the boisturous and obnoxious game show host; Sam Ting, a Norwegian immigrant; Pete Bogg; and Gunnar, an 1880s pioneer.

The TREES program is actually five separate programs. Each character, Sam Ting, Pete Bogg, Gunnar, or Darin Ewe (who stars in two programs) is part of a different presentation. The programs can be presented in lyceum style or individual classrooms. Each presentation costs \$43, although the program is generally presented at no cost to the school. Local soil conservation districts and grants from the EPA, North Dakota Wetlands Trust, and the North Dakota Non-Point



"Sam Ting" meets Governor Ed Schafer at the state capitol. Sam Ting is just one of the many characters that environmental educator, Tom Gibson, portrays in the Foster County SCD TREES Program.

Continued on next page . . .

Source Pollution Task Force help defray the costs for schools. Programs are 30 to 60 minutes in length, depending on the grade. A description of each of the programs follows:

Kindergarten - Grade 3 (each program is 30 minutes in length)

- **Program Ia: *Pete Bogg and the Amazing Water Machine*.** The lovable Pete Bogg demonstrates the "Amazing Water Machine" for the students and shares some ways that we all can practice conserving water.
- **Program Ib: *Water You Doing?*** Taking the students and teacher back to the early 1800's, "Gunnar" portrays the captivating struggle to obtain adequate water in the everyday life of an early settler.

Kindergarten - Grade 12 and Adult (each program is 60 minutes in length)

- **Program II: *Sam Ting*.** Sam captures the attention of any audience with his delightful Norwegian humor. Sam teaches natural resource conservation awareness through the story of the Weasel family.

Grades 4-6 (each program is 60 minutes in length)

- **Program IIIa: *Common Cents*** is a fast moving, energetic game show hosted by "Darin Ewe". Students are the contestants who respond to natural resource based questions and either win valuable "Conservation Bucks" or receive "Common Cents".
- **Program IIIb: *More Common Cents*.** Darin Ewe is back as host with more game show fun. Designed to demonstrate the inter-dependencies of our natural resources, the students are again given the opportunity to be contestants in this test of their "Common Cents" knowledge.

For more information about TREES or to schedule programs, contact either your local County Soil Conservation District Office, or Jill Vigesaa, Program Coordinator, Foster County Soil Conservation District, 6720 Highway 200, Carrington, ND 58421, (701) 652-2551 or (701) 652-3033. Programs are currently being scheduled for Fall, 1998. Programs are usually coordinated for an entire county, so as to minimize expenses. Vigesaa reports that not only schools utilize the TREES program; 4-H clubs, Kiwanis, and other organizations for both parents and kids are utilizing the program. Learning is truly a lifelong process!

A DIFFERENT TYPE OF SUMMER CAMP FOR 7TH AND 8TH GRADERS

Science in the Circle of Life is a summer science camp run by the University of North Dakota Department of Biology and the Dakota Science Center, and funded by the Howard Hughes Medical Institute. The program is for students interested in expanding their knowledge in all fields of science and will be held from July 19 - August 1 at the University of North Dakota in Grand Forks. The program is designed to strengthen science skills and increase awareness of the academic and career opportunities available to students in science. Students will be exposed to professionals who will increase student confidence in applying newly acquired scientific skills. Students applying should be enthusiastic about trying new situations.

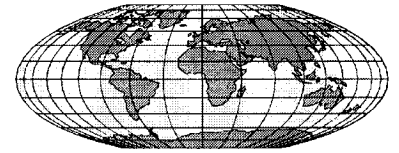
While at Science Camp, students will explore many different science sites around the UND campus. Working scientists will guide students through experiments and hands-on activities. Then students will become working scientists! Students will use newly acquired skills to investigate one subject area in-depth. Students and their teammates will develop a project and present the results to the camp community. The evenings will be spent making friends and having fun.

While participating in the program, students will reside in university residence halls and eat in campus cafeterias. All students participating in the camp are expected to comply with program conduct rules and regulations. A code of behavior agreement, signed by both the student and a parent or guardian, is required of all participants upon acceptance into the program.

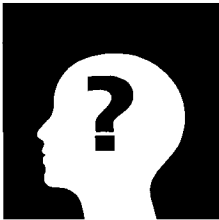
Students interested in attending Science Camp should contact: Dakota Science Center, Science in the Circle of Life, P.O. Box 5023, Grand Forks, ND 58206 - (701) 795-8500.

The application deadline is May 8. Applications include a completed and signed application form (available from the Dakota Science Center), an essay and a letter of recommendation from a teacher or counselor. There will be no fees for students chosen to participate in the program. Room and board, travel, and materials will be provided through the generous assistance of the Howard Hughes Medical Institute. There are only 50 spaces available for students enrolled in the 7th or 8th grade in a North Dakota school. Students who attend rural or reservation schools are especially encouraged to apply.

