NEWSLETTER

NDGS

NORTH DAKOTA GEOLOGICAL SURVEY 1895

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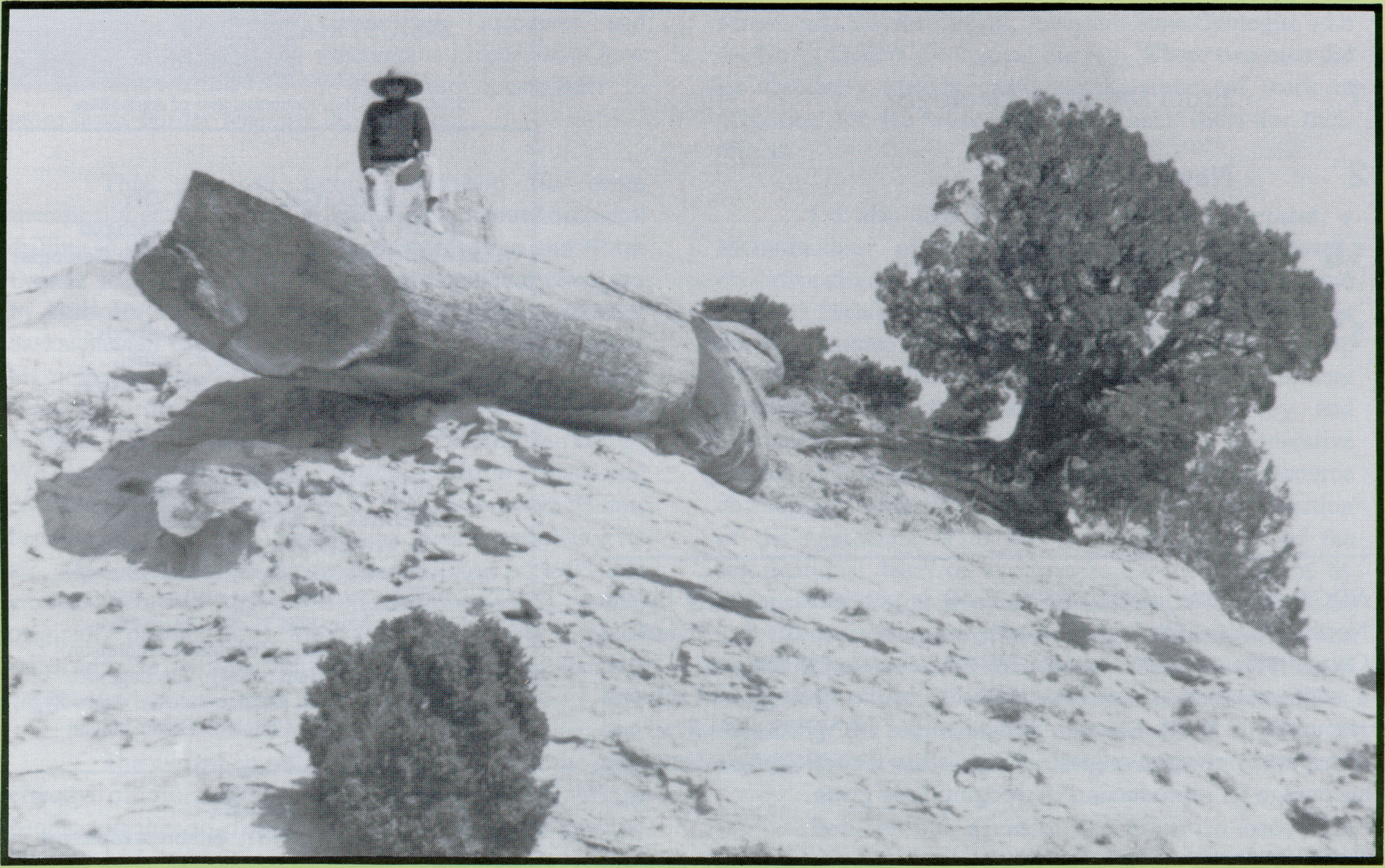

A fantastic variety of concretions and nodules can be found in North Dakota. The example above is a sandstone "log" from the Paleocene Bullion Creek Formation in Slope County. Sandstone "logs" are elongate sand bodies that have been cemented, principally by calcium carbonate, to form log-like concretions. Because they are often visible on aerial photographs, the "logs" have provided geologists with a simple tool for mapping ancient stream channels. See page 6 for an article on this and other concretions and nodules. *Photo by Bob Biek.*

FEATURES

DEPARTMENTS

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NEWSLETTER
NDGS

NORTH DAKOTA GEOLOGICAL SURVEY 1895

FROM THE STATE GEOLOGIST

by John P. Bluemle

Encouraging Petroleum Production in the Williston Basin

The *Second International Williston Basin Horizontal-Well Workshop* was held on April 24-26 in Minot. By all measures, the event was a success. The people who attended the workshop heard talks on Williston Basin geology, horizontal drilling activity and technology, successes and failures, and ideas about how to open the door wider to more cross-border business development.

This was our second workshop, an event specifically aimed at sharing information about horizontal drilling in the Williston Basin in Saskatchewan and North Dakota. The idea was first conceived about two years ago by Malcolm Wilson, Director of Energy Management at Saskatchewan Energy and Mines. Malcolm and some of his colleagues and three of us from the North Dakota Geological Survey met in Estevan, Saskatchewan in October, 1992 to rough out plans for the first workshop. We envisioned about 70 participants, 35 from Canada and 35 from the U.S. We decided to hold the event in Minot, because of its central location and easy accessibility by air. The first workshop was held in May of 1993 and attracted about 170 people, a hundred more than we had originally planned for. This year, 334 people from 14 states and 4 provinces attended — about 100 more than we expected when we began planning late last year.

The workshop setting is, perhaps, one of the most effective of information exchange mechanisms as it brings people together to discuss topics of mutual and specific interest and value. In contrast to the more formal structure of most conferences, the informal atmosphere of our workshop was quite conducive to the exchange of ideas and information, in this case horizontal drilling for oil in the Williston Basin. The informal setting also provided a mechanism for oil industry representatives to meet and discuss business opportunities. We went to some lengths to insure a casual atmosphere — admittedly this was not easy at times, given the unusual number of participants. Even so, conversations I had with people who attended the workshop satisfy me that we accomplished this goal.

This year we moved the meeting date ahead a couple of weeks to coincide with the frost travel bans when fewer field operations are underway. Response to the changed date was positive and made it possible for more people to attend. The actual arrangements for the workshop were handled, almost entirely, by Ken Stalwick, Research Assistant with the Saskatchewan Energy and Mines, and Bill McClellan, Assistant State Geologist with the North Dakota Geological Survey. These two men did an absolutely amazing and brutal amount of work in preparing for the workshop; I do thank them for their efforts.

