NEWSLETTER

NDGS

Industrial Commission of North Dakota, North Dakota Geological Survey Vol. 21, No. 4, Winter 1994

The Killdeer Mountains consist of two mesas (North Killdeeer Mountain and South Killdeer Mountain) that rise 700 feet above the surrounding countryside in northern Dunn County. The rocks that cap the Killdeer Mountains, shown in this photo looking north to the southeast edge of the South Killdeer Mountain, consist of tuffaceous sandstone, siltstone, and carbonates. These carbonates have been studied for their suitability in the manufacture of portland cement. See article on page 11. *Photo by Ed Murphy.*

FEATURES

DEPARTMENTS

NDGS Newsletter (ISSN: 0889-3594) is published quarterly by the North Dakota Geological Survey, a division of the Industrial Commission of North Dakota. *NDGS Newsletter* is designed to reach a wide spectrum of readers interested in the geology and mineral resources of North Dakota. Single copies of *NDGS Newsletter* are distributed free upon request. Please share the *NDGS Newsletter*; we encourage its reproduction if recognition is given.

Your comments - and contributed articles, photographs, meeting announcements, and news items - are welcome. Correspondence, subscription requests, and address changes should be addressed to Editor, *NDGS Newsletter*, North Dakota Geological Survey, 600 E. Boulevard Ave., Bismarck, ND 58505-0840; (Tel. 701-328-4109).

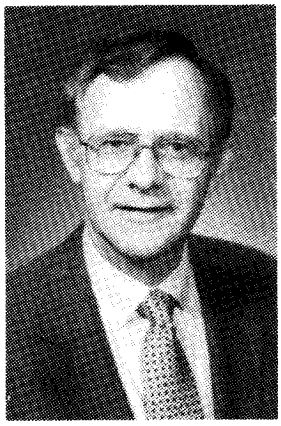
When requesting a change of address, please include the number on the upper right hand corner of the mailing label.

NDGS NEWSLETTER

FROM THE STATE GEOLOGIST

by John P. Bluemle

The North Dakota Geological Survey's Regulatory Responsibilities



Many people probably think that the Geological Survey simply studies the geology of North Dakota and reports its findings in the form of technical, geological reports. In recent issues of the *NDGS Newsletter*, I've pointed out just a few of our many activities. I've written about the Survey's public service and educational roles, our role in economic development, how we are working to encourage oil production in North Dakota, and a variety of other topics.

What I'd like to do here is discuss another of the North Dakota Geological Survey's activities — its regulatory responsibilities.

The Industrial Commission, acting through the office of the State Geologist, is charged with regulation of coal exploration, geothermal resources, subsurface minerals, underground injection control, paleontological resources, and oil-well core and drilling samples. Although we have no staff dedicated strictly to regulatory functions, each of our geologists handles certain regulatory programs as part of his or her other duties.

The Geological Survey's earliest regulatory duties were related to oil and gas. North Dakota's first oil and gas conservation statute was enacted in 1911. It was intended to protect landowners and the public from the escape of natural gas from open or improperly abandoned gas wells, but no regulatory authority was specifically charged with enforcing the law. In 1929, the first statute was passed that required the permitting of wells and filing of basic data and the State Geologist was named as the regulatory authority. A later law, passed in 1937, provided for the conservation of oil and gas and, like the previous law, it too stipulated that the State Geologist enforce the law. In 1941, the legislature passed the first comprehensive oil and gas conservation law. This law was revised in 1953.

The State Geologist continued to administer the state's oil and gas conservation law until 1981. In 1981 the Legislature created a separate division of the Industrial Commission, the Oil and Gas Division, which since then has administered the conservation law; however, responsibility for oil-well core and samples remains with the Geological Survey.

Core and drilling samples. In addition to our responsibility for oil- and gas-well core and samples, we also require that cores and samples from subsurface mineral and coal exploration be provided to us. All of these are stored at the Wilson M. Laird Core and Sample Library in Grand Forks, where they are used by industry, government, and academic researchers as a tool for finding more oil, developing effective secondary recovery programs, etc. Our regulatory responsibilities with respect to cores and samples are set forth in North Dakota Century Code Chapter 38-08-04 and North Dakota Administrative Code 43-02-03-38.1.

Coal exploration. Since 1975, we have regulated drilling for coal exploration and evaluation. A report of company findings must be filed with the State Geologist. Collectively, these reports comprise a database, which we maintain, that is valuable to private and government coal researchers. The reports also provide information necessary for geologic correlations and economic forecasting. Our coal-exploration regulatory responsibilities are covered in Chapters 38-12.1 and 43-02-01 of the North Dakota Century and Administrative Codes, respectively.

Geothermal resources. Since 1984, we have been responsible for regulating "commercial" geothermal (ground source) heating and cooling systems. Such systems require a permit from the Geological Survey prior to installation (permits are not required for residential systems). Our permit review process helps us to insure that geothermal systems are properly designed and constructed and it minimizes the risk of groundwater contamination or other environmental problems. Geothermal resources are covered in Century Code Chapter 38-19 and Administrative Code 43-02-07.

Subsurface minerals. The NDGS regulates the exploration for, development of, and production of sub-

(continued on p. 20)

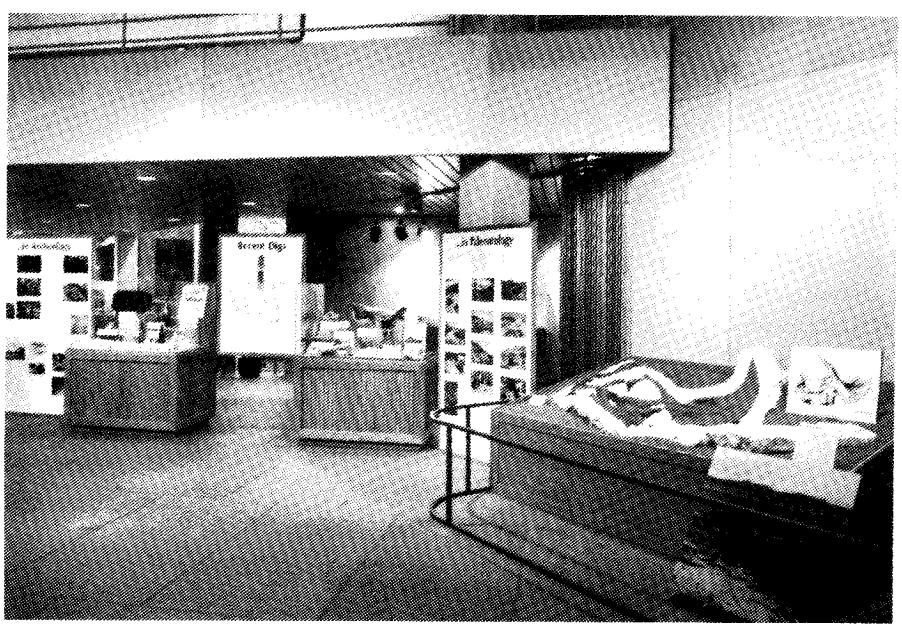
Two New Geological Exhibits Open at the Heritage Center in Bismarck

by John W. Hoganson

Recent Digs Exhibit

It is a source of frustration to paleontologists and archeologists that many people confuse the two sciences. In recognition of this problem, a continuing education course for teachers was offered at the Heritage Center this summer that compared the two sciences. The course was arranged through the Education and Interpretation Division (E & I) of the State Historical Society of North Dakota and the University of North Dakota. Marcia Wolter Britton (Director of E & I), Fern Swenson (Chief Archeologist for the Historical Society), and I taught the course. An exhibit titled "Recent Digs," comparing and contrasting paleontology and archeology, was developed in conjunction with the course.

The introduction to the "Recent Digs" exhibit discusses the differences and similarities between paleontology and archeology. It also defines the differences between human-made objects (artifacts) studied by archeologists and the remains of plants and animals (fossils) of interest to paleontologists. These differences and similarities are illustrated by exhibits of objects collected in North Dakota at sites currently being studied, and by murals that show activities at the sites. Brule Formation mammal fossils (about 30 million years old) from the Little Badlands Natural Area, fish and invertebrate fossils from the Cannonball Formation (about 60 million years old) found in the central part of North Dakota, and Hell Creek Formation dinosaur and plant remains (about 65 million years old) from the Stumpf Site Natural Area south of Mandan are displayed in the paleontology part of the exhibit. Artifacts that span the entire chronology of human occupation in North Dakota are exhibited in the archeology part of "Recent Digs." Included in that part of the display are Paleo-Indian projectile points from the Lake Ilo Wildlife Refuge and the Alkali Creek sites (about 10,500 years old), Plains Village (about A.D. 1400) pottery and other artifacts, fur trade objects from the Fort Mandan Historic Site, and military artifacts from Fort Buford State Historic Site and Fort Abraham Lincoln State Park. The "Recent Digs" archeology exhibit was developed by Signe Snortland and Fern Swenson of the Historical Society.



"Recent Digs" archeology and paleontology exhibit at the Heritage Center. Triceratops skull in foreground. Photo by Todd Strand, Photo Archivist, State Historical Society of North Dakota.

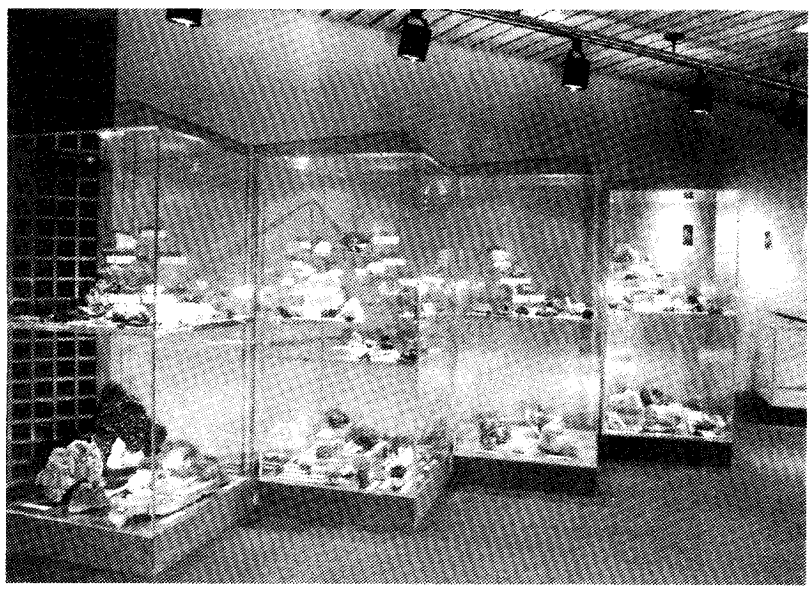
Blossomae Campbell Mineral and Mel Anderson Cabochon Exhibit

In the Winter 1993 (Vol. 20, No. 4) issue of the *NDGS Newsletter* I wrote about two major collections of rocks, minerals, and fossils donated to the Survey's State Fossil and State Rock, Mineral, and Gemstone collections at the Heritage Center — the Blossomae Campbell and Mel Anderson collections. I am pleased to announce that

mineral specimens and cabochons ("cabs" are precious stones cut in convex shapes, polished but not faceted, that are often made into jewelry) from these collections are now on exhibit at the Heritage Center.