ESIC NEWS



The NDGS is an affiliate of the Earth Science Information Center (ESIC) network. Coordinated by the U.S. Geological Survey, the nationwide ESIC network provides information about geologic, hydrologic, topographic and land use maps, books and reports; aerial, satellite, and radar images and related products; earth science and map data in digital form and related applications software; and geodetic data. As an ESIC office, the NDGS can assist the public in locating earth science materials dealing with North Dakota, as well as other states. For more information, contact Karen Mitchell or Ryan Waldkirch at (701) 328-8000.



GENERAL INFORMATION/EDUCATIONAL MATERIALS

Land Use/Land Cover Fact Sheet

The "Land Use and Land Cover Digital Data" fact sheet, number FS-94-052, dated October 1994 has been declared out-of-print and is no longer available.

Land use/land cover digital data is still available through the Global Land Information System (GLIS) on the Internet or by using the "US GeoData Products" order form and price list available from the NDGS ESIC office.

Information about historical data (1970s -1980s) is available through the GLIS Web site at <http://edcwww.cr.usgs.gov/webglis>. Detailed information about land use/land cover data is contained in Data User's Guide #4, "Land Use and Land Cover Digital Data from 1:250,000- and 1:100,000-Scale Maps". *Reprinted from ESIC Information Bulletin 386.*

Satellite Image of Chesapeake Bay

A satellite image map of the Chesapeake Bay watershed was recently published by the USGS. Composed of Landsat thematic mapper scenes collected from 1990 through 1994, the map covers the entire 64,000-square-mile drainage basin of the Chesapeake Bay. It provides a snapshot of recent surface conditions, including vegetation, and can be compared with historical and future images to help monitor land use changes to the ecosystem in the Bay watershed.

The poster was produced as a result of the USGS participation in the Chesapeake Bay Program, a multi-agency effort started in 1993 to restore the Bay and its resources. Other activities such as measuring surface-water and ground-water flow and quality; conducting studies of past and present natural and human-induced changes; providing cartographic analysis; helping to modify hydrologic and geologic models of the Bay system; and working to improve the understanding of living resources in the Bay are also part of the Chesapeake Bay Program.

The map (file number TUS5676) costs \$4.00, plus \$3.50 handling charge per order. Orders can be placed by calling the NDGS Publications Clerk at (701) 328-8000, or by ordering from the USGS - Information Services, Box 25286, Denver, CO, 80225. Credit card order for the USGS can be faxed to (303) 202-4693. The Chesapeake Bay Watershed map is searchable in the Global Land Information system at <http://edcwww.cr.usgs.gov/webglis> and can be found by looking for printed maps, choosing small scale maps, and searching the map category "image maps-satellite". Additional information about USGS work in the Chesapeake Bay watershed is available at <http://chesapeake.usgs.gov/chesbay>. *Reprinted from ESIC Information Bulletin 390.*

Exploring Caves

The USGS has published a new educational product, "Exploring Caves." "Exploring Caves" is an interdisciplinary set of materials on caves for children in grades K-3, covering geology, cartography, and hydrology. This packet contains a poster, an instructional book, and a list of multimedia resources on caves. The instructional book contains a read-aloud story, lessons, and student activity handout sheets.

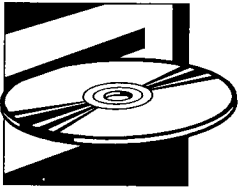
"Exploring Caves," is available free of charge to educators from either the NDGS ESIC office at (701) 328-8000 or the USGS-Information Services, Box 25286, Denver, CO 80225. Customer requests should be submitted on school letterhead. The file number for "Exploring Caves" is 97-0400. *Reprinted from ESIC Information Bulletin 398*

Revised "Educational Materials" Fact Sheet

The following fact sheet has been revised and recently received from the printer: "Educational Materials from the U.S. Geological Survey" - FS-225-96 (Revised November 1997; supersedes November 1996 edition). Orders for this fact sheet can be mailed to USGS-Information Services, Box 25286, Denver, CO 80225 or faxed to (303) 202-4693. *Reprinted from ESIC Information Bulletin 394.*

Publications of the U.S. Geological Survey, 1996

The "Publications of the U.S. Geological Survey, 1996" has been received from the printer and is now available for sale. This is an indexed compilation of USGS publications printed in 1996. It is available from the USGS, Box 25286, Denver, CO 80225. The file number is 60-PUB-96. The price is \$7.50 each, plus a \$3.50 handling charge per order. Credit card orders can be faxed to (303) 202-4693. *Reprinted from ESIC Information Bulletin 396.*