I'd also like to comment on an agreement, a Memorandum of Understanding, that Phil Reeves, executive director at Saskatchewan Energy and Mines, and I signed during the workshop on Monday, April 25, (at the last minute, Phil was unable to attend the workshop and Malcolm Wilson stood in for him). This agreement between the North Dakota Geological Survey and Saskatchewan Energy and Mines calls for cooperative studies and sharing of information on natural resource development of the Williston Basin. The primary function of the agreement is to try to eliminate some of the informational barriers to cross-border development by industry. By formalizing this agreement, we expect to be able to cooperate more effectively with Saskatchewan and North Dakota oil producers in developing the Williston Basin's oil potential. We are particularly interested in furthering the development of horizontal drilling to increase yields and reduce production costs.

Both of our agencies are trying to encourage greater economic activity across the border through events like the workshop and increased sharing of information. Our two agencies can and will cooperate in numerous ways. For example, even though the rocks in the Williston Basin extend across the border uninterrupted, two different systems for naming the rocks have developed and this has resulted in confusion for people trying to work in both Canada and the United States. Geologists for NDGS and SEM are already working together on specific studies to sort out some of these differences and to correlate the names of rock layers across the border. We will share data more freely and we will also look at other methods of making relevant data and information available to the industry. Different regulatory structures have also had an impact on the way the industry has developed on either side of the border. It might be useful to examine the different approaches the two jurisdictions have taken and how they have affected development of the industry.

Still another way we are cooperating with our Saskatchewan colleagues is by participating in their annual Open House in Regina. The Open House is their forum for highlighting recent geological work undertaken in the province to industry and the interested public. Last November Saskatchewan Energy and Mines invited us to participate in their annual open house in Regina and we did so. We set up a booth at their open house and spent two days explaining to Canadians how the oil industry operates in North Dakota and also discussing other opportunities to develop the state's mineral resources. Although we don't currently have such an open house forum in North Dakota, I do hope we can reciprocate by providing some sort of similar avenue in the future.

In closing, the workshop is certainly the most tangible evidence of cooperation between Saskatchewan Energy and Mines and the North Dakota Geological Survey. Right now we are appraising the results of the workshop, what was accomplished, whether we should hold future workshops and if so, where and when. Many of these decisions will depend on the responses we get from workshop participants over the next few weeks.

NEWS IN BRIEF

compiled by Bob Biek

WILLISTON BASIN HORIZONTAL-WELL WORKSHOP

By William A. McClellan

The first day of the Williston Basin Horizontal-Well Workshop was devoted to Williston Basin geology and horizontal drilling opportunities. There were talks on prospective formations (Red River, Lodgepole, Madison) and areas for exploration in North Dakota. From Canadian speakers came presentations of field developments at Weyburn and Manor in Saskatchewan. The latter is a case where the Spearfish reservoir is only economic through horizontal drilling, which can access the 200 million barrels of reserves without having the wells invaded by water from the underlying formation.

On the second day the stage was devoted to engineering. There was a review of horizontal drilling in southeast Saskatchewan and opportunities in Manitoba. Other speakers discussed new technology in short radius drilling and the application of geologic models to optimize development drilling. Also presented were a decline analysis of Rosebank field in Saskatchewan and the results and lessons learned from horizontal drilling in the Tyler Sand of North Dakota.

Between talks everyone had a chance to review poster presentations of cores, field studies, new tools and techniques, data services, and displays related to the talks. During this time there were many opportunities for informal discussions and exchange of ideas that ranged from exploration concepts to what kind of drill bits to use. Everyone seemed enthusiastic about horizontal drilling and the Williston Basin, and several people mentioned plans for drilling later this year. It seems that people still like this basin for oil development and the industry still has a good future here.

A publication of the workshop proceedings (see table of contents at right) with abstracts, texts, and figures of the talks is available from the NDGS Publications Clerk for $6.00 plus shipping.

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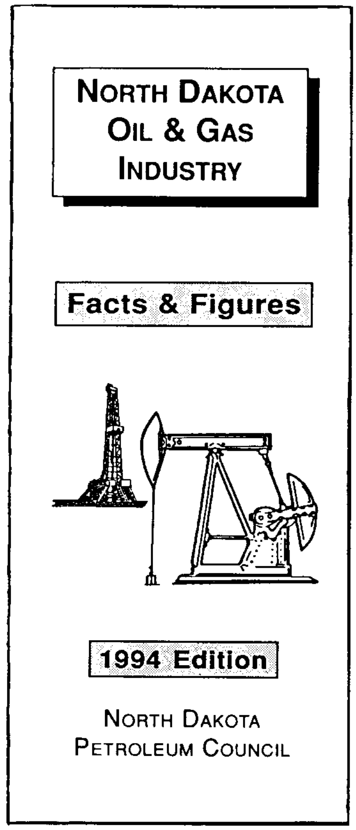


North Dakota Oil and Gas Industry: Facts and Figures is published annually by the North Dakota Petroleum Council. This interesting and highly informative brochure succinctly summarizes exploration and production activity for the past year and compares it to activity in previous years. It also highlights where the petroleum comes from; employment; tax revenues; refining and transportation; uses of petroleum; and other interesting facts. The brochure is available from the North Dakota Petroleum Council, Box 1395, Bismarck, ND 58502 (tel. 701-223-6380).

U.S. Bureau of Mines *1992 Annual Report* Available

The *1992 Annual Report*, summarizes nonfuel industry activity in North Dakota for the 1992 calendar year. Included are discussions on trends and developments, employment, environmental issues, legislation and government programs, and a review by mineral commodity. The report is available free of charge from the North Dakota Geological Survey (while supplies last) or from Robert H. Wood II, U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, P.O. Box 25086, Denver CO, 80225 (Tel. 303-236-0451).

Nonfuel Mineral Industry Statistics

The U.S. Bureau of Mines (USBM) recently released 1993 estimates of nonfuel mineral production in North Dakota. According to USBM estimates, the value of nonfuel minerals produced in North Dakota in 1993 was about $25 million, down slightly from the $25.8 million reported in 1992, but a significant gain over the 1991 total of $17.4 million. Construction sand and gravel accounted for about 82% of the value of North Dakota's nonfuel mineral production. Elemental sulfur (recovered from natural gas processing and oil refining) and other by-products (krypton, xenon, anhydrous ammonia, liquid nitrogen, and cresylic acids recovered from coal gasification), are not included in USBM estimates.