The Blossomae Campbell mineral collection, which includes specimens from all parts of the world, is arranged by mineral classes based on chemical composition (e.g., sulfates, carbonates, halides, etc.). When possible, several specimens of each mineral are exhibited to illustrate natural variations of color and form. Labeling for the specimens, by Bob Biek, includes collecting location information and chemical composition. The Mel Anderson lapidary collection of cabochons is arranged into three groups: cabochon shapes, cabochons made from North Dakota materials (e.g., Knife River Flint), and cabochons made from rocks and minerals from other parts of the world. We anticipate that this exhibit will attract visits from Earth Science classes, and we are developing educational activities to accompany the exhibit to assist teachers of those classes.

We hope that you will all visit the Heritage Center to see these exhibits. The natural beauty of these minerals is greatly enhanced by the exhibit designs of Ms. Claudia Berg, the Exhibits Curator of the State Historical Society of North Dakota.



Blossomae Campbell and Mel Anderson mineral exhibit. Photo by Todd Strand, Photo Archivist, State Historical Society of North Dakota.

North Dakota, Manitoba Reach Accord on Mineral Resource Development

The state of North Dakota and the province of Manitoba have reached an agreement calling for cooperative studies and sharing information on mineral resource development in the Williston Basin. The agreement was announced November 21 in Winnipeg at the annual Manitoba Mining, Minerals and Petroleum Convention.

Manitoba and North Dakota are already parties to the North Dakota - Manitoba Agreement on Consultation and Cooperation (1985) and the Manitoba - Minnesota - North Dakota - Saskatchewan Regional Cooperation Statement (1989). In April 1994, North Dakota and Saskatchewan signed an accord on Williston Basin development in Minot.

The Winnipeg agreement recognizes the importance of the mineral resource industry to the economies of North Dakota and Manitoba. It should foster improved cooperation and coordination of the activities of the mineral development staffs of the Manitoba Energy and Mines and North Dakota Geological Survey. In addition to joint studies already underway, both agencies expect to enhance their sharing of information to industry through workshops and other means.

The 87th Annual Meeting of the North Dakota Academy of Science will be held April 20-21, 1994 in Mandan. Researchers throughout North Dakota present the results of their work at Academy meetings. Presentations of similar research are grouped into symposia, and at the upcoming meeting in April, one such symposium will be titled "North Dakota Geology." This symposium is being organized in honor of the Geological Survey's Centennial in 1995. John Hoganson, principal organizer of the symposium, has already received 17 commitments for presentations, which should make this one of the Academy's best geological symposia in recent years.

Survey Staff Aid Development of Science Discovery Center

Gateway to Science Center

A grand opening ceremony for the Gateway to Science Center was held November 25 at the Gateway Mall in Bismarck. This interactive science center provides people of all ages with an opportunity to experience science in a fun, hands-on manner. The Center is the brainchild of Frank Koch, a Professor of Chemistry at Bismarck State College, and was developed with the help of a 14-member advisory board, volunteers who staff the center and create interactive displays, and the support of several local businesses and organizations. NDGS geologist Randy Burke has been involved since the inception of the project and has taken on the roles of vice-chairman of the advisory board and in building exhibits. John Hoganson and other NDGS geologists will participate in presenting special Saturday programs about geology in North Dakota.

The interactive exhibits are grouped into themes such as light, mechanics (motion), sound, electricity, astronomy, and a "fun table." Each exhibit has a simple, written description of what the exhibit is, what it is supposed to show, how to make it do its "thing," and what else to look for. Volunteers at the Center can answer questions and help with the displays. The Center is available for use by schools and groups, and on alternate Saturdays beginning January 7 special kids programs will begin that highlight specific themes.

The Center is open Sunday through Friday Noon to 5:00 p.m. and Saturday 10:00 a.m. to 6:00 p.m. Admission for children 6 to 18 is $1.00 and that for adults is $3.00. Annual memberships are available that provide free unlimited entry to the Center as well as other benefits.

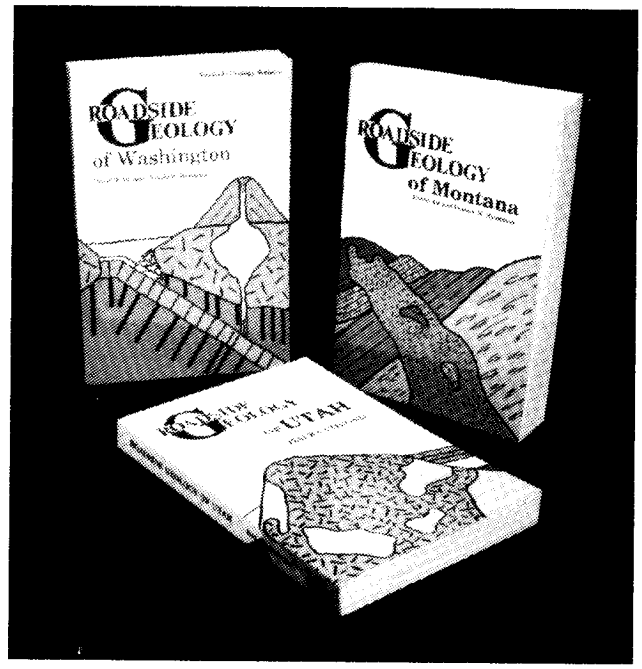
ROADSIDE GEOLOGY OF NORTH DAKOTA

by
John W. Hoganson

I am sure that those of you who are interested in learning about the geology of areas that you drive to and through on vacation or during business trips are aware of the Roadside Geology book series published by Mountain Press Publishing Company in Missoula, Montana. Books on the geology of 17 states have already been completed in this popular Roadside Geology series. These books are written for people who are not geologists but are interested in their natural surroundings. Ed Murphy, Don Schwert (Geoscience Department, North Dakota State University), and I have begun working on the **Roadside Geology of North Dakota**.

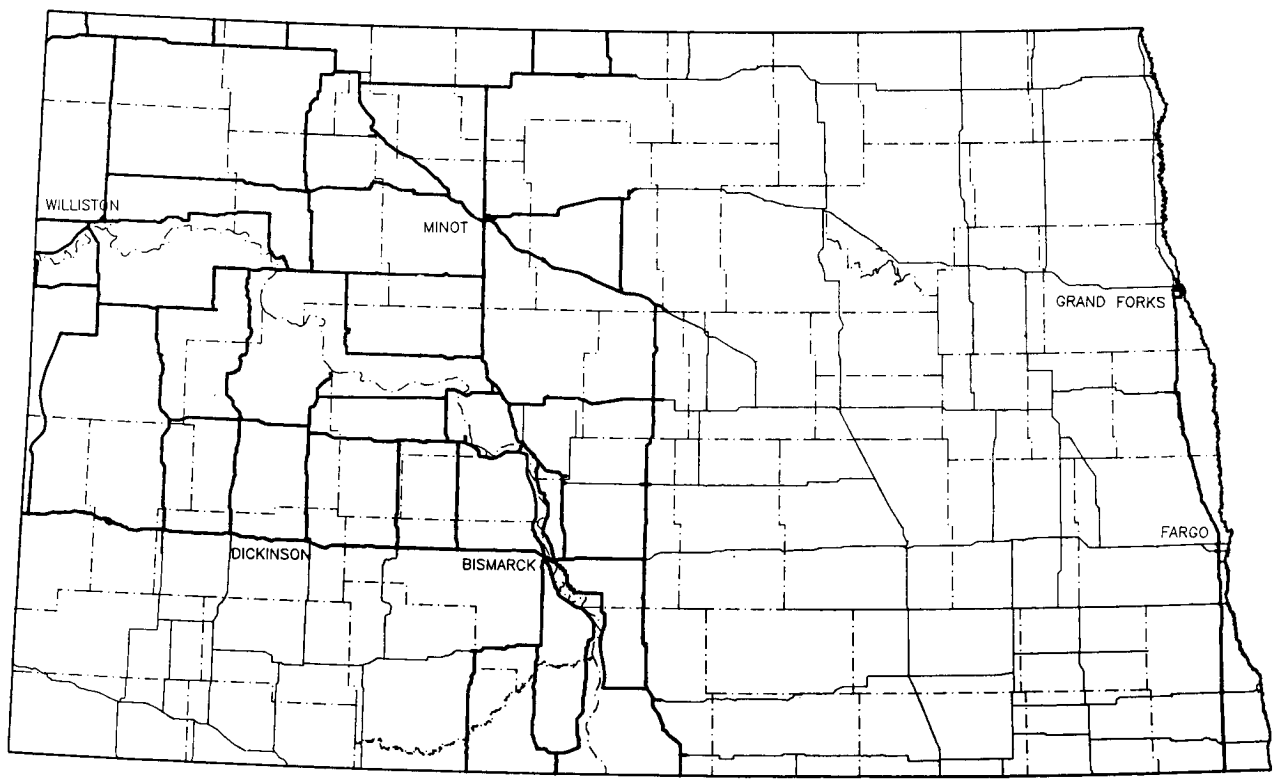
Roadside Geology of North Dakota will begin with an introductory chapter on the general geology and stratigraphic framework of the state. Subsequent chapters

will contain discussions of the geology of the different physiographic regions of the state, such as the Red River Valley. Detailed interpretations of the formation of specific features of geologic interest in each physiographic region will be given, such as the Little Missouri Badlands in the Missouri Slope Uplands region and glacial landforms (e.g., drumlins) in the Glaciated Plains region.



The book will contain many pictures and illustrations of these geologic features. The chapters will also contain geologic strip maps along main roadways showing precise locations of the geologic features. We also plan to include information about the kinds of plants and animals that existed in North Dakota at different times in the geologic past and the kinds of habitats that they lived in. This will include some illustrations of fossils and ancient habitat reconstructions.

Mapping of geologic exposures and features along the major roadways in North Dakota began this past summer, and we were able to complete most of the western part of the state. This mapping phase of the project will be finished next year. We plan to have the manuscript completed and ready for submittal to Mountain Press in 1996. "Ecotour" vacationing is becoming increasingly popular in this country. We anticipate that this guide to the geology of North Dakota will prompt visitors to venture off the main highways to more remote areas where additional interesting geologic features can be observed.



Map showing highways that will be included in the ***Roadside Geology of North Dakota.*** *Fieldwork for many of the highways in the western part of the state (heavy lines) has been completed; the fieldwork for the remaining highways will be completed in 1995. Roadside Geology books, such as those above, have been completed for 17 states.*

NDClear Online

North Dakota's Digital Spatial Data Clearinghouse
on the "Information Superhighway"

by Mark Luther

Since 1991, the NDGS has operated a digital spatial data (DSD) clearinghouse (introduced in the June 1991, *NDGS Newsletter*) to keep track of map-related digital data that has been produced for North Dakota. During the subsequent three years, the clearinghouse has provided many of the benefits anticipated, including greater ease of locating existing data and reductions in costly duplication of data collection/creation. However, the amounts of available DSD have since increased several fold, along with the number of requests for clearinghouse information. It has become increasingly difficult to maintain an up-to-date listing of DSD (in spreadsheet form), and to relay that information to the user community (primarily GIS users).