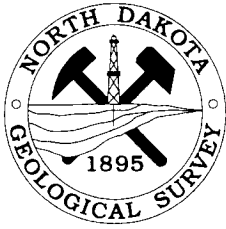
DIGITAL DATA

Volcanoes of the Alaskan Peninsula CD-ROM

The following digital data series CD-ROM is now available for sale: DDS-40 "Volcanoes of the Alaska Peninsula and Aleutian Islands, Alaska - Selected Photographs." This CD-ROM contains 97 digital images of photographs selected to portray Alaska's volcanoes, to document recent eruptive activity, and to illustrate the range of volcanic phenomena observed in Alaska. It has Portable Document Format (PDF) files for viewing text and the photographs, as well as installers for Adobe Acrobat Reader 3.0 for both Windows and Macintosh. The file number is 01-DDS-040. DDS-40 can be ordered from either the USGS-Information Services, Box 25286, Denver, CO, 80225, or by calling the NDGS GIS Center at (701) 328-8003. Please add \$3.50 handling per order. *Reprinted from ESIC Information Bulletin 388.*

Digital Elevation Model Viewing Software

USGS has developed Windows 95 software for viewing USGS Digital Elevation Models (DEMs). Called dem3d, the USGS is offering an experimental version to the public for a limited time while additional testing and research are conducted. To download dem3d, a users manual, and sample DEM's, visit the dem3d web page at http://mcmweb.er.usgs.gov/viewers/dem_view.html. Feedback from users will be considered in decisions about continued availability of and support of this viewer. If favorable responses and results are received, the USGS may make the viewer available as a standard supplement to USGS DEM's. Please send comments about dem3d to djgview@mailrmon1.er.usgs.gov. *Reprinted from ESIC Information Bulletin 389.*



North Dakota Geological Survey

INDUSTRIAL COMMISSION

Edward T. Schafer - Governor, Chairman

Heidi Heitkamp - Attorney General

Roger Johnson - Commissioner of Agriculture

John P. Bluemle, State Geologist

Dear Fellow Geoscientists:

Once again we ask for your cooperation in completing the accompanying geologic projects report form. On the form, we request information about areas in North Dakota - and nearby areas of adjoining States and Provinces - being studied by geoscientists in your university or agency during 1997-98.

All geoscientists should complete the form (on the back of this page) - industry, academic, and government professionals, as well as graduate and undergraduate students. Please circulate this form among your staff or colleagues for the required information and return by October 1, 1998.

This biennial summary is an excellent way to let people know about geologic research underway or recently completed in North Dakota and nearby areas; past survey results show that 74% of *NDGS Newsletter* subscribers read the summary. The geologic projects summary will appear in the Winter 1998 issue of the *NDGS Newsletter*. We hope that it will spur interaction among researchers and other interested persons.

Please detach and return the completed form to:

Editor, NDGS Newsletter
North Dakota Geological Survey
600 East Boulevard Avenue
Bismarck, ND 58505-0840

Thank you for your cooperation.

Sincerely,

John P. Bluemle
State Geologist

Please detach and return completed form!

Investigator(s): _____

Organization(s): _____

Address: _____

City: _____ State: _____ Zip: _____

County(ies) (refer to county codes below): _____

Location of Study: _____

Type of Study (refer to study codes below): _____

Title/Subject: _____

Scale of Geologic Mapping (if applicable): _____

Date of Inception: _____ Anticipated Completion Date: _____

Location of Information (i.e. University thesis; state or technical agency open-file report or publication; other publication; company, confidential - where, release date and provision): _____

May the NDGS have a copy of the completed report and/or map for our library? YES _____ NO _____



COUNTY CODES

AdamsAD
 BarnesBA
 BensonBE
 BillingsBI
 BottineauBO
 BowmanBW
 BurkeBU
 CassCA
 CavalierCV
 DickeyDI
 DivideDV
 DunnDU
 EddyED
 EmmonsEM
 FosterFO
 Golden ValleyGV
 Grand ForksGF
 GrantGR
 GriggsGG
 HettingerHE
 KidderKI
 LaMoureLM
 LoganLO
 McHenryMH
 McIntoshMI
 McKenzieMK
 McLeanML

MercerME
 MortonMO
 MountrailMR
 NelsonNE
 OliverOL
 PembinaPE
 PiercePI
 RamseyRA
 RansomRN
 RenvilleRE
 RichlandRI
 RoletteRO
 SargentSA
 SheridanSH
 SiouxSI
 SlopeSL
 StarkSK
 SteeleST
 StutsmanSM
 TownerTO
 TraillTR
 WalshWA
 WardWD
 WellsWE
 WilliamsWI
 StatewideSW
 MinnesotaMN
 MontanaMT
 South DakotaSD

ManitobaMB
 SaskatchewanSK

TYPE OF STUDY CODES

Economic Geology:
 a. GeneralEC
 b. CoalCG
 c. Nonfuel MineralsNF
 d. PetroleumPG
 Engineering GeologyEG
 Environmental GeologyEV
 GeochemistryGC
 GeochronologyGR
 Geologic HazardsGH
 Geologic MappingGM
 GeomorphologyGO
 GeophysicsGP
 HydrogeologyHG
 MineralogyMN
 PaleomagnetismPM
 PaleontologyPA
 Palynology/PaleobotanyPY
 PetrologyPT
 Quaternary GeologyQG
 SedimentologySD
 SoilsSO
 StratigraphyST
 Structural Geology/TectonicsSG

North Dakota Clay

by
Ann Fritz

When my husband and I travel, we like to take the back roads. We do this out-of-the-way traveling, in part, because I am fascinated by the older homes in small towns. I have noticed that you can learn much about the geology of a region by examining the building materials used in old houses and buildings. Many brick houses are constructed using local clays, and "natural" lawn decorations, such as scoria or petrified wood, are generally from a local source. Early settlers recognized an important resource when they saw one (or sank in it, as the case may be).