NONFUEL MINERAL PRODUCTION IN NORTH DAKOTA[1]

Mineral		1991		1992		1993[e]	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Clays (common)	thousand metric tons	28	W	W	W	W	W
Gemstones		NA	$6	NA	$643	—	—
Lime	thousand short tons	98	5,360	111	4,288	110	$4,249
Sand and gravel:							
Construction	do.	[e]5,000	[e]12,000	8,740	20,609	8,500	20,400
Industrial	do.	—	—	W	W	5	345
Stone (crushed)	thousand short tons	11	W	11	W	—	—
Combined value of other industrial minerals and values indicated by symbol W		XX	(2)	XX	210	XX	(2)
Total		XX	[3]17,366	XX	25,750	XX	[3]24,994

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value" data. XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Value excluded to avoid disclosing company proprietary data.
[3]Partial total, excludes values that must be concealed to avoid disclosing company proprietary data.

Mapping Grant

The NDGS was recently awarded a $23,031 federal grant for geologic mapping in the Dickinson area. The grant comes from the State Geologic Mapping Element (STATEMAP) of the National Geologic Mapping Program. The grant was for the full amount requested by the NDGS, and will be used to match State funds on an equal basis.

The STATEMAP grant will enable the NDGS to produce geologic maps of the Dickinson North, Dickinson South, Davis Buttes, and Lehigh 7.5 minute quadrangles. The mapping will be done at a scale of 1:24,000 (one inch on the map equals 24,000 inches or 2,000 feet on the ground). The mapping is scheduled for completion by June, 1995.

This mapping project is part of an effort to make avaliable detailed geologic maps of the State's major urban, recreational, and other critical areas. (Results of our first STATEMAP project, the Jamestown -Spiritwood Lake area, will soon be released. A summary of that project will appear in the next issue of the *NDGS Newsletter*.) The maps and reports should be useful for land use planning, environmental and mineral resource assessment, and educational purposes, and will enable a better understanding of the geologic history of such areas. To learn more about this mapping project, please call Bob Biek at (701) 224-4109.

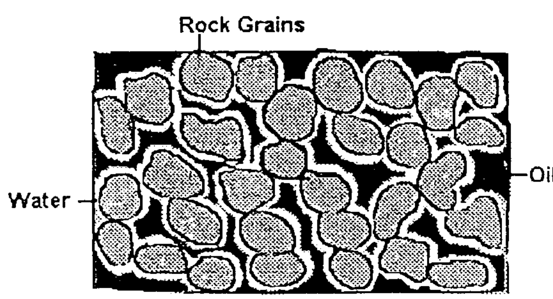


Figure 3. Cartoon drawing illustrating oil and water occurring in the pore space around the grains that compose the rock.

POOLS and RESERVOIRS: DIFFERENT THINGS TO DIFFERENT PEOPLE

by Paul Diehl

"Oh, and what do you do?" This is a question I often hear after being introduced or after making a new acquaintance. My usual answer is: "I'm a petroleum geologist." Depending upon the person, the conversation may go from what a petroleum geologist is to how does one find oil - where do you look? About this time I often hear: "You mean to tell me that oil doesn't occur as underground rivers and lakes! What about those *pools* and *reservoirs* I've heard 'oil patch' people talking about?" I have noticed that many people not familiar with - and some actually employed by - petroleum exploration companies have the misconception that oil and gas exists as large underground rivers and lakes. With rare exceptions, this is not so.

The use of the terms "pools" and "reservoirs" in the petroleum industry may add to the misconception. Most people associate the word "pool" with a small and rather deep body of water. Similarly, the term "reservoir" invokes an image of an artificial lake. It seems natural then that pools and reservoirs should mean essentially the same thing when oil and gas instead of water are the fluids under discussion. However, this is not the case. Although oil and gas are found in pools within reservoirs, the terms have different meanings than when they refer to bodies of water.

Oil in the subsurface exists in the rocks themselves. It is found in tiny, most often microscopic, open spaces called *pores* between the grains and crystals that make up the rocks(Figures 1 & 2). Many rocks have pores and are said to be porous but some are much more porous than others. More specifically, porosity is defined as the percent of the total rock which is pore space: (total

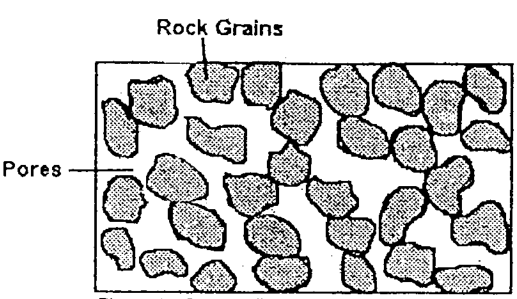


Figure 1. Cartoon illustrating a rock composed of grains and pore spaces between them.

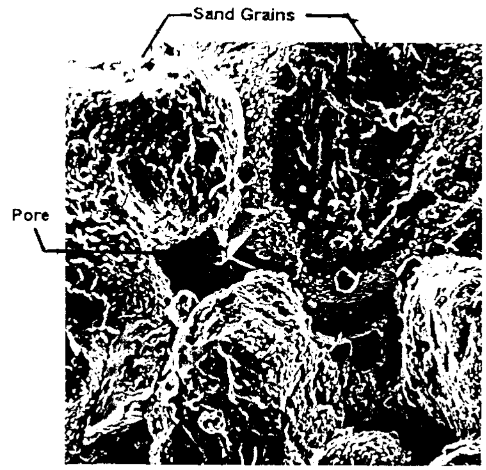


Figure 2. *Scanning electron micrograph of reservoir sandstone (Nugget Sandstone, Wyoming).* From J. E. Welton, SEM Petrology Atlas: AAPG, 1984. Original courtesy of R. L. Burtner and Chevron Oil Field Research Co.

pore volume within the rock divided by the total rock volume) times 100. A rock with 25% porosity consists of 75% solid rock and 25% void spaces.

It is in these tiny pores within the rocks that oil is found. In fact, most often, oil and water both occupy the pore spaces (Figure 3, previous page). The greater the porosity the greater the volume of oil that can be stored in a given volume of rock. Rocks that have porosity and the property that allows oil and/or gas to flow from it in commercial quantities are called *reservoir* rocks. The property of a rock that allows fluids to move through it is called permeability. Not all rocks are porous and not all porous rocks are permeable. To illustrate this point think of a large (say ten pound) block of swiss cheese. The holes in the cheese are obvious, thus you would say that the cheese is very porous. But, if you poured water into one end of the cheese it would not flow through the cheese and out the other end. It is not permeable. Unless the holes or pores are connected to one another, fluids cannot flow through the cheese. It is the same with reservoir rocks; the pores must be connected.

Oil and gas *pools* are continuous but usually limited areas of oil and/or gas accumulations in the pore spaces of *reservoir* rocks.

While it might be true that you can't get blood from a stone, you can get oil from a rock.