Fortunately, technology has come to the rescue. Many of the agencies, businesses, and the public that have used the clearinghouse in the past now have access to the Internet. This worldwide computer network allows people to search other computers connected to the Internet for **available** information of interest, then easily transfer computer information, data, and even mail. This recent widespread (and growing) access to the Internet is a key component in solving the dilemma of satisfying the increased demand for information with static or declining staff levels.

The NDGS' GIS group is currently working on a user-friendly method for those utilizing the clearinghouse, to access both a text and graphics-based index of DSD available for North Dakota. We are calling this enhanced service "**NDClear Online.**" Establishing NDClear Online requires that three major components exist: creation of digital indexes, online access to these indexes, and a method for DSD creators/collectors to have a record of their DSD incorporated on these and updated indexes.

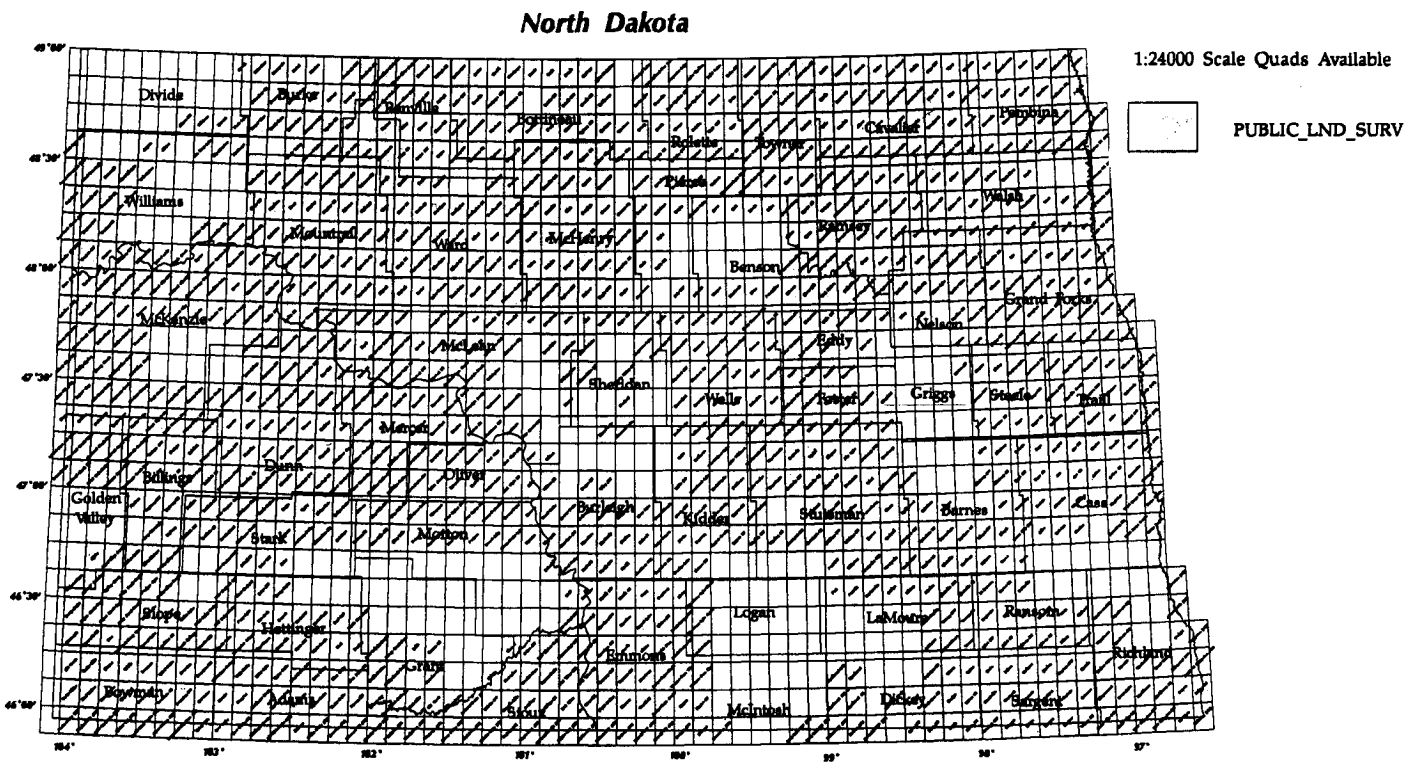


Figure 1. *Example of new ARC/INFO graphics file showing availability of 1:24,000-scale Public Land Survey digital data. Reduced from full-color originial.*

Creation of both the text and graphics-based indexes is being accomplished in the NDGS' Geographic Information Systems Center, using ARC/INFO software. Separate files are being created for each scale and category of DSD. Text files will consist of alphabetical listings of USGS quadrangle maps (various scales) for which a given category of DSD is available. Graphics-based files will present the same information, but will consist of ARC/INFO graphics files (converted to a GIF format) illustrating USGS quadrangle map areas for which DSD is available (Figure 1). If space permits, we will also provide ARC/INFO graphics files (you will need ARC/INFO to view these) which provide greater detail for the indexes than the GIF files.

The NDClear Online files will be available to anyone worldwide who has access to the Internet and a gopher client program. The files will reside on a gopher server operated by the State of North Dakota through the Information Services Division of the Office of Management and Budget. Although the state gopher server is not fully operational as this goes to press, it is expected that NDClear Online will be ready for use early in 1995. To access this server via gopher, one can enter the following: **gopher gopher.state.nd.us**

Upon reaching the state gopher server, a series of menus will be displayed. To reach NDClear Online, one must choose "North Dakota Government" from the first menu, "State Agencies" from the second, "Geological Survey" from the third, and "NDClear" from the fourth menu. A README file will be present once access to NDClear has been gained. The README file will explain the types of files available, and the steps required to search for the category of clearinghouse information desired.

To submit information about the availability of DSD to the clearinghouse coordinator, for inclusion in NDClear Online, send your information (via E-mail on the Internet) to: **mark@eagle.ndgs.state.nd.us** Your information should include the following: unit of coverage (statewide, county, 7.5' quad, 30'X60' quad, etc.) and the name of that unit; category (roads, soils, etc.); data source, including scale (1:24,000 scale, 1:250,000 scale, etc.); and the name, address, and phone number of the person from whom this data may be obtained. For those lacking access to the Internet, the same information may be mailed to the clearinghouse coordinator for inclusion in NDClear Online.

We hope that this "second generation" clearinghouse will provide a more efficient and accurate means for those requiring DSD, to enable them to locate and inexpensively acquire this most expensive part of any computer-based mapping or modeling system.

The NDGS' Clearinghouse Coordinator is Mark R. Luther

Stumpf Site Registered as a North Dakota Natural Area

by

John W. Hoganson

A private ceremony was held at John Stumpf's ranch on September 2nd to commemorate the addition of the Stumpf Site to North Dakota's Registry of Natural Areas. Jesse Hanson, coordinator of the Planning and Natural Resource Division of the North Dakota Parks and Recreation Department, and I presented John Stumpf with a plaque and certificate endorsed by Governor Schafer in recognition of Mr. Stumpf's commitment to preserving this important paleontological site (Fig. 1). Kathy Armstrong-Olson, coordinator of the North Dakota Parks and Recreation Department's Nature Preserve/Natural Heritage Program, and John Campbell, Earle Campbell, and Mike Marquart representing the North Dakota Paleontological Society (a partner in study and preservation of the site), and John Stumpf's brother and sister-in-law also attended.

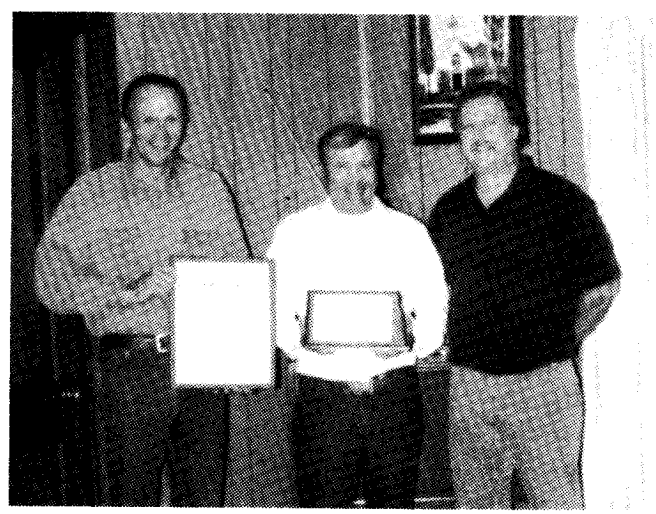


Figure 1. *Stumpf Natural Area Registry ceremony. l. to r: Jesse Hanson, John Stumpf, and John Hoganson.*

The North Dakota Natural Areas Registry is an important part of North Dakota's Nature Preserves Program and relies on citizen-based conservation to help preserve important natural areas in private ownership. The Registry Program was developed by the North Dakota Parks and Recreation Department and North Dakota Chapter of the Nature Conservancy; when fossil sites are involved the North Dakota Geological Survey takes an active role. Currently there are about 55 Natural Areas in North Dakota. Most of these are biological sites — sites of rare or endangered species or unique habitats. The Stumpf Site is the fourth site in North Dakota on the Registry because of its paleontological significance. The other registered paleontological sites are the Little Badlands Natural Area, Fitterer Ranch Natural Area, and Obritsch Ranch Natural Area.

Through the Registry Program, landowners are notified of natural features on their land having state significance and are asked to voluntarily protect those areas. The Registry is a volunteer, non-binding, non-regulatory program. State officials advise the landowner of the significance of their site and suggest management strategies. They also provide official signs stating that the site is a North Dakota Natural Area. Landowners are asked to notify Registry Program managers of any proposed changes in use or ownership of the site. Registry site owners may terminate participation in the program at any time.

The Stumpf Natural Area is a site of dissected terrain south of Mandan where erosion has exposed approximately 54 meters of fossil-bearing rocks (Fig. 2). At this site 45 meters of the Late Cretaceous age (65 million years old) Hell Creek Formation is overlain by 9 meters of Paleocene age Ludlow Formation (Fig. 3). The basal 15 meters of the Hell Creek Formation, consisting of sandstones and siltstones deposited in a deltaic and marine shoreline setting, have yielded a diverse assemblage of fossils (Fig. 4).