In North Dakota, we have a rich history of utilizing native clay resources for both functional and decorative purposes. An exhibit at the North Dakota Heritage Center that opened February 8 examines the history of clay utilization and some of its present uses. I hope to give you a little background information so that you can enjoy the Heritage Center exhibit more fully.

What is Clay?

Geologists use the term "clay" in one of two ways, either as a rock term or a particle-size term. Rocks are made up of different minerals. Clay or claystone is comprised of various

clay minerals, hence it is a rock term. Clay minerals are members of the phyllosilicate family. Phyllosilicates are minerals that have a platy structure and will preferentially break along one plane. Members of the phyllosilicates, which include other minerals such as chlorite and mica, also tend to be rather soft, and because of their atomic structure, can be flexible or even elastic.

Clay minerals are composed of hydrous aluminum silicates, but most clays contain a variety of elements such as iron, magnesia, potassium and sodium. Variations in color, appearance and behavior of clays occur due to the addition or substitution of these other elements in their atomic structure. The most common clay mineral (and its chemical composition) is kaolinite - $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$. *Figure 1* is a scanning electron microscope image of kaolinite and shows the sheet-like structure of clay minerals.

Another clay mineral group commonly found in North Dakota (and its chemical composition) is montmorillonite $(\text{Al,Mg})_8(\text{Si}_4\text{O}_{10})_3(\text{OH})_{10} \cdot 12\text{H}_2\text{O}$. Montmorillonites are also known as "swelling clays" or "popcorn clays" because of their ability to absorb water and the crumbly, popcorn-like appearance after they have dried out. Bentonite is

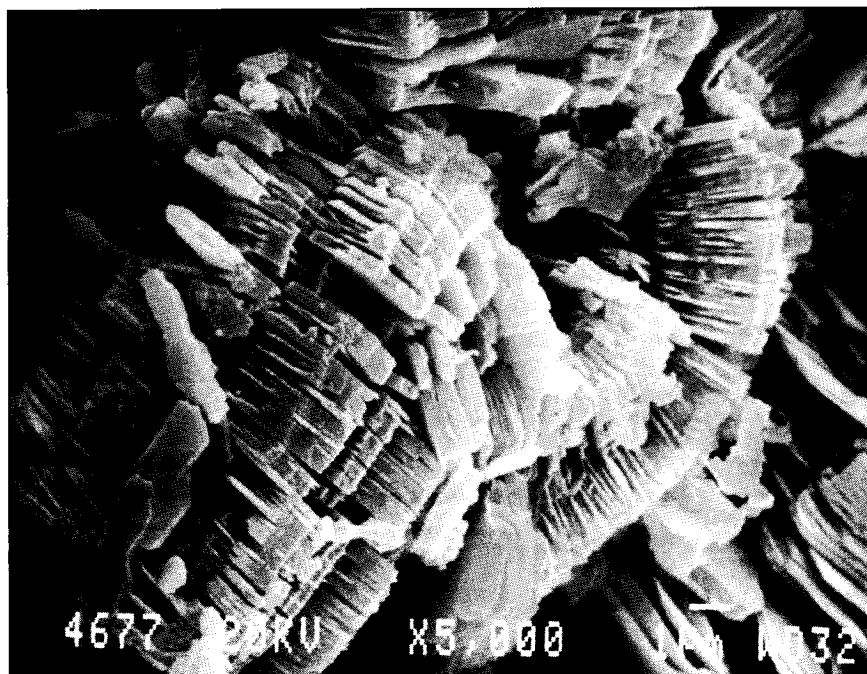


Figure 1. Scanning electron microscope image of kaolinite "booklets". This sample is from thermally altered geological materials from the Rocky Mountain 1 underground coal gasification test site, Carbon County, Wyoming. The scale bar, lower right hand side, is 1 micrometer (1×10^{-6} meters). *Courtesy of Energy and Environmental Research Center, Grand Forks.*

weathered volcanic ash and is composed primarily of montmorillonite. It too has an amazing capacity to absorb water. Bentonite is used as a drilling fluid additive, as grout for water wells, and has many other industrial uses.

The term clay can also refer to particle size; a clay particle is smaller than 0.002 mm. The term "clay" as used in the phrases "clay soil" or "clay till" does not necessarily mean that the material contains just clay minerals. Rather, the sediment contains particles which are clay-size or fine-grained. Non-clay minerals that can be clay-sized include quartz, mica, feldspar, carbonates or other minerals that are smaller than 0.002 mm. These clay-size minerals are the primary ingredients in soil. Weathering by the sun, wind and rain eventually reduces the rock to a crumbly pile of . . . clay!