CONCRETIONS AND NODULES IN NORTH DAKOTA

- Cannonballs, Logs, and Other Oddities -

by Bob Biek

North Dakota, especially in the wondrously sculpted badland areas of the west, has a fantastic variety of concretions and nodules. Some are the size and shape of petrified logs, while others, perched atop pedestals of softer sediments that they shield from erosion, have lens or disk shapes. Some - like the classic cannonballs - are perfectly spherical. Still others form black iron-like masses that weather out as a protective lag, or armor, on badland slopes; or are widely scattered, such as the soft, transparent nodules of selenite and the bronze-colored marcasite nodules; some even contain fossils of inestimable value in understanding paleogeographic environments. Like all good things geological, concretions and nodules are interesting in their own right, and also contain evidence geologists can use to better understand the geologic history of an area.

A concretion is a clearly bound body of rock within generally softer enclosing sediments of the same composition. The term comes from the Middle English *concret*, itself derived from the Latin *concrescere*, meaning to grow together or harden. Concretions form by the selective precipitation from ground water of dissolved minerals, most commonly calcium carbonate, the stuff of which limestone is made and an important component of concrete, toothpaste, and a host of other products. Siderite (iron carbonate or "ironstone") is also an important cement. As these minerals precipitate, they fill in pore spaces between grains of sediment thereby cementing them together. Concretions can be massive and structureless, or they may preserve fossils or internal sedimentary structures such as crossbeds.

Nodules are hard bodies of rock similar to concretions, though of different composition than the sediments that contain them. The term nodule derives from the Latin *nodulus*, a diminutive of *nodus*, meaning knot. Nodules may also form by the selective precipitation of dissolved minerals that completely replace the original sediment, though some, such as siderite nodules, may form from a gel precipitated under reducing conditions.

Concretions and nodules are found in all of the geologic formations exposed in southwestern North Dakota, and some can be found in glacial sediments and bedrock formations that occur in the eastern half of the State as well. They are most conspicuous, however, in

Above: Two-foot diameter concretions from the Bullion Creek Fm., Theodore Roosevelt National Park. *Photo by John Bluemle.* **Right:** Concretions in the Sentinel Butte Formation, Lake Sakakawea. *Photo by Ed Murphy.*

badland areas, where they are often concentrated at the base of rapidly eroding slopes and less easily hidden by the sparse vegetation.

Classification

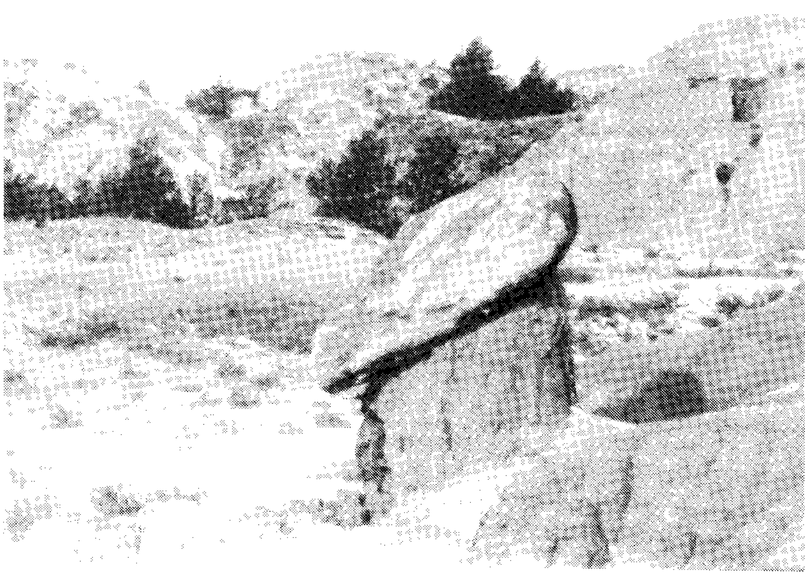
Although there is no comprehensive classification scheme for the great variety of concretions and nodules found in North Dakota, such a scheme would have to take into account three basic factors: shape, composition, and cementing agent. Such a scheme was developed for concretions and nodules of the Hell Creek Formation by Groenewold (1971).

Table I simply illustrates the wide variety of concretions and nodules found in one geologic unit in southwesternmost North Dakota. Many of these are found in other geologic formations as well, and there are other common concretions and nodules not found in the Hell Creek Formation. Examples include fossiliferous concretions of the underlying Fox Hills Formation and even older Pierre Formation, marcasite or pyrite nodules found in lignite beds of the Sentinel Butte Formation, and selenite nodules found in lake clays of the Red River Valley. Furthermore, gradational relationships exist between many of these named types. Still, the table identifies the principal characteristics of many types of concretions and nodules and gives one an idea of the diversity of types to be found in the Hell Creek Formation.

What follows is a discussion of three types of concretions and nodules that I find particularly interesting, and that illustrate the diverse nature of shape, composition, and formation.

Sandstone Logs

Sandstone "logs" are elongate sand bodies that have been cemented, principally by calcium carbonate, to form log-like concretions (they are not petrified wood logs, though some could be so mistaken at a distance) (see cover photo). The elongate form of the concretions results from preferred growth parallel to the direction of paleo-groundwater flow. They are common in channel sands of the Cretaceous Hell Creek and overlying Paleocene formations and are typically 1 to 3 meters (3 to 9 feet) in diameter and 5 to 15 meters (15 to 45 feet) in length. Most are oval in cross-section, though they may be circular or grade into sheet-like forms. Bedding and other sedimentary structures are usually well preserved in these concretions.



Above: Iron-stained sandstone concretions in the Bullion Creek Formation, Theodore Roosevelt National Park. **Left:** Sandstone concretion shielding pedestal of softer sediments, Theodore Roosevelt National Park. *Photos by John Bluemle.*

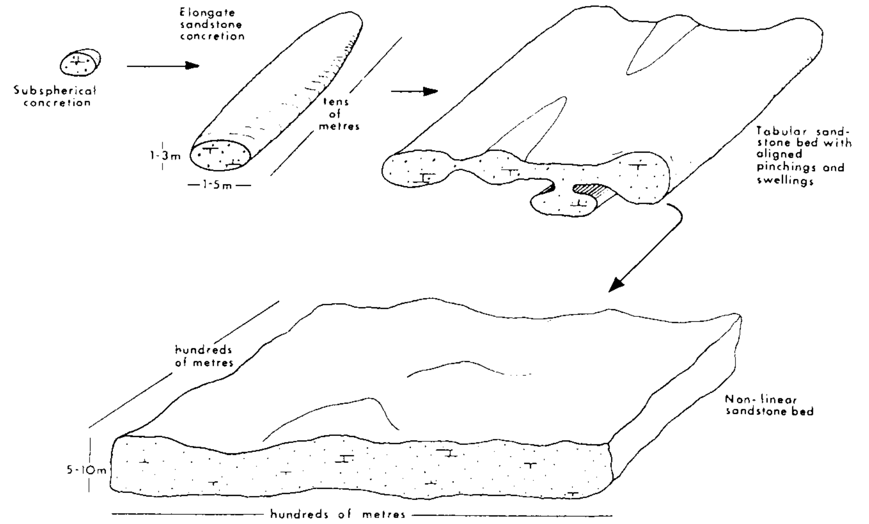


Figure 1. Sequence of forms developed by continued sandstone concretion growth. All four types, with many intermediate shapes, are present in south-western North Dakota. *From Parsons (1980).*