At least 34 vertebrate taxa and 9 invertebrate taxa have been identified from the several hundred fossils recovered from the Hell Creek Formation at the Stumpf Natural Area (Hoganson, et al., 1994). The non-marine fossil assemblages (Fig. 3, levels A and B) are dominated by disarticulated skeletal remains of dinosaurs, mostly hadrosaurs (duckbilled dinosaurs, Fig. 5a). Fossils of at least 8 species of dinosaurs have been found at the site, including in addition to hadrosaurs, ceratopsians (horned dinosaurs, Fig. 5b), ankylosaurs (armored dinosaurs), tyrannosaurs (large carnivorous dinosaurs, Fig. 5c), and dromaeosaurs (small carnivorous dinosaurs, Fig. 5d). The remains of freshwater fish, amphibians, turtles, crocodiles,

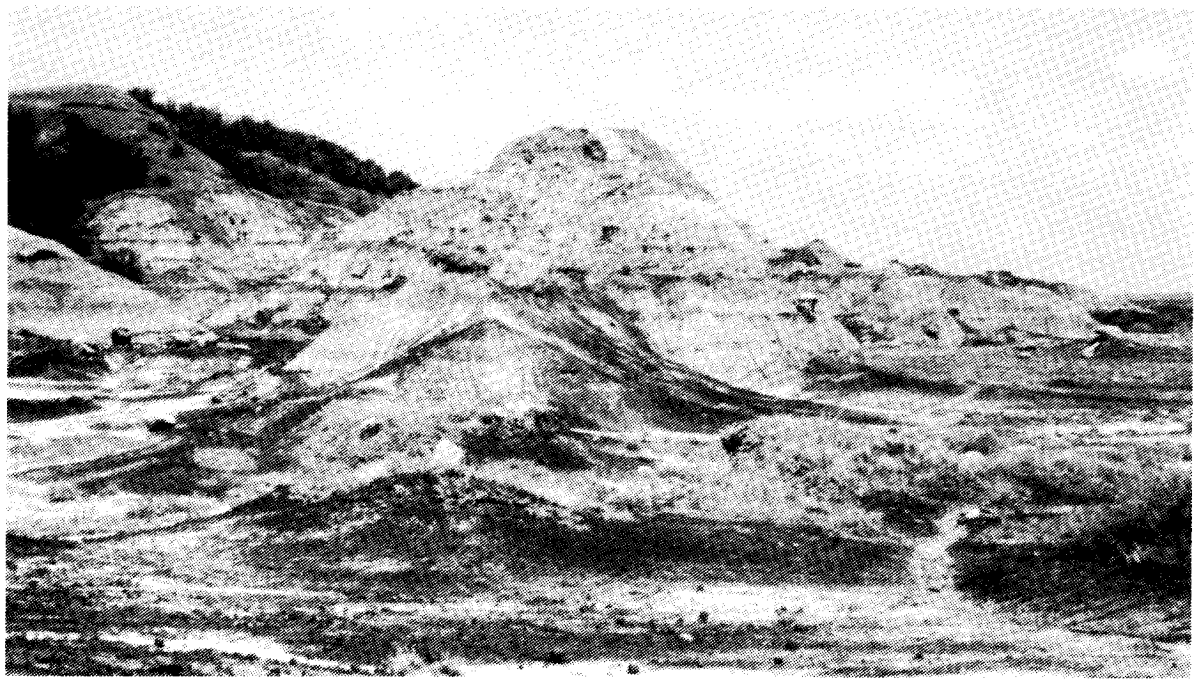


Figure 2. *Hell Creek Formation exposed at the Stumpf site. It was at the end of the Cretaceous, as the Hell Creek Formation was being deposited, that the last dinosaurs died.*

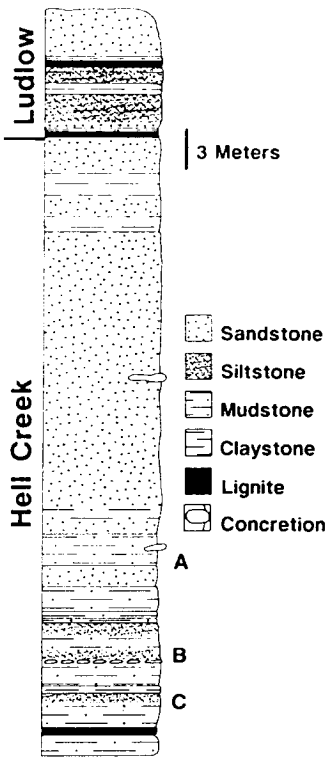


Figure 3. *Geologic section at the Stumpf site and stratigraphic position of fossil assemblages (A, B, C).*

Figure 4. *Excavation of a dinosaur rib at the Stumpf site. From l. to r: Dallas Schneider, Michele Gutenkunst, John Campbell, Austin Schneider, and Ian Mitchell.*

crocodile-like champsosaurs (Fig. 5e), alligators, mammals (Fig. 5f), snails (Fig. 5g), clams, and plants (Fig. 5h) are found associated with the dinosaur fossils. Three meters above the base of the site (Fig. 3, level C) is a marine sandstone, called the Breien Member of the Hell Creek Formation, that contains shark (Fig. 5i) and ratfish (Fig. 5j) fossils.

The Stumpf Natural Area is significant for several reasons. It contains the most diverse assemblage of fossils from the Hell Creek Formation in central North Dakota, including dinosaurs and early mammals. It is the farthest east Hell Creek fossil assemblage so far discovered in the United States. Fossils from this site provide intriguing insights about the ecosystem that existed in central North Dakota 65 million years ago. The marine fossils found in shoreline sandstones near the base of the site provide information about the kinds of organisms that inhabited the last Cretaceous sea to cover North Dakota. The site is also currently part of a research project to investigate the cause of the extinction of dinosaurs and other organisms at the end of the Cretaceous (Murphy, et al., 1993). Archaic (probably about 4,000 years old), Late Woodland (about 1,000 years old), and Plains Village (about 300 years old) artifacts found at the site suggest that it is also of archeological significance. The rugged badland terrain is also a refuge for abundant wildlife.

Federal and state governments cannot and should not be held solely responsible for survival of our significant fossil sites and specimens. Individual landowners must play an integral role in conserving our fossil resources. Without their active participation and commitment we will lose, year by year, more of these sites and objects of our natural heritage. I would like to take this opportunity to thank Mr. John Stumpf for his willingness to participate in the Natural Areas Registry Program and preserve this important fossil site.

REFERENCES

Hoganson, J. W., Campbell, J. M., and Murphy, E. C., 1994, Stratigraphy and paleontology of the Cretaceous Hell Creek Formation, Stumpf Site, Morton County, North Dakota: North Dakota Academy of Sciences, v. 48, p. 95.

Murphy, E. C., Hoganson, J. W., Nichols, D. J., and Forsman, N. F., 1993, The Cretaceous/Tertiary boundary in south-central North Dakota: Geological Society of America Abstracts with Programs, v. 25, no. 6, p. A-113.

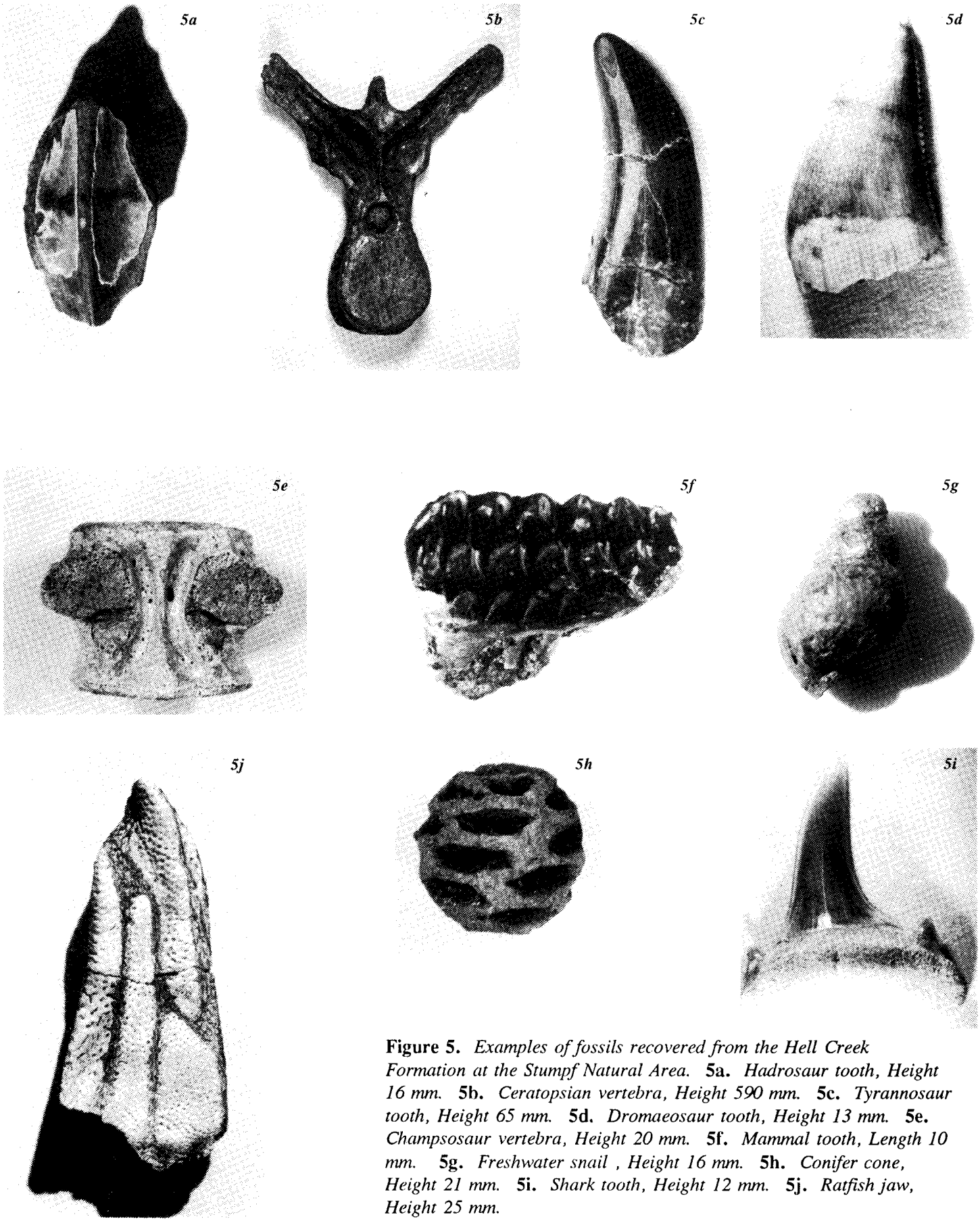


Figure 5. *Examples of fossils recovered from the Hell Creek Formation at the Stumpf Natural Area.* **5a.** *Hadrosaur tooth, Height 16 mm.* **5b.** *Ceratopsian vertebra, Height 590 mm.* **5c.** *Tyrannosaur tooth, Height 65 mm.* **5d.** *Dromaeosaur tooth, Height 13 mm.* **5e.** *Champsosaur vertebra, Height 20 mm.* **5f.** *Mammal tooth, Length 10 mm.* **5g.** *Freshwater snail , Height 16 mm.* **5h.** *Conifer cone, Height 21 mm.* **5i.** *Shark tooth, Height 12 mm.* **5j.** *Ratfish jaw, Height 25 mm.*

Cement Rock In North Dakota

by Ed Murphy

The early studies of the North Dakota Geological Survey concentrated on the economic uses of the following four natural resources: coal, clay and claystone, cement rock, and water. The Geological Survey undertook several studies of the feasibility of cement production in both eastern and western North Dakota during the 1890s, early 1900s, and again in the 1940s, 1950s, and 1960s (Babcock, 1901; Barry and Melstad, 1908; Powers, 1946; Hansen, 1953; Carlson, 1964; Anderson and Haraldson, 1968).