Economic Values of Clays

How can something that is simply a result of weathering have an economic impact on North Dakota? According to 1996 statistics, the estimated value of marketable clay products in the United States was approximately \$1.7 billion dollars. The U.S. apparent consumption of clays was 39.2 million tons during that same year (U.S. Geological Survey, 1997). Also in that year, 59,000 metric tons of clay were mined in North Dakota. In 1995, a single company, the Hebron Brick Company, accounted for 75% of the clay mined in North Dakota. Hebron Brick continues to be the leader in clay products production in North Dakota. Obviously, the North Dakota clay industry is not as geographically diverse as it was in days past, but it does have an important impact on the state's mineral economy.

Early Exploration and Development of North Dakota Clays

Much of the information I have included here on the early days of the clay industry is from an NDGS publication titled *North Dakota Clays: A Historical Review of Clay Utilization in North Dakota* by Ed Murphy (1995). Murphy completed a thorough review of clays and claystone in the state, including lightweight aggregate potential, fuller's earth, bentonite, cement rock, and brickmaking. I have only included the history of the clay industry through the 1930s, although there have been many investigations completed since that time. I have focused on that time period because the early part of this century was the high point of the North Dakota clay industry.

In days past, there were small brickyards scattered throughout North Dakota. Most of these small brick operations were built for specific purposes: construction of a store, bank, or other commercial property. The cover photo, for example, shows a clay press used to make bricks at Fort Totten. The equipment and the clay pit were used between 1870 and 1876 to construct the buildings at Fort

Totten. Both the press and the pit were abandoned after all the buildings at the fort were completed.

Recognizing the economic potential of clay products, the early studies of the NDGS concentrated on the economic uses of clay and claystone, as well as coal, cement rock, and water. Earle J. Babcock, geologist and chemist, was hired by Webster Merrifield, president of the University of North Dakota, in 1889. Using a bicycle as his primary mode of transportation, Babcock completed field surveys of the lignite, clay and coal resources of North Dakota during the summers that followed. In 1892, Babcock, Dean of the Chemistry Department and the Mining Department at the University of North Dakota and soon to become State Geologist (from 1895 to 1902), published the first article on the various types of clays and claystone in the state. Later, Babcock and C. H. Clapp did the first comprehensive study of North Dakota claystone and published the results in 1906 as part of the NDGS's Fourth Biennial Report (1906a and b). In this report, Clapp and Babcock obtained 122 samples from throughout the state for physical analysis. The analyses included a determination of plasticity, chemical composition, and the results of test firing of samples. They also determined the influence of natural chemical variations in the claystone on the final fired product.

Clay was once used solely for brickmaking or other industrial uses, but as knowledge about the composition and extent of ND clays grew, so did the variety of the clay products. Clapp and Babcock (1906b) determined that the North Dakota clays best suited for brickmaking were taken from either the Bear Den Member of the Golden Valley Formation (Eocene) or from glaciolacustrine deposits. They also recognized that the Bear Den Member claystone could be used in the manufacture of stoneware. Their analysis revealed that the Bear Den Member at Black Butte, Hettinger County, contained a higher percentage of kaolinite than any other sample they tested and was "in a class by itself . . . which could be worked by almost any process and molded into any desired form" (Clapp and Babcock, 1906b, p.175). The brick plants at Hebron and Dickinson used clays from the Bear Den Member. Babcock and Clapp determined that the Hell Creek and Fort Union claystone were "not of great economic importance" because the majority of them were too sandy and could not be worked (Clapp and Babcock, 1906b, p.130).

North Dakota Clay Road Show

In the early 1900s, Babcock promoted the use of North Dakota clays to the rest of the world. He sent North Dakota clay to eastern pottery firms and asked them to make vases, dinnerware and other stoneware items for his upcoming display at the Louisiana Purchase Exhibition, which was to be held in St. Louis, Missouri in 1904. Pottery made from North Dakota clay was displayed in St. Louis

where it gained considerable attention. Babcock had also arranged that North Dakota clay and ceramic products be exhibited at the National Corn Exposition in Omaha, Nebraska in 1909.

By 1909, ceramics courses were available through the chemistry department at the School of Mines at the University of North Dakota. With the addition of Margaret Kelly Cable to the staff of the Ceramics Department in 1910, the department was now not only an experimental laboratory, but also a producer of nationally-renowned art pottery. Under Cable's direction, the staff and students at UND produced both decorative and functional pieces that were exhibited at the Panama Pacific International Exposition in San Francisco in 1915.

In the 1930s, William Budge, a professor of ceramic engineering at UND, authored several reports of the clay deposits of North Dakota. Budge focused on the swelling claystone of the western part of the state. Budge continued Babcock's promotion of North Dakota clay, and was instrumental in bringing the Works Project Administration (WPA), Federal Arts Project to North Dakota. The WPA/FAP lasted from 1936 to 1942 and was initially based in Dickinson, then moved to Mandan.