Table I. Classification and characteristics of concretions and nodules of the Cretaceous Hell Creek Formation in Slope and Bowman Counties. Many of these concretions and nodules are also found in other formations, and other types not present in the Hell Creek are found elsewhere in North Dakota. Still, this table hints at the diversity to be found in North Dakota. *Modified from Groenewold (1971).*

	Type	Abundance	Size Range	Relation to Bedding	Enclosing Sediment
CONCRETIONS	**Calcareous sandstone types**				
	lens	abundant	1-10m long 0.1-2m thick	randomly distributed bedding undisturbed	sandstone
	log	common	5-15m long 1-3m dia	randomly distributed bedding undisturbed	sandstone
	irregular mass	abundant	0.5-1m dia	concentrated in layers bedding disturbed	sandstone
	irregular mass	rare	0.5-1m dia	concentrated in layers bedding disturbed	bentonitic sand
	Sideritic sandstone types				
	lens	common	1-3m long 0.2-1m dia	randomly distributed bedding undisturbed	sandstone
	irregular mass	common	0.5-1m dia	concentrated in layers bedding undisturbed	sandstone
	Lignitic sandstone types				
	calcareous lens	rare	1-5m long 0.5-1m thick	randomly distributed bedding undisturbed	lignitic sandstone
	sideritic lens	abundant	5-20m long 0.5-2m thick	concentrated in layers bedding disturbed	lignitic, bentonitic shale
	Other types				
	fossil-cored mass	common	5-20cm dia	randomly distributed bedding disturbed	lignitic bentonite shale
	jarosite sphere	common	10-30cm dia	randomly distributed	sandstone
	pyrite sphere	rare	2-5cm dia	randomly distributed	sandstone
	baritic sandstone lens	rare	0.5-1cm long 5-10cm thick	randomly distributed bedding undisturbed	sandy bentonite
	cone-in-cone mass	rare	0.5-2cm dia	randomly distributed	bentonitic to lignitic sand and silt
NODULES	**Nodules**				
	siderite mass	abundant	0.1-0.2cm in dia	concentrated in layers bedding truncated	bentonitic sandstone
	siderite lens	rare	1-2m long 2-10cm thick	concentrated in layers bedding undisturbed	sandy bentonite
	iron oxide sphere	rare	10-50cm dia	concentrated in layers	bentonitic sand and silt

In a detailed study of elongate concretions in Adams County, North Dakota, Parsons (1980) found that sandstone "logs" may be just an intermediate stage of complete lithification of an entire sand bed (Figure 1). As the "logs" grow, they can coalesce, ultimately forming a broad, tabular sandstone body, such as those that cap many of the buttes of southwestern North Dakota. These sandstone logs thus may represent the initial stages of lithification of some sandstones.

Many geologists, for example, Groenewold (1971) and Jacob (1973), have noted that the long axis of the "logs" lies parallel to bedding and to the axis of the channel sands in which they are found. Because they are often visible on aerial photographs, these "logs" can be a simple tool for mapping paleochannel patterns (and thus helping to understand the configuration of ancient streams and landscapes). By measuring paleocurrent directions in associated channel sand bodies, Parsons (1980) confirmed a strong correlation between the orientations of sandstone "logs" and associated channels.

At the microscopic level, Groenewold (1971) noted that sandstone "logs" from the Hell Creek Formation differ from their unconsolidated host in that relative to the concretion, the enclosing sediments often have more clay, chert, and volcanic materials. That these materials are either highly altered in, or absent from, the concretions, suggests that they have been partially or totally replaced by cementation.

Siderite Nodules

Siderite or "ironstone" nodules are heavy, dark brownish black nodules that occur as small isolated spheres, through complex rounded forms, to thin beds tens of feet long. They often form an erosion-resistant armor on badland slopes, where their black color contrasts sharply with the gray, clayey, eroded sediments out of which they weather (Figure 2). Siderite nodules are typically found in lignitic bentonitic sediments and are often concentrated along certain horizons. They are especially common in the Cretaceous Hell Creek Formation.

Siderite (from the Greek *sideros*, meaning iron) is an iron carbonate and an important ore of iron in many parts of the world. (Though common, siderite nodules are too widely spread in North Dakota to be valuable as ore.) Siderite rarely exists in its pure state as $FeCO_3$, but rather forms a solid solution series with rhodochrosite (a black-weathering, brilliant pink manganese carbonate, $MnCO_3$) and magnesite (a normally chalk-like magnesium carbonate, $MgCO_3$). That is, siderite, rhodochrosite, and magnesite are the pure end members and intermediate forms exist. To a lesser extent, calcium and cobalt can also substitute for the iron in siderite, further complicating the chemistry of sideritic minerals. The black color of most siderite nodules in North Dakota probably comes from partial substitution of manganese for iron.

The outer rind of siderite nodules is often weathered to dark brown limonite, a "catch-all" name for relatively soft, complex mixtures of iron oxides and hydroxides. Underneath the weathered rind, nodules are dark purplish black in color, probably due to increased manganese content. Most nodules are characterized by a pattern of polygonal ridges, sometimes with raised welts at the center of each polygon, aptly described as "alligator skin" (Figure 3).

Abundant field evidence - including truncated but otherwise undisturbed bedding around the nodules, and

Figure 2. Siderite nodules in the Hell Creek Formation. These dark colored, heavy, iron-carbonate nodules often form an erosion-resistant armor on badland slopes. *Photo by Ed Murphy.*