Concrete, North Dakota

In the 1890s, Earle Babcock discovered lime-rich shales in the Niobrara Formation exposed at the surface in Pembina County. In 1899, Babcock, his brother Otto, and Webster Merrifield (President of the University of North Dakota from 1892-1909) incorporated the Pembina Portland Cement Company (Figure 1). Babcock was State Geologist at that time and the potential for a conflict of interest existed with this arrangement. However, it should be noted that prior to 1899, no appropriations had been made to the Geological Survey and Babcock in his own words "devoted most of his summer vacations for eight years to geological investigations of the state and in efforts to encourage the development of the mineral resources....

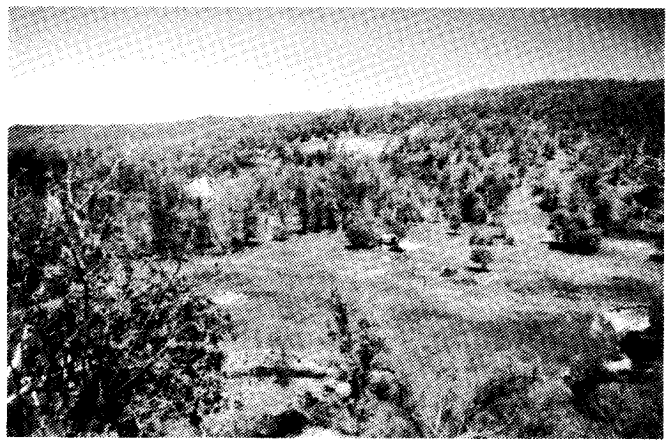


Figure 1. *All that remains of the natural-cement plant site at Concrete, North Dakota.*

During six years of this time the state paid nothing for the work, the expenses were borne by the writer, and his time during these vacations cheerfully contributed for the good of the cause" (Babcock, 1901, p.3). The plant was established in eastern Cavalier County just west of the present town of Concrete (Figure 2). In 1909, it was reorganized as the Northern Cement and Plaster Company and produced bricklayer's cement, hydraulic cement, cement plaster, and stucco (Folsom, 1980; Barry and Melstad, 1908). A zone of highly calcareous shale in the

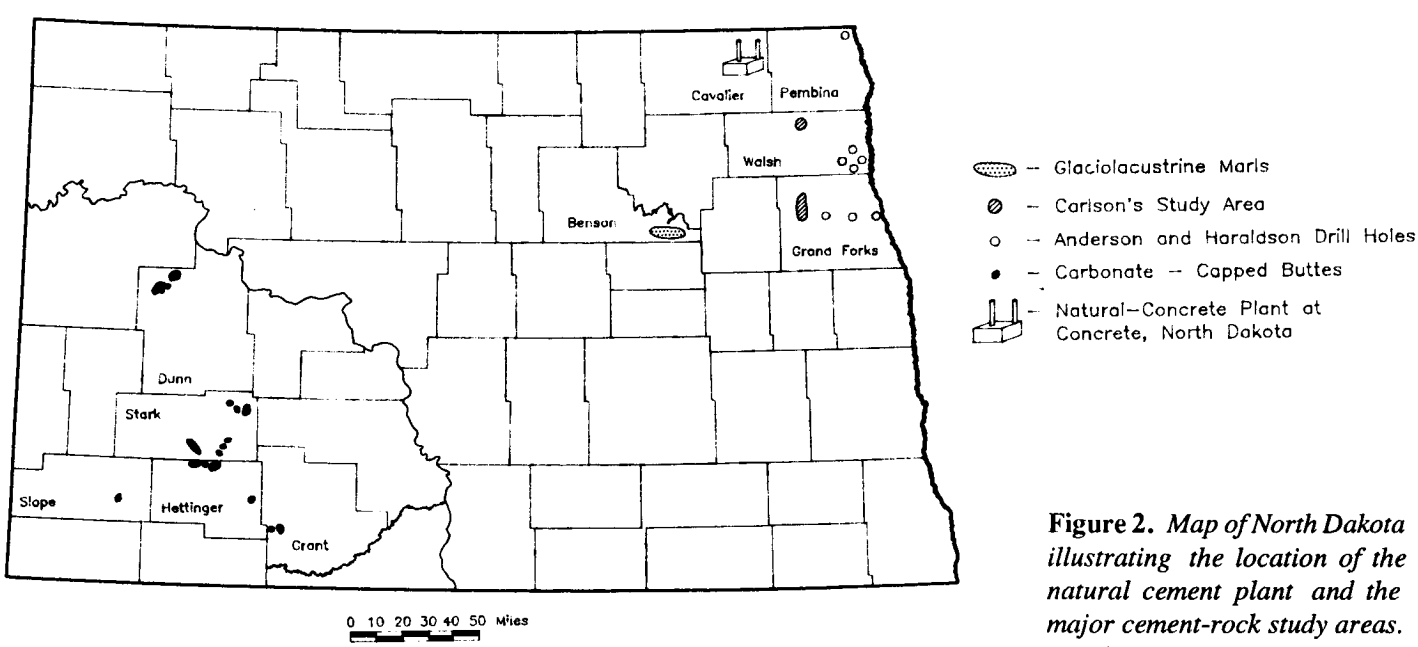


Figure 2. *Map of North Dakota illustrating the location of the natural cement plant and the major cement-rock study areas.*

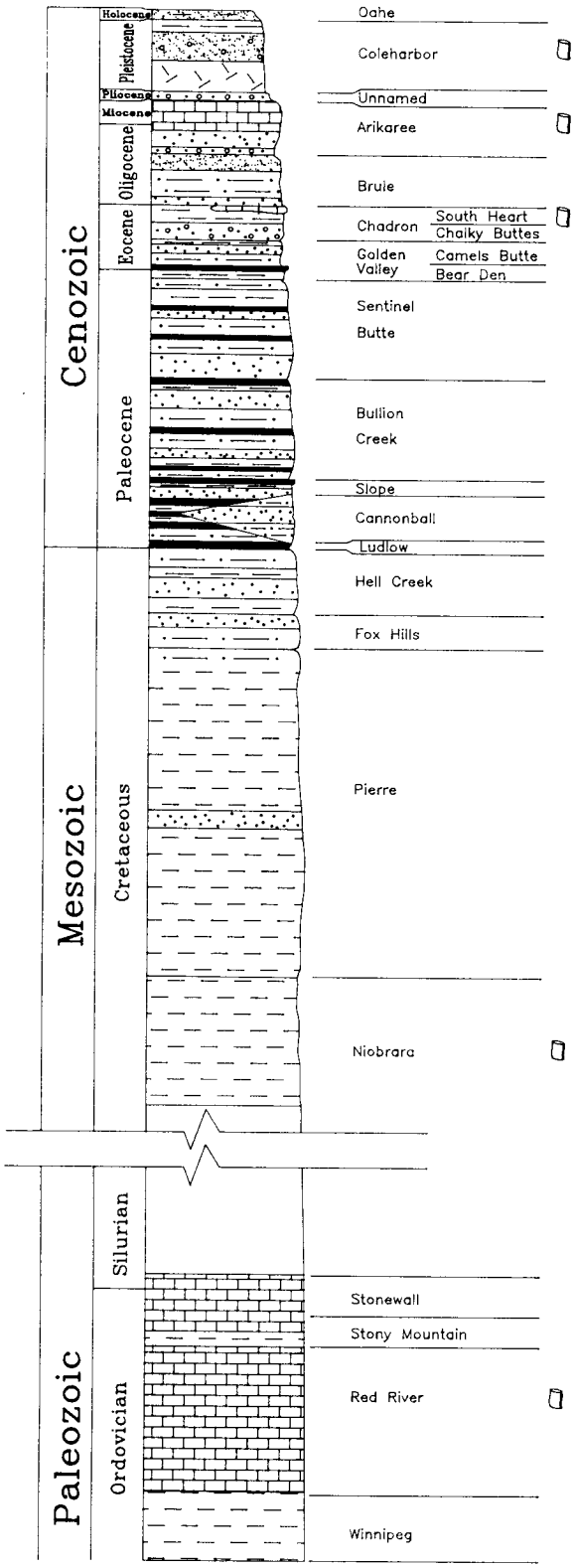


Figure 3. *The upper and lower portions of the generalized stratigraphic column of North Dakota. "Sacks" represent units evaluated for their cement rock potential.*

upper Niobrara Formation (Cretaceous) is present in scattered outcrops along the valley of the Tongue River in the vicinity of the cement plant (Figures 3 and 4). The calcareous shale was extracted through mine tunnels; approximately 900 feet of tunnels were sunk into outcrops along the valley of the Tongue River. The calcareous shale was baked in kilns at the plant and ground into a fine powder and packaged. The natural cement produced at the plant had a difficult time competing with superior grades of portland cement and ceased operation in 1909 as a result of problems in production and marketing (Grand Forks Herald, 1957). In 1955, a fire destroyed the main building and today the only evidence of the plant's existence are the foundations of a half dozen buildings, the base of the kilns, and scattered pieces of rusting equipment (Figures 5 and 6).

In 1947, the Geological Survey entered into a joint venture with the North Dakota Research Foundation (an entity that operated under the Industrial Commission from 1943 to 1957) to determine the feasibility of re-establishing a cement plant at or near Concrete (McMillan and Hanning, 1949). To assess the viability of a plant, the Survey supervised the drilling of five holes near the old plant site at Concrete. The holes ranged in depths from 170 to 330 feet into the Niobrara Formation. Samples were obtained at two- to three-foot intervals and were analyzed for concentrations of calcium carbonate, aluminum, silica, iron, magnesium, and sulfur. The results of this study were summarized by Hansen (1953). The drilling program determined that the high lime zones in the Niobrara Formation in this area generally occur at depths in excess of 150 feet below the surface, but do not correspond to a particular horizon or given elevation. By 1949, at least 230 samples had been analyzed from the Concrete area and it was determined that the lime content of the shale was not sufficient to make establishment of a portland cement plant at this site feasible (Burr, et al., 1949).

Red River Valley

Continued interest in establishing a viable cement plant in eastern North Dakota resulted in the Geological Survey further investigating the cement rock potential of limited areas in Walsh and Grand Forks Counties in the 1960s (Carlson, 1964). Carlson drilled 14 boreholes ranging in depth from 30 to 170 feet (Figure 2). Unlike the Concrete area, Carlson was able to trace in the subsurface a ten-foot-thick calcareous shale lens or "high lime zone" within the Niobrara shales at his study sites near Edinburg, Park River, and Larimore in Walsh and Grand Forks Counties. Carlson determined this "high lime zone," which ranged from 60 to 65 percent calcium carbonate, occurred approximately 100 feet below the top of the Niobrara Formation in these areas. He determined that the most promising area for mining was the Shawnee-McCanna area west of Larimore where this horizon is

within 50 feet of the surface. Although this horizon offered the most suitable raw material for cement manufacturing in this area, it was roughly equal in calcium carbonate content to the Niobrara shales that had previously been mined for cement rock at Concrete. At both localities, the rocks were found to average 15 to 20 percent below the required concentrations of 80 percent calcium carbonate to manufacture portland cement (Carlson, 1964). Carlson noted that some type of beneficiation would have to be used in order to make these rocks acceptable for the manufacture of portland cement.