The Exhibit

The North Dakota Heritage Center exhibit, called *Earth, Water and Fire*, opened on Sunday, February 8, and will continue through August 30, 1999. The exhibit examines clays and the clay industry in North Dakota. Beautiful, early artifacts made of clay (*Figure 2*), as well as more recent examples of North Dakota ceramics are featured in this exhibit. The exhibit leads the visitor through a maze of clay utilization, from the old to the new, from the decorative to the functional. The exhibit shows the versatility and uses of North Dakota clays, something that North Dakotans have known for years.

The exhibit is divided into two parts, the Documentary Gallery, on the entrance level, houses the pre-historic and art

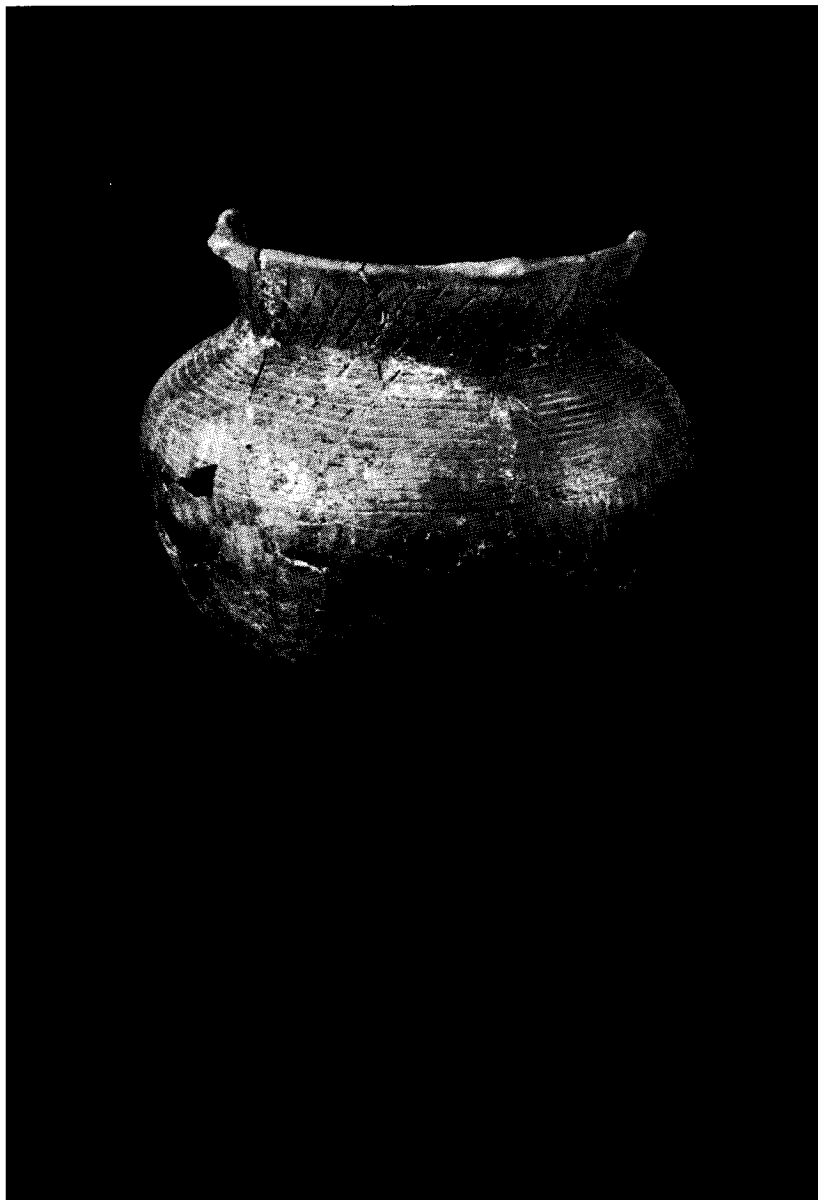


Figure 2. Riggs Ware from Havens archeological site, Emmons County. From about A.D. 1200 -1500, most vessels produced in the Mandan Indian Villages had straight rims and are referred to by archeologists as Riggs Ware. This vessel has a corn stalk design etched into the sides of the pot and will be on display through August, 1999 at the ND Heritage Center. Photo by Todd Strand, ND Historical Society.

pottery, as well as numerous pieces of UND pottery, WPA ceramic projects, and some modern ceramic pieces crafted by UND ceramic instructors Dawn Miller and Katie McCleery. The mezzanine level shows the industrial uses of clay and clay products, including examples from Hebron Brick Company (Figure 3).

The high point of the North Dakota clay industry was in the early 1900s. The exhibit shows the versatility of North Dakota clay products produced at that time. It should also be recognized that there is still economic potential for North Dakota's clay industry, for both artistic and industrial purposes.