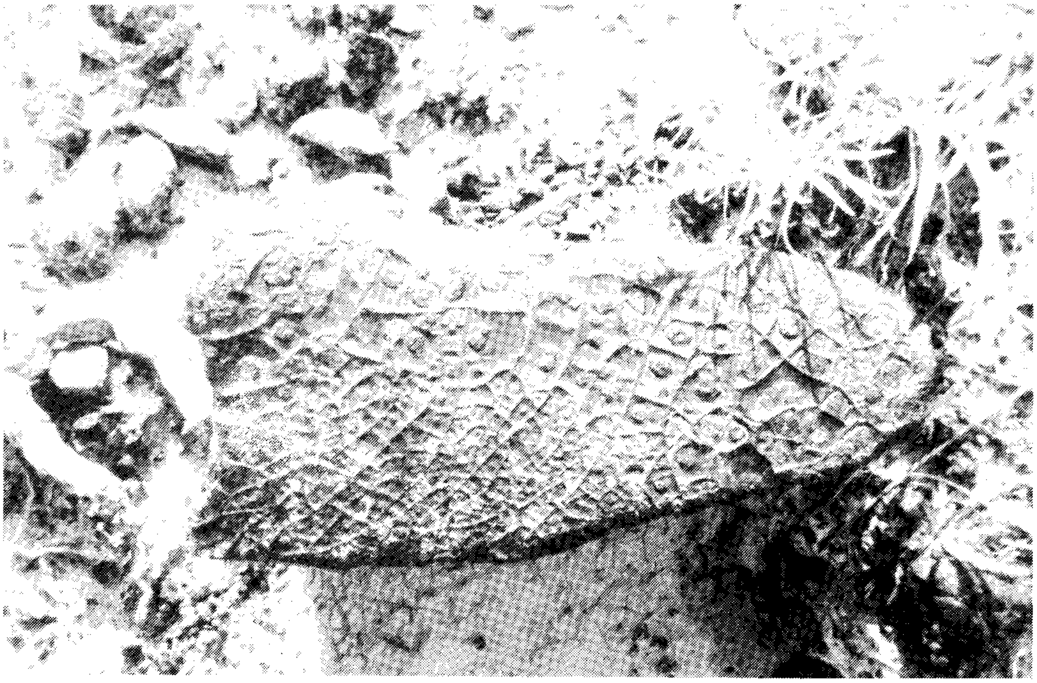


Figure 3. Siderite nodule with characteristic "alligator skin" surface. This pattern of ridges and raised welts may have resulted from solidification of an iron-carbonate gel. *Photo by Ed Murphy.*

soft sediment deformation - indicates that the nodules formed contemporaneously with sedimentation (Frye, 1967), not later as in the case of the sandstone "logs" discussed above. The nodules probably formed at the bottoms of shallow ponds or lagoons, perhaps as a gel. In some cases, minor wave action rolled the gel, thus incorporating sand and fossil fragments or even breaking the gel into pieces now preserved as a sideritic conglomerate. The source of the iron may simply have been the abundant clay itself. Surface films of iron oxides are common on clay particles. If these particles are deposited in a reducing (oxygen-poor) environment, the iron may return to solution and be deposited as siderite.

The polygonal ridges - "alligator skin" - characteristic of many siderite nodules may have resulted from the solidification (dewatering) of the gel and infilling of shrinkage cracks (Franks, 1969). That is, as cracks developed in the rind, the still gel-like interior flowed outward to fill the cracks. The raised welts at the center of some polygons may indicate that flowage of gel did not take place there.

Fossiliferous Concretions

Fossiliferous, carbonate-cemented concretions of the Upper Cretaceous Fox Hills Formation are well known for their exceptional molluscan fauna (bivalves, gastropods, and ammonites). In an effort to understand the chemical and physical processes responsible for concretion formation, Carpenter et al. (1988) studied changes in trace element and isotopic compositions between successive concretionary layers. Their results are fascinating.

The concretionary cements record the chemical signature of regional geologic events, including the initial shallow burial of concretionary sediments in a shallow marine environment, followed by deltaic progradation, relative sea level rise, and finally continued progradation of deltaic sediments. These conclusions are supported by independent sedimentologic and stratigraphic studies that show that the Fox Hills Formation is part of a regressive, marginal marine sequence.

I find concretions and nodules interesting precisely because they are different than what surrounds them. They stand out in a crowd: they are the classic, restored, old car in a long line of look-alike modern automobiles; the double play that everyone yearns for at a baseball game; the sparks from a campfire. Concretions and nodules exist in fantastic variety in North Dakota. They are most easily seen in areas of badland topography, and in fact add much to the character and intrigue of such places, but those with a sharp eye can find them throughout the State.

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Groenewold, Gerald H., 1971, Concretions and nodules in the Hell Creek Formation, south-western North Dakota: Unpublished UND M.S. Thesis, 84 p.

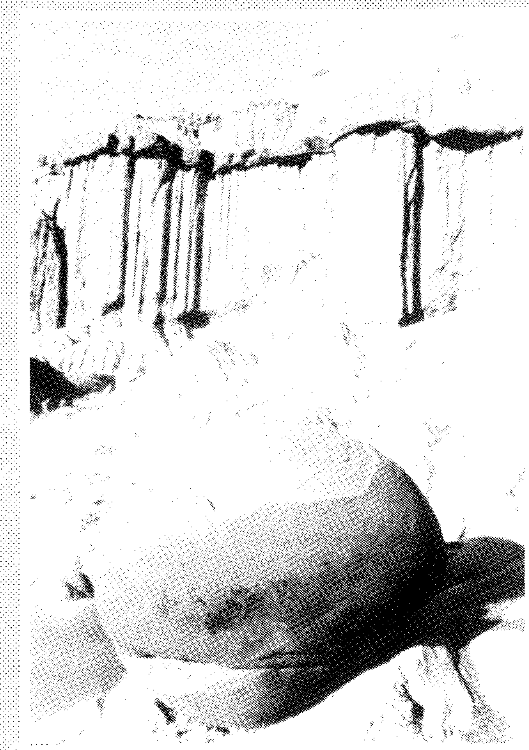
Jacob, Arthur F., 1973, Elongate Concretions as Paleochannel Indicators, Tongue River Formation, (Paleocene), North Dakota: Geological Society of America Bulletin, v.84, p. 2127-2132.

Parsons, Michael W., 1980, Distribution and origin of elongate sandstone concretions, Bullion Creek and Slope Formations (Paleocene), Adams County, North Dakota: Unpublished UND M.S. Thesis, 133 p.

Cannonballs

Among the more unusual concretions are "cannonballs," from which the Cannonball River, the town of Cannon Ball, and a host of proprietary Cannonball names are ultimately derived. "Cannonballs" are large, spherical sandstone concretions. They are common though not abundant in the Cannonball and Fox Hills Formations in Morton and Sioux Counties and can be found in badland areas farther west. (Perhaps cannonballs are even more common as lawn and driveway ornaments in the Bismarck-Mandan area!) They are seldom greater than two to three feet in diameter. Like most other concretions, they are more resistant to weathering than enclosing sediments and often can be found at the base of slopes.

The cannonballs formed by cementation, with calcium carbonate being the principal cementing agent. They may contain a small nucleus of organic material (a shell or plant fragment). Their spherical form suggests that growth was unconstrained by primary sedimentary structures or fabrics, such as would be the case for more flattened or irregularly shaped concretions.



Spherical concretion in the Sentinel Butte Fm., Theodore Roosevelt National Park. Note differences in weathering (castellate = vertical columns, rill = slope in foreground, exfoliation = concentric peeling of concretion). Photo by Ed Murphy.