A study was also undertaken by the North Dakota Geological Survey to determine the feasibility of mining Paleozoic carbonates (in the Stonewall, Stony Mountain, and Red River Formations and Winnipeg Group in the Red River Valley of eastern North Dakota) for the production of cement (Figure 3) (Anderson and Haraldson, 1968). Eight test holes were drilled during this project ranging in depth from 260 to 500 feet (Figure 2). The Paleozoic carbonates were encountered at depths of 200 to 250 feet in this area. Analysis of these carbonates determined that most were dolomites or dolomitic limestones with magnesium concentrations that exceeded the 4 to 5 percent desirable limit established for the manufacture of portland cement. Anderson and Haraldson determined that the Red River Formation near Manvel had a concentration of 86 percent calcium carbonate and 7.5 percent magnesium carbonate. They estimated that these rocks could be made suitable for the manufacture of portland cement if they were mixed in a ratio of 1 part Red River carbonate to 2.3 parts low magnesium, limy shale from the Niobrara Formation. It was anticipated at the time that, if mining of the carbonates proceeded, it would be done by "tubing," that is, by sinking a large-diameter access shaft down into the carbonates (Sid Anderson, personal communication). Open pit mining was not thought to be feasible due to the anticipated heights of the high walls (approximately twice as high as encountered in most coal mines in western North Dakota), the relative instability of the glacial deposits, especially the glaciolacustrine clays, and potentially high volumes of groundwater emanating from the Dakota Group (when present).

Figure 4 (top). *An outcrop of shale from the upper portion of the Niobrara Formation adjacent to the old cement plant at Concrete, North Dakota.*

Figure 5 (above). *Remnants of the kilns used to bake the limy shale during the cement making process.*

Figure 6 (left). *One of several small pieces of abandoned machinery left at the site of the old cement plant at Concrete, North Dakota.*

At least one cement company, Lehigh Portland Cement, evaluated the cement rock potential of northeastern North Dakota in the late 1950s and early 1960s but did not pursue it further (Carlson, 1964).

Marl Deposits Near Devils Lake

Prior to the 1940s, W.E. Budge investigated near-surface marl deposits south of Devils Lake in Benson County (Figures 2 and 3). In the late 1940s, Laird and Burr revisited these glaciolacustrine deposits and took additional samples. It was estimated that seven of these small deposits contained 106,000 cubic yards of marl with a lime content ranging from 6 to 44 percent. It was determined from the information gathered that these deposits were not feasible as raw material for the manufacture of portland cement (Burr, et al., 1949).

Western North Dakota

The potential sources of cement rock in western North Dakota are freshwater limestones in the South Heart Member of the Chadron (Eocene) and the Arikaree (Oligocene and Miocene) Formations (Murphy, et al., 1993). The South Heart limestones can be found in five western counties including many small buttes in southeastern Stark and northeastern Hettinger Counties. Freshwater carbonates in the Arikaree Formation cap the Killdeer Mountains, Dunn County and parts of the Chalky Buttes, Slope County (Figures 2 and 3).

In 1945, Bill Powers, a professor of geology at Northwestern University and a temporary geologist with the North Dakota Geological Survey, undertook the first study to determine the feasibility of using the South Heart limestones as raw material in the manufacture of portland cement. During the course of this study, he mapped the South Heart limestones in several of these buttes (White, Lefor, Bull) and the Arikaree carbonates in the Killdeer Mountains, estimated the amount of available limestone, and took various samples for analysis (Powers, 1946).

A 1949 North Dakota Research Foundation report concluded that the only viable source for portland cement in North Dakota were the limestones in the buttes that Powers had studied. Although the limestones were thin (generally less than 3 feet thick) they generally had little overburden. The report concluded that the calcium carbonate content of the limestones was such that they would have to be beneficiated before they could be used in the manufacture of portland cement.

In 1951, the North Dakota State Legislature directed the North Dakota Geological Survey to investigate the carbonate deposits in the state and to report their findings to the North Dakota Research Foundation which would issue a report to the legislature. In response to this directive, Assistant State Geologist Miller Hansen conducted a detailed investigation of many of the same buttes that Powers had previously studied (Hansen, 1953). Hansen's investigation included topographic and geologic mapping of the buttes, compilation of detailed measured sections and drill hole logs, sample collection, and analysis of rock samples. Samples were analyzed to determine the calcium carbonate, aluminum oxide, and silicon dioxide content of both carbonates and the adjacent claystones. He found that the calcium carbonate of the limestones ranged from 60 to 80 percent. Hansen determined from his investigations that individual limestone beds could not be traced laterally from butte to butte and often could not even be traced very far within a given butte. This observation was confirmed by later workers (Murphy, et al., 1993). Hansen concluded that there were approximately 21 million tons of limestone available for mining from 5 buttes (White, Lefor, Bull, School, and Straight) in Stark and Hettinger Counties (Figure 7). Hansen also noted that the thin nature of the limestones, the relatively high ratio of overburden to limestone, and the presence of chert in some of the carbonates were potential obstacles to the mining of these buttes. In spite of Hansen's reservations, the Foundation

Figure 7. Aerial photograph of White Butte, Hettinger County. The white ring visible at the top of the butte is the carbonate caprock.

Research report to the legislature concluded that a cement plant was viable and that there was sufficient raw material in White, Lefor, and Bull Buttes to supply a medium-sized portland cement plant for 20 years. The plant was never built.

Burr, et al. (1949) and Hansen (1953) ruled out the use of the Arikaree carbonates in the Killdeer Mountains for the manufacture of portland cement due to low lime content, the dolomitic nature of the carbonates, and relatively high overburden. Additional petrographic studies of the Killdeer Mountains have been conducted by Delimata (1975) and Forsman (1986) and determined that these carbonates are generally tuffaceous.

In spite of the scientific studies carried out by the Geological Survey and the economic studies by the North Dakota Research Foundation, a portland cement plant was never built in North Dakota. As a result, the calcareous rocks in North Dakota have not been mined for cement rock since the plant at Concrete closed in 1909. At the present time, North Dakota imports portland cement from several plants in the region including Rapid City, South Dakota; Helena, Montana; Mason City, Iowa; and Winnipeg, Manitoba, Canada. The only recent utilization of these rocks occurred when carbonates in the Arikaree Formation were mined and crushed from the Killdeer Mountains and Chalky Buttes for road gravel (Figure 9).

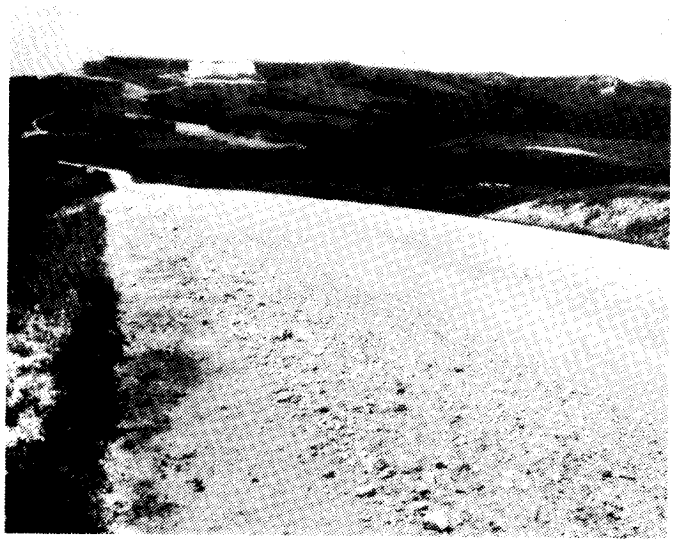


Figure 9. *Photo taken looking west to North Killdeer Mountain, Dunn County. The large rock pile at the top of the mountain was excavated from the adjacent rock quarry (white area) and has been used for gravel on the road in the foreground.*

REFERENCES

Anderson, S.B., and Haraldson, H.C., 1968, Cement-rock possibilities in Paleozoic rocks: NDGS Report of Investigation No. 48, 62 p.

Babcock, E.J., 1901, Report of the Geological Survey: NDGS 1st Biennial Report, 103 p.

Barry, J.G., and Melstad, V.J., 1908, The Geology of Northeastern North Dakota: NDGS Fifth Biennial Report, p. 172-173.

Burr, A.C., Fallgatter, W.S., and McMillan, W.M., 1949, Is a portland cement manufacturing plant technically and economically practical in North Dakota?, Part 2: North Dakota Research Foundation, January, 23 p.

Carlson, C.G., 1964, The Niobrara Formation of eastern North Dakota: Its possibilities for use as a cement rock: NDGS Report of Investigation No. 41, 56 p.

Delimata, J.J., 1975, Petrology and geochemistry of the Killdeer carbonates: Grand Forks, University of North Dakota, PhD. dissertation, 256 p.

Forsman, N.F., 1986, Documentation and diagenesis of tuffs in the Killdeer Mountains, Dunn County, North Dakota: NDGS Report of Investigation No. 87, 13 p.

Folsom, C.B., Jr., 1980, A history of the North Dakota Geological Survey: NDGS Miscellaneous Series No. 58, 51 p.

Grand Forks Herald, 1957, History of valley cement-making told, page 11, June 12.

Hansen, Miller, 1953, Geologic report on limestone deposits in Stark County and Hettinger County, North Dakota: NDGS Report of Investigation No. 8, 33 p.

McMillan, W.M., and Hanning, I.L., 1949, Is a portland cement manufacturing plant technically and economically practical in North Dakota? Part 1-Can the North Dakota market support a plant?: North Dakota Research Foundation, January, 13 p.

Murphy, E. C., Hoganson, J. W., and Forsman, N. F.,1993, The Chadron, Brule, and Arikaree Formations in North Dakota - The buttes of southwestern North Dakota: NDGS Report of Investigation No. 96, 144 p.

Powers, W.E., 1946, Cement rock and limestone deposits of North Dakota: NDGS Open File Report, p. 3-16.

CURRENT GEOLOGIC INVESTIGATIONS

compiled by Bob Biek

The next three pages contain a list of current and recently completed NDGS geologic investigations. The investigations are grouped under four headings: oil and gas projects, geologic projects, paleontologic projects, and environmental projects. In each case, the titles of projects completed in 1994 are italicized; all other investigations are in progress.