References

- Clapp, C.H. and Babcock, E.J., 1906a, *Clay and its properties with special reference to North Dakota Clays*, in *The Fourth Biennial Report of the North Dakota Geological Survey*, p. 9-62.
- Clapp, C.H. and Babcock, E.J., 1906b, *Economic geology of North Dakota clays*, in *The Fourth Biennial Report of the North Dakota Geological Survey*, p.95-190.
- Murphy, Ed, 1995, *North Dakota Clays: A Historical Review of Clay Utilization in North Dakota*, North Dakota Geological Survey Miscellaneous Series No. 79, 18 p.
- U.S. Geological Survey, 1997, *Mineral Industry Statistics*, CD-ROM.

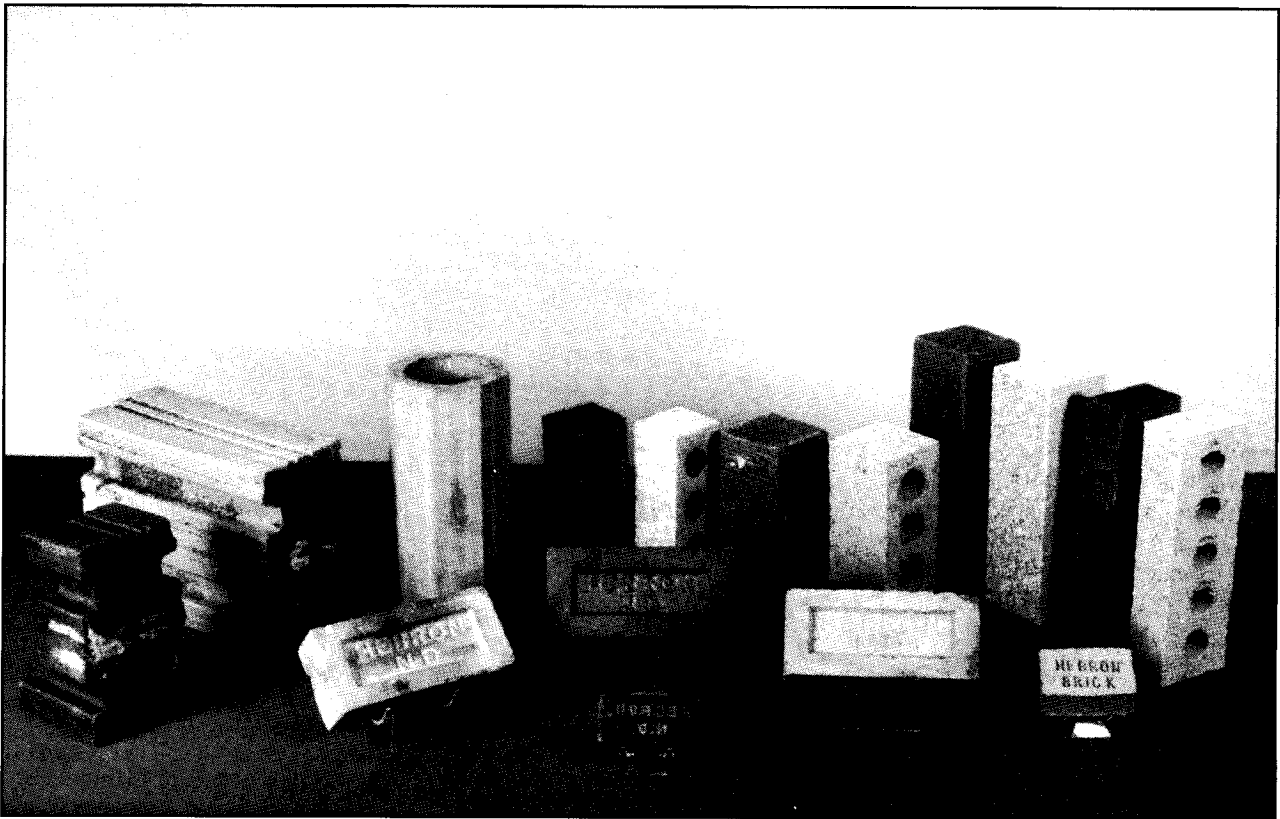


Figure 3. Some of the many varieties of brick and clay products produced at the Hebron Brick Company in Hebron. These bricks and other artifacts from the Hebron Brick Company are on display at the North Dakota Heritage Center. Photo by Todd Strand, ND Historical Society.