Geologic Projects in North Dakota
1994

Compiled by Bob Biek

In the last issue of the *NDGS Newsletter*, we requested information about areas in North Dakota - and nearby areas of adjoining States and Provinces - currently being studied by government, university, and industry geoscientists. In addition to its inclusion in the newsletter, the request for information was sent directly to 74 individuals known to have worked on geologic projects in North Dakota in the recent past. The reasons for the request were simple: To help keep one another appprised of current geologic projects, and to stimulate interaction among geologic researchers in North Dakota.

I owe a great deal of thanks to all those who responded to the survey. A total of 65 responses were received, identifying 96 geologic projects. Certainly the list is incomplete - some reseachers may not have seen the request for information; some, with a history of research in North Dakota, may not have a current North Dakota project underway or simply failed to respond; and some research, particularly that of industry, is often confidential. Even so, I believe the list represents a significant percentage of the total geological research currently underway in North Dakota. We are encouraged by the response, hope that you too find it useful, and will strive to make future lists more complete.

In a few instances, I have opted to exclude responses that seemed too distant from North Dakota, even though such work may be indirectly relevant to our state. Such is the nature of geologic work throughout the world - some has important implications for research here at home. Our intent here is to simply provide a list of research that directly involves North Dakota and adjacent areas.

The *Bibliography and Index of North Dakota Geology*, currently being updated by Larry Greenwood, Library Director at Minot State University, contains additional insight into geological research in North Dakota. The difference between such bibliographies and this list, however, is that bibliographies are "after the fact" while this list contains current geologic projects.

We intend to solicit (in the Spring) and publish (in the Summer) this information on an annual basis. Searches of this data base can be made by type of study, researcher, organization, or county at no charge. Thanks again to those of you who responded.

Adams	AD
Barnes	BA
Benson	BE
Billings	BI
Bottineau	BO
Bowman	BW
Burke	BU
Burleigh	BL
Cass	CA
Cavalier	CV
Dickey	DI
Divide	DV
Dunn	DU
Eddy	ED
Emmons	EM
Foster	FO
Golden Valley	GV
Grand Forks	GF
Grant	GR
Griggs	GG
Hettinger	HE
Kidder	KI
LaMoure	LM
Logan	LO
McHenry	MH
McIntosh	MI
Mckenzie	MK
McLean	ML
Mercer	ME
Morton	MO

Mountrail	MR
Nelson	NE
Oliver	OL
Pembina	PE
Pierce	PI
Ramsey	RA
Ransom	RN
Renville	RE
Richland	RI
Rolette	RO
Sargent	SA
Sheridan	SH
Sioux	SI
Slope	SL
Stark	SR
Steele	ST
Stutsman	SM
Towner	TO
Traill	TR
Walsh	WA
Ward	WD
Wells	WE
Williams	WI
Statewide	SW
Minnesota	MN
Montana	MT
South Dakota	SD
Manitoba	MB
Saskatchewan	SK

Economic Geology:	
a. General	EC
b. Coal	CG
c. Nonfuel minerals	NF
d. Petroleum	PG
Educational geology	GE
Engineering Geology	EG
Environmental Geology	EV
Geoarchaeology	GA
Geochemistry	GC
Geochronology	GR
Geographic Information Systems	GS
Geologic Hazards	GH
Geologic Mapping	GM
Geomorphology	GO
Geophysics	GP
Hydrogeology	HG
Mineralogy	MN
Paleomagnetism	PM
Paleontology	PA
Palynology/Paleobotany	PY
Petrology	PT
Quaternary Geology	QG
Sedimentology	SD
Soils	SO
Stratigraphy	ST
Structural Geology/Tectonics	SG

GEOLOGIC PROJECTS IN NORTH DAKOTA

Investigator(s)	Organization(s)	County(s)	Location	Type of Study	Title/Subject	Scale of Map
Aber, J.S.	Emporia State Univ	RA,BE	Devils Lake region	GO,HG, QG,SG	Glaciotectonics and hydrology	- 0 -
Anonymous	MNDNR-DW	MN	Red River Valley	HG	Groundwater monitoring	- 0 -
Basinger, J., McIver, E.	Univ of Saskatchewan	SK	Southern Saskatchewan	PY	L Cret/E Tertiary flora	- 0 -
Bickel, D.	ND PSC	DU,ML,ME, OL,SR	Active surface mining areas	EC,CG,HG	Characterization and modelling of water resources	- 0 -
Biek, R.F.	NDGS	BL	State capitol	GE	Building stones	- 0 -
Biek, R.F.	NDGS	SM	Jamestown area	GE	Geologic guidebook	- 0 -
Biek, R.F., Murphy, E.C.	NDGS	SR,DU	Dickinson N + S, Lehigh, Davis Buttes quads	GM	Geologic maps	1:24000
Biek, R.F.	NDGS	SM	Jamestown, Bloom, Spiritwood Lake quads	GM,ST	Geologic maps	1:24000
Bluemle, J.P.	NDGS	SW	Statewide	GE	Natural science of North Dakota	- 0 -
Bluemle, J.P.	NDGS	SW	Central North Dakota	QG,GO	Glaciotectonic features	- 0 -
Bluemle, J.P.	NDGS	SW	Interstate 94	GE	Roadlog	- 0 -
Boleneus, D.E. McHugh, E.L.	USBM	BW,DU,GV, MK,RN,SA, SH,SL,MT,SD	Custer National Forest	CG,NF,PG	Mineral resources appraisal	1:126000 1:200000
Brevik, E.	UND	CA,GF,PE, RI,TR,WA	Red River Valley	GO,QG,SG	Isostatic rebound of Lake Agassiz Basin	- 0 -
Burke, R.B., Diehl, P.E.	NDGS	SR	Dickinson area	PG,PT,SD	Lodgepole cores and cuttings	- 0 -
Burke, R.B., Haidl, F.	NDGS/SEM	SW,SK	Williston Basin	ST	Silurian strat problems	- 0 -
Burke, R.B., Diehl, P.E., Heck, T.J.	NDGS	SW	Dickinson area/statewide	PG	Lodgepole reservoir characterization	- 0 -
Burke, R.B.	NDGS	ML	western McLean Co	PG,ST,SD	Lucky Mound field study	- 0 -
Cates, S.W., Macek	USGS-WRD	MR,ME,ML,	Fort Berthold Indian Res	GP,HG, SG,GC	Water resources of FBIR	- 0 -
Cates, S.W.	USGS-WRD	DU,MK	sw Fort Berthold Indian Res	HG,GC	Mandaree area groundwater	- 0 -
Colton, R.B.	USGS	DV,MK,WI,MT	Glendive, Plentywood, Culbertson 30x60 quads	GM,QG	Geologic maps	1:1000000
Cowdery, T.	USGS-WRD	RN,RI	Sheyenne Delta, McLeod area	HG	Land-use effects on groundwater quality	- 0 -
Diehl, P.E.	NDGS	SW	western ND	ST,PT,PG	Tyler Fm/petroleum production	- 0 -
Diehl, P.E.	NDGS	SW	western ND	PG,ST,SD	Rocky Ridge - Tracy Mtn field study	- 0 -
Ellis, M.S., Colton, R.B.	USGS	BI,BW,SL	Powder R. Basin, surrounding area	GM	Geologic map of the PRB	1:500000
Erickson, J.M.	St Lawrence Univ	BW,SL,AD,GR, SI,EM,BL,LO,MI	Upper Midwest, SK	PA,PY,ST	Pierre-Fox Hills-Cannonball Fms. paleontology, strat, paleogeography	- 0 -
Fullerton, D.S.	USGS	SW,MN,MT, MB,SK	Dakotas, Big Horn Mtns, Regina, Winnipeg 1:1M quads	QG,GM	Quaternary geologic maps	1:1000000
Gerlach, T.	UND	RE	nw Renville Co.	PG,SG,GP, MN,PT,ST	Newporte (impact?) structure	- 0 -
Gilbertson, J.	SDGS	SD	Roberts County	GM,HG, QG,ST	Geology and water resources of Roberts County	1:100000
Greer, P.L., Olson, J.	NDGS/NDSWC	SI	Selfridge	EV,HG	Selfridge landfill investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	WA	Grafton	EV,HG	Grafton landfill investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	GF	Northwood	EV,HG	Northwood landfill investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	MK	Watford City	EV,HG	Watford City landfill Investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	PE	Hamilton	EV,HG	Valley Landfill Assoc investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	CA	Fargo	EV,HG	Fargo landfill Assoc investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	GF	Grand Forks	EV,HG	Grand Forks landfill Investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	ED	New Rockford	EV,HG	New Rockford landfill Investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	WA	Park River	EV,HG	Consolidated landfill investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	PE	Neche	EV,HG	Jensen landfill investigation	- 0 -