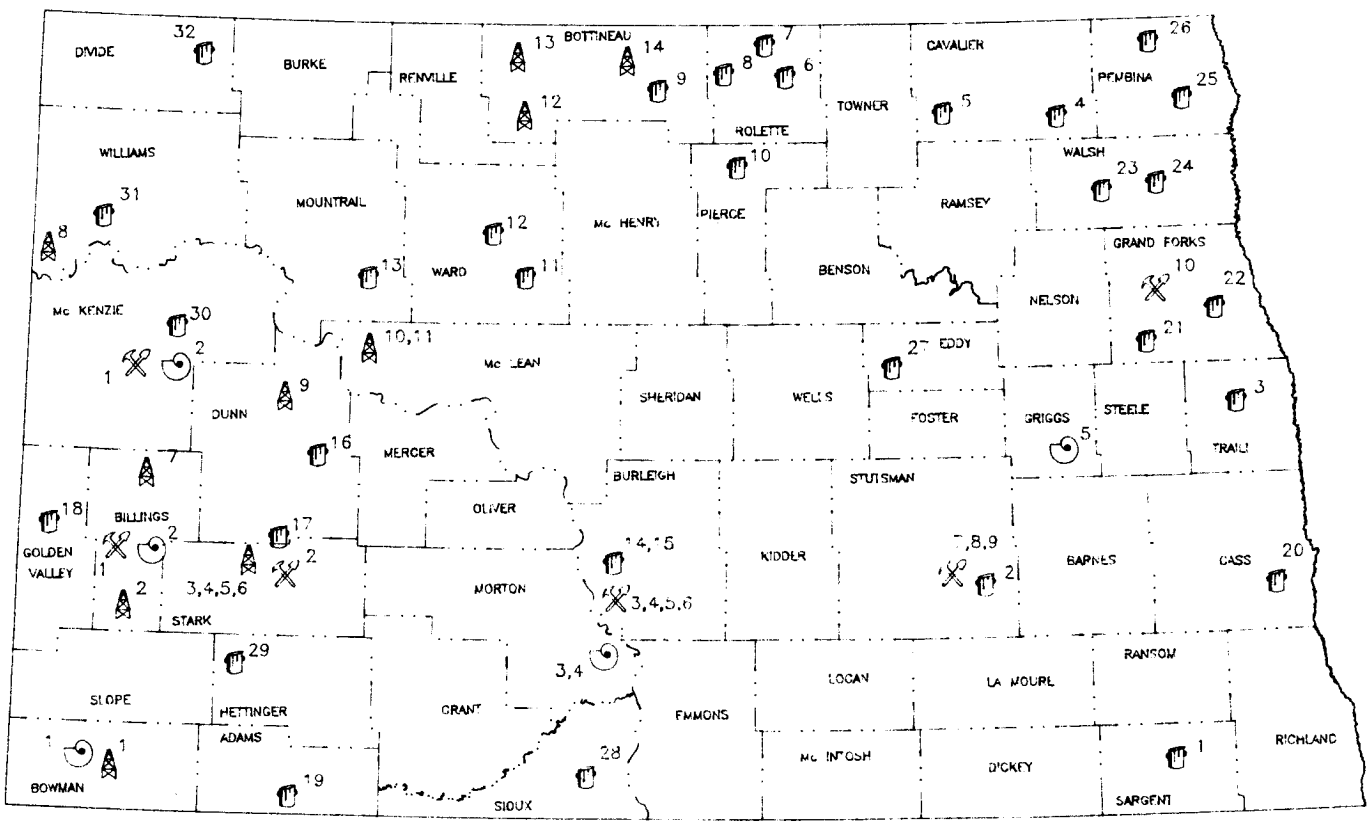
The map below shows the location of site-specific projects; the symbol and number directs one to the appropriate project catagory and title.

Investigations of a regional or statewide nature are not shown on the map, but are listed under each project heading.

Regional oil and gas projects include those numbered 15 through 31;

Regional geologic projects include those numbered 11 through 29; and

Regional paleontologic projects include those numbered 6 through 8.



Oil and Gas Projects Geologic Projects Paleontologic Projects Environmental Projects

Oil and Gas Projects

1. Red River Fm. (Ordovician) oil potential in Bowman Co. - Bill McClellan.

2. Rocky Ridge Field Study - Paul Diehl.

3. Lodgepole Fm. reservoir characterization - Paul Diehl.

4. *Fracture and Vugular Porosity in the Dickinson Mound: A Potential Horizontal Drilling Target?*, 1994, by Randolph B. Burke and Paul E. Diehl: *in*, W.A. McClellan compiler, Proceedings of the Second International Williston Basin Horizontal-Well Workshop, p. B3-1 to B3-28.

5. *Comparative Analysis of Waulsortian Carbonate Buildups in Core and Outcrop from the Williston Basin*, 1994, by Randolph B. Burke: Presentation to the SEPM Carbonate Research Group, 1994 Annual Meeting, Denver, CO.

6. Tectonic and stratigraphic setting of the Conoco, Inc. Waulsortian-like mound, Lodgepole Fm. reservoir: Perspectives from surface and subsurface studies - G.W. Shurr (St. Cloud State Univ.), A.C. Ashworth (NDSU), Randy Burke, and Paul Diehl.

7. Sherwood Shoreline stratigraphy - Bill McClellan.

8. Buford Field Study - Bill McClellan.

9. Tectonic controls on Paleozoic stratigraphic patterns - Bill McClellan.

10. Lucky Mound Field Study - Randy Burke.

11. *Mississippian Subaerial Exposure Surfaces within the Sherwood Subinterval, Mission Canyon Formation, Lucky Mound Field, North Dakota*, 1994, by Randolph B. Burke: AAPG 1994 Annual Convention, Official Program, vol. 3, p. 112.

12. Geology of the Wiley Field - Mark Luther.

13. South Antler Creek Field Study - Tom Heck.

14. Landa Field Study - Julie LeFever.

15. Lodgepole Fm. core and sample workshop for the 7th International Williston Basin Symposium - Randy Burke, Paul Diehl, and Tom Heck.

16. Preliminary comparison between Waulsortian mound facies of the Williston and Illinois Basins - Randy Burke and Z. Lasemi (ISGS).

17. Fault control on late-stage diagenetic creation and enhancement of reservoirs - R.A. Inden (LSSI, Denver) and Randy Burke.

18. Tyler Formation stratigraphy and petrography - Paul Diehl.

19. *Basin-center Gas in the Williston Basin*, 1994, by Thomas J. Heck: AAPG 1994 Annual Convention, Official Program, vol. 3, p. 168.

20. Central-basin gas - Tom Heck and Julie LeFever.

21. *Oil Exploration and Development in the North Dakota Williston Basin: 1992-1993 Update*, in press, by Thomas J. Heck: NDGS Miscellaneous Series No. 79, 24 p.

22. *Madison Producing Trends in North Dakota*, 1994, by Thomas J. Heck and R.A. LeFever (UND): *in*, W.A. McClellan compiler, Proceedings of the Second International Williston Basin Horizontal-Well Workshop, p. B1-1 to B1-26.

23. Oil-Potential Assessment - Tom Heck, Rich LeFever (UND).

24. *Horizontal Activity Updates*, 1994, by Julie LeFever: *in*, W.A. McClellan compiler, Proceedings of the Second International Williston Basin Horizontal-Well Workshop, p. A2-1 to A2-5.

25. Lithofacies and petroleum potential of the Birdbear Fm. (Upper Devonian), southwestern Manitoba and north-central North Dakota - Julie LeFever, Carol Martiniuk (MEM), and Harvey Young (Brandon Univ.).

26. Relationship of salt patterns to hydrocarbon accumulations - Julie LeFever and Richard LeFever (UND).

27. *Horizontal Drilling Potential of the Spearfish Fm. (Triassic), north-central North Dakota*, 1994, by Julie LeFever: Manitoba Mining, Minerals, and Petroleum Conference.

28. *Dysfunctionalism in the Williston Basin: The Bakken/mid-Madison Petroleum System*, 1994, Leigh C. Price (USGS) and Julie LeFever:

Bulletin of Canadian Petroleum Geology, vol. 42, no. 2, p. 187-218.

29. *Sherwood Subinterval of the Mission Canyon Formation in central western North Dakota*, in press, by Bill McClellan: NDGS Report of Investigation No. 97, 11 p., 7 plates.

30. Proceedings of the *Second International Williston Basin Horizontal-Well Workshop*, 1994, compiled by William A. McClellan, approx. 240 p.

31. *The Red River Formation: Potential Horizontal Target in Southwestern North Dakota*, 1994, by William A. McClellan: *in*, W.A. McClellan compiler, Proceedings of the Second International Williston Basin Horizontal-Well Workshop, p. B5-1 to B5-10.

Geologic Projects

1. *Roadlog Guide for the North and South Units, Theodore Roosevelt National Park*, by Edward C. Murphy, John P. Bluemle, and Bruce M. Kaye (NPS): NDGS Educational Series No. 22 (published by the Theodore Roosevelt Nature and History Assoc.), 30 p.

2. Geologic mapping of the Davis Buttes, Dickinson North and South, and Lehigh quadrangles - Bob Biek and Ed Murphy.

3. *Building Stones of the North Dakota Capitol Grounds*, in press, by Robert F. Biek: State Historical Society of North Dakota.

4. Slope stability in the Bismarck-Mandan area - Ed Murphy.

5. Geologic mapping of the Bismarck quadrangle - Ed Murphy.

6. *The Northern Pacific Railroad Bridge at Bismarck*, in press, by Edward C. Murphy: State Historical Society of North Dakota.

7. *Geology of the Jamestown, Bloom, and Spiritwood Lake Quadrangles, Stutsman County, North Dakota*, 1994, by Robert F. Biek: NDGS Open-File Report 94-1, 62 p., 6 plates, 1:24,000.

8. *Geology of the Jamestown Quadrangle, North Dakota*, in press, by Robert F. Biek.

9. *Till Stratigraphy of the Jamestown - Spiritwood Lake Area, Stutsman County, North Dakota*, 1994, by Robert F. Biek: AMQUA Program and Abstracts of the 13th Biennial Meeting, p. 62.

10. GIS prototype project - Mark Luther.

11. Digital shaded-relief of North Dakota (with thematic varients) - Rod Bassler and Mark Luther.

12. *The Mineral Industry of North Dakota*, 1994, by R.H. Wood II (USBM) and Robert F. Biek: U.S. Bureau of Mines 1992 Annual Report, 6 p.

13. *The Mineral Industry of North Dakota*, in press, by R.H. Wood II (USBM) and Robert F. Biek: U.S. Bureau of Mines 1993 Annual Report, 6 p.

14. Profiles of North Dakota's geology - Bob Biek and John Bluemle.

15. Natural Science of North Dakota, *in* North Dakota Blue Book - John Bluemle.

16. History of the North Dakota Geological Survey - John Bluemle.

17. *North American Glaciotectonic Map*, in press, by J.S. Aber (Emporia State Univ.), J.P. Bluemle, J. Brigham-Grette (Univ. Mass., Amherst), L.A. Dredge (Univ. of Regina), D.J. Sauchyn (Geological Survey of Canada), and D.L. Ackerman (Univ. of Regina): GSA.