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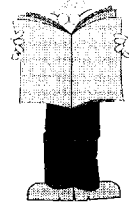
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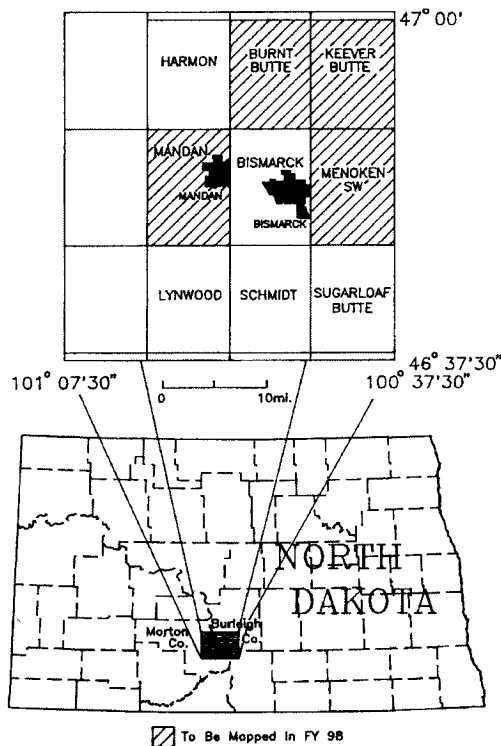


A Preliminary Report on the Geology of Bismarck-Mandan, North Dakota Area by Edward C. Murphy and Ann M.K. Fritz

The first phase of the Bismarck-Mandan mapping project has recently been completed. The purpose of the mapping project is to create nine 1:24,000-scale multi-purpose geologic maps and technical reports of the Bismarck-Mandan area. The mapping area, shown in the figure below, consists of a block of nine adjoining 7.5 minute quadrangle maps. Open File Report 97-1 includes only the Bismarck, Schmidt, and Sugarloaf Butte 7.5 minute quadrangles. The maps and accompanying report is intended to assist contractors, developers, city planners and engineers, geotechnical consultants, home owners and gravel pit companies in identifying areas of unstable ground, poor load-bearing sediments, buried waste, and gravel deposits. This project was completed by funds from the State of North Dakota and the STATEMAP program sponsored by the U.S. Geological Survey (44 pages + 3 plates).

OFR-97-1

\$10.00



ABOVE: The nine quadrangle maps included in the Bismarck-Mandan mapping project. The Bismarck, Sugarloaf Butte, and Schmidt quadrangles were completed as OFR-97-1. Harmon and Lynwood quadrangles were completed as an EDMAP project in 1997 by UND graduate student Jon Ellingson. The remaining four quadrangles, Burnt Butte, Kever Butte, Mandan, and Menoken SW, are scheduled to be mapped this summer.

ABSTRACT

Fort Union chronostratigraphic and depositional sequences, Williston Basin, North Dakota, South Dakota, and Montana, by Peter D. Warwick (U.S. Geological Survey), Romeo M. Flores (U.S. Geological Survey), Douglas J. Nichols (U.S. Geological Survey), Edward C. Murphy (North Dakota Geological Survey), and John D. Obradovich (U.S. Geological Survey).

The Fort Union Formation (FUF) in the Williston Basin (ND, SD, and MT) is composed of chronostratigraphic and depositional sequences from Early, Middle, and Late Paleocene time. Chronostratigraphic sequences are based on palynostratigraphic (pollen and spore) biozones and radiometric ($^{40}\text{Ar}/^{39}\text{Ar}$) ages obtained from tonstein partings in coal beds. Depositional sequences are based on lithofacies analyses constrained by the radiometric ages.

The Early Paleocene (P1-P2 biozones with the P2-P3 transition dated 64.4 ± 1.8 Ma) contains three marine parasequences in ND, which sequentially onlapped westward (lower Ludlow and Cannonball Members, FUF). These parasequences were correlated biostratigraphically to a tidal, distributary, and fluvial channel complex in the Cave Hills, northwestern SD. This complex is interpreted to be a remnant of the Late Cretaceous "Sheridan delta of the Hell Creek Formation" (Cherven and Jacob, 1985), which was reworked as a result of the Cretaceous-Paleocene paleoshoreline turnaround and subsequent rise in sea level. The parasequences consist of shoreface sandstones (with ravinement lags) deposited by barrier systems. Landward of the barrier systems, tidal-estuarine and mire deposits accumulated thick but laterally discontinuous peat beds (e.g. Beta, Upper-Lower Coal Pairs, and Yule coal beds in southwestern ND). However, landward of the coastal deposits, the laterally equivalent T-Cross/Big Dirty zone? (dated 64.78 ± 2.1 Ma) in southeastern MT formed as thick, laterally extensive peat deposits in mires of fluvial setting.

Middle Paleocene (P3-P4 biozones) strata consist of a regressive shallow marine and lower delta-tidal system that thins toward the east ("Marmarth delta") and an overlying lignite-bearing fluvial facies (Tongue River Member, FUF) containing the laterally persistent Hansen-Harmon coal zone ($61.23 \pm .38$ Ma). Biozones P5-P6 are represented by fluvial coal-bearing strata that contain several laterally persistent coal beds (HT, and Beulah-Zap/Hagel zones, Sentinel Butte Member, FUF).

** This abstract was printed in the Geological Society Abstracts with Programs, volume 29, no. 6, pp. A-204. The paper was presented in October, 1997, at The Geological Society of America Annual Meeting in Salt Lake City, Utah, and won Best Paper Award in the Coal Geology Division. Congratulations!