Investigator(s)	Organization(s)	County(s)	Location	Type of Study	Title/Subject	Scale of Map
Greer, P.L., Olson, J.	NDGS/NDSWC	HE	New England	EV,HG	New England landfill investigation	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	DV	Noonan	EV,HG	Northwest Solid Waste landfill invest	- 0 -
Greer, P.L., Olson, J.	NDGS/NDSWC	WI	Williston	EV,HG	Williston landfill investigation	- 0 -
Haidl, F.M.	SEM - PG Branch	SK	Williston Basin	ST,SD	Geology of Silurian strata in SK	- 0 -
Harris, K.L., Benson, S., Lusardi, B., Nuutinen, A., Trojan, M.	MGS/MNDNR-DW	MN	Southern Red River Valley	QG,ST,HG	Regional Hydrogeologic assessment	1:200000
Harris, K.L., Falteisek,J. Trojan, M.	MGS/MNDNR-DW	MN	Northern Red River Valley	HG	Regional Hydrogeologic Assessment	1:200000
Harris, K.L., Luther, M.R.	MGS/NDGS	BA,CA,GF,NE, RN,RI,ST,TR,MN	Southern Red River Valley	QG,ST	Quaternary geology of southern RRV	1:250000
Hartman, J.H.	EERC	SW	Western ND Williston Basin	CG,PA,ST,GS	L Cret/E Tert paleo + coal strat	- 0 -
Hatnal, Z., Redly, P., Zhu, C.	Univ of Saskatchewan	MH,MR,WD, WI,MT	MT; plus T158N, R74W - R103W	GP,ST,SG	Williston Basin seismic strat	- 0 -
Heaton, T.	Univ of S. Dakota	SR,SL,SD,MT SK	Oligocene badlands	PA	*Ischyromys* (rodent) and *Leptomeryx* (deer) fossils	- 0 -
Heck, T.J., LeFever, J.A.	NDGS	SW	western ND	PG	Basin center gas	- 0 -
Heck, T.J.	NDGS	SW	western ND	PG	Potential-gas estimates	- 0 -
Heck, T.J.	NDGS	SW	western ND	PG	1993 Petroleum update	- 0 -
Heck, T.J.	NDGS	SW	western ND	PG	Oil-potential assessment	- 0 -
Heck, T.J.	NDGS	BO	western Bottineau Co	PG	S Antler Creek field study	- 0 -
Hendry, H., Renant, R. Kasper, D., Ferdano, H.	Univ of Saskatchewan	SK	Saskatchewan	PG,ST,SD PT	Bakken Fm	- 0 -
Hertel, E.	Coteau Properties Co	ME	Freedom Mine	CG	High-ash zones in the Beulah bed	- 0 -
Hoganson, J.W.	NDGS	MO	Stumpf site, Huff area	PA,ST	Hell Cr Fm strat + paleontology	- 0 -
Hoganson, J.W.	NDGS	EM,SI,MI,LO, BW,MO	sw + south-central ND	PA	Fox Hills Fm vert paleontology	- 0 -
Hoganson, J.W.	NDGS	EM,BL,SI MO,BW	sw + south-central ND	PA	Brien Mbr of Hell Cr Fm	- 0 -
Hoganson, J.W.	NDGS	GG	Cooperstown area	PA	Pierre Fm paleontology	- 0 -
Hoganson, J.W., Murphy, E., Schwert, D.	NDGS/NDSU	SW	Statewide	GE	Roadside geology of ND	- 0 -
Jirsa, M., Runkel, A., Chandler, V., Boerboom, T.	MGS	MN	nw MN, s bndry = 47°	GM,GP	Bedrock geologic map nw MN	1:250000
Johnson, K.R.	Denver Museum NH	BW,SL,MT	Marmarth area	PY	L Cret/E Tert paleobotany	- 0 -
Kehew, A.E.	West Michigan Univ	MB,SK	Southern MB, SK	QG	Meltwater paleohydrology	- 0 -
Kreis, L.K.	SEM - PG Branch	SK	Southern SK	GM,ST	Computer-generated geologic map	1:1000000
Langer, W.H., Throckmorton, C.K. Schilling, S.P.	USGS	SW,SD,MT	Missouri River Basin	EV,GH,GO	Earth Science issues in the Missouri River Basin	1:2000000
LeFever, J.A.	NDGS	BO	central Bottineau Co	PG	Landa field study	- 0 -
LeFever, J.A.	NDGS	SW	western ND	PG	Bakken Fm	- 0 -
LeFever, J.A., Price, L.	NDGS/USGS	SW	western ND	PG	Bakken + Madison oil migration	- 0 -
Lehr, J.D.	MNDNR-DM	MN	Isanti and Clay Counties	NF,QG	Aggregate resources, Quat geology	