18. Roadside Geology of North Dakota - John Hoganson, Ed Murphy, and Don Schwert (NDSU).

19. Flakable lithic resources in North Dakota - Mark Luther and Robert Christensen (NDDOT).

20. Red River Valley surficial geologic map - Ken Harris (MGS) and Mark Luther.

21. Red River Valley Quaternary stratigraphy - Ken Harris (MGS) and Mark Luther.

22. Trace elements in Cretaceous shales - Mark Luther and David Brekke (EERC).

23. *Sandstone Petrography as a Tool in Mapping Cenozoic Rock Units in Southwestern North Dakota*, 1994, by Nels F. Forsman (UND), Edward C. Murphy, and John W. Hoganson: *in*

R. Garvey, ed., Proceedings of the North Dakota Academy of Science, v. 48, p. 76.

24. *North Dakota Clays*, in press, by Edward C. Murphy: NDGS Misc. Series No. 79, 24 p.

25. The Cretaceous/Tertiary boundary in south-central North Dakota - Ed Murphy, John Hoganson, Doug Nichols (USGS), and Nels Forsman (UND).

26. The occurence of uranium in Fort Union, White River, and Arikaree strata in southwestern North Dakota - Ed Murphy.

27. Coal stratigraphy in western North Dakota - Ed Murphy, Romeo Flores (USGS), Bill Keighin (USGS), Peter Warwick (USGS), and Doug Nichols (USGS).

28. Coal in North Dakota - Ed Murphy.

29. See also Paleontology #3

Paleontologic Projects

1. Paleontology of the Chadron Formation at the Medicine Pole Hills site - John Hoganson.

2. Paleontology of Theodore Roosevelt National Park - John Hoganson.

3. *Stratigraphy and Paleontology of the Cretaceous Hell Creek Formation, Stumpf Site, Morton County, North Dakota*, 1994, by John W. Hoganson, John M. Campbell, and Edward C. Murphy: *in* R. Garvey, ed., Proceedings of the North Dakota Academy of Science, v. 48, p. 95.

4. Stratigraphy and Paleontology of the Cretaceous Hell Creek Formation, Stumpf Site, Morton County, North Dakota - John Hoganson.

5. Paleontology of the Cooperstown Pierre Shale site - John Hoganson.

6. *Reptiles of the Timber Lake Member (Cretaceous:Maastrichtian), Fox Hills Formation, North Dakota*, 1994, by John W. Hoganson, J. M. Erickson (St. Lawrence Univ.), and M.R.C. Getman (St. Lawrence Univ.): Journal of Vertebrate Paleontology, vol. 14, supplement to no. 3, p. 29A.

7. Paleontology of the Breien Member of the Hell Creek Fm. - John Hoganson.

8. Vertebrate paleontology of the Fox Hills Formation in North Dakota - John Hoganson.

Environmental Projects

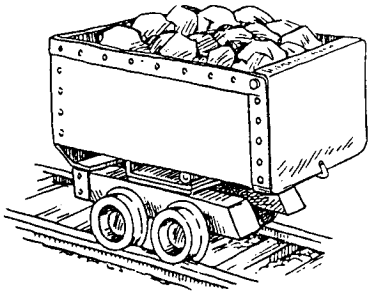
The following landfill investigations, by Phil Greer and Jeff Olson (State Water Commission), were completed in 1994 and published jointly with the State Water Commission as Site Suitability Reviews:

1. Dakota landfill near Gwinner
2. Jamestown landfill
3. Mayville landfill
4. Osnabrock landfill
5. Alsen landfill
6. Murphy Services landfill at Rolla
7. Murphy Services landfill at St. John
8. Murphy Services landfill at Dunseith
9. Bottineau landfill
10. Volk landfill at Rugby
11. McDaniel landfill near Sawyer
12. Minot landfill
13. Geving Sanitation landfill near Parshall
14. Dakota Sanitation landfill North of Bismarck
15. Bismarck landfill
16. Halliday landfill
17. Dickinson landfill
18. Beach landfill
19. Adams County landfill

The following landfill investigations, by Phil Greer and Jeff Olson (SWC) should be completed by February, 1995:

20. Fargo landfill
21. Northwood landfill
22. Grand Forks landfill
23. Consolidated landfill at Park River
24. Grafton landfill
25. Valley Landfill Association
26. Jensen landfill at Neche
27. New Rockford landfill
28. Selfridge landfill
29. New England landfill
30. Watford City landfill
31. Williston landfill
32. Northwest landfill at Noonan

Free Educational Materials from MII



Since 1980, the Mineral Information Institute (MII) has provided free and low-cost earth science and mineral resource materials to K-12 teachers. Recognizing the often over-looked fact that "if it is not grown, it has to be mined," MII has developed or help to develop numerous teaching supplements, including lesson plans and activities, books, videos, and posters. MII also has a list of sources for more information. For further information, contact MII at:

Mineral Information Institute, Inc.
475 17th Street, Suite 510
Denver, CO 80202
tel. (303) 297-3226 fax (303) 295-6463

From the State Geologist, Cont.

surface minerals. We require a permit for these activities, reports on production, mining plans, etc. Our subsurface mineral regulations, which became effective in 1967, apply to many of the minerals not included in the oil and gas and coal regulatory programs. In the event of a conflict in subsurface mineral production (for example, an oil well in the same location as a coal mine or other subsurface mineral mine), the State Geologist is responsible for resolving the conflict. Regulation of subsurface minerals is covered in Chapters 38-12 and 43-02-02 of the Century and Administrative Codes; Century Code Chapter 38-15, passed in 1971, deals with conflicts.

Underground injection control. We are responsible for a portion of the State's Underground Injection Control program, regulating the disposal of fluids into Class III wells. We work closely with the State Department of Health on this. Class III wells are defined as those that inject fluids for the extraction of minerals or energy. Currently, North Dakota has no underground mineral production (apart from oil, gas, and coal), but we have, in the past, been responsible for regulating salt production. Chapters 61-28 and 43-02-02 of the Century and Administrative Codes, respectively, deal with underground injection control.

Paleontological resources. Finally, since 1989 we have regulated paleontological (fossil) resources on land owned by the State of North Dakota and its political subdivisions (county-owned land, etc.). A permit is required to investigate, excavate, collect, or otherwise record vertebrate and certain other fossil resources on these public lands though we do not, of course, have jurisdiction over private lands. The rules also provide a mechanism for monitoring paleontological activities on State lands, thereby providing information for State resource-management plans. Chapters 54-17.3 and 43-04 of the North Dakota Century and Administrative codes, respectively, cover paleontological resources.

In addition to its own direct regulatory authority, the Geological Survey acts as an advisor, providing geological information to other state, local, and federal agencies to assist them in their regulatory duties. We evaluate oil and gas lease sale lands for the North Dakota Land Department, including reserve potential in unitizations, general production potential, decline rates, possible impact on fossil resources, etc. We also advise the U.S. Forest Service, Corps of Engineers, and Bureau of Land Management about issues relating to management of fossil resources on federally administered lands in North Dakota.

Over the years, North Dakota legislators have recognized that geology plays a critical role in fostering sound economic development in North Dakota. From creating basic exploration information for operator use and databases useful for guiding future production (oil-well cores, coal exploration, subsurface minerals), to safeguarding the environment (Class III injection wells, subsurface mineral production), to encouraging the safe use of alternative energy (geothermal), to protecting and managing our fossil resources, the basic application of geology plays an important role in the lives of North Dakotans.

NEW PUBLICATIONS

North Dakota Clays - A Historical Review of Clay Utilization in North Dakota, in press, by Edward C. Murphy: NDGS Miscellaneous Series No. 79, 18 p.

The clays and claystones present at the surface in North Dakota can be grouped into three general catagories: bedrock (which includes Cretaceous through Miocene units), glacial deposits, and modern alluvium. They can also be grouped into several types in relation to desired properties: swelling, nonswelling, calcareous, bleaching ability, and alumina content.

Several detailed studies, dating back to the beginning of statehood, have been done on North Dakota clay resources, including mineralogy, resource evaluation, workability, and usefulness in various manufacturing endeavors. In 1905, the state contained at least two dozen brick-making facilities, of which only the Hebron Brick Company has survived to the present. Although the manufacture of bricks has historically been the most successful endeavor, North Dakota clays and claystones have also been used for making pottery, kitty litter, sewer pipe, lightweight aggregate, soaps, filters, natural cement, and as a source of alumina. The clay resources of North Dakota have played an important role in the economic development of the state. As needs and technology change, the database developed through previous studies of clays and claystones will help identify future uses of this resource.

Sherwood Subinterval of the Mission Canyon Formation in Central Western North Dakota, in press, by W. A. McClellan: NDGS Report of Investigation No. 97, 11 p., 7 plates.

The Madison Group (Mississippian) has long been a favorite target for oil exploration in North Dakota, and few horizons have been as productive as the Sherwood subinterval. Since the discovery of Sherwood Field in 1958 on the Renville County/Saskatchewan border, the Sherwood shoreline play has been extended a short distance north, and south all the way to Billings County. This report illustrates the relationship between major structural features and changing depositional patterns for the Sherwood subinterval in portions of Dunn, McLean, Mountrail, and Ward Counties.

The study area can be separated into two parts, with the depositional history of each being affected by a major basement structural block. The boundary between the two blocks forms part of the Killdeer Trough, and is recognized by a series of northwest-trending structural elements. Depositional patterns for each block represent a lateral transition from shoreline sabkha anhydrites to open-marine limestones. The pattern for the western block was one of slow, continuous subsidence and gradual northerly regression of the Sherwood sea. However, intermittant movement of the eastern block allowed the development of porous grainstone shoals adjacent to a shoreline controlled by basement lineaments. Evidence for this interpretation is offered by a series of maps and other information, which should be useful in exploring for additional shoreline fields in the prolific Sherwood subinterval.

Oil Exploration and Development in the North Dakota Williston Basin: 1992-1993 Update, in press, by Thomas J. Heck: NDGS Miscellaneous Series No. 80, 23 p.

This report, the most recent in a series of biennial oil and gas updates, summarizes oil and gas development and exploration in North Dakota in the 1980s and 1990s and focuses on events and changes of 1992 and 1993. Each field or productive horizon is discussed, with particular attention paid to the Pennsylvannian Tyler Sandstone play, the Bakken Formation, and increased drilling to pre-Bakken horizons.

The report contains numerous bar and line graphs that clearly illustrate trends in tax revenues, number of wells drilled each year, number of new pools discovered, annual crude oil production, and other factors. Also included are two maps that show the location of all known oil fields in North Dakota, including those fields discovered in 1992 and 1993, and a list of new field/pool discoveries.

NDGS publications and USGS topographic maps are available at our sales office (1022 E. Divide Ave, Bismarck), by telephone (701-328-4109), by FAX (701-328-3682), or by mail (see address on mailing label). Cash, money order, or check, payable to the North Dakota Geological Survey, will be accepted. Minimum charge per order is $1.00. Reasonable requests for items for which no price is quoted are sent free of charge. Customers will be invoiced for materials plus shipping costs, if applicable. A free copy of *NDGS List of Publications* will be sent upon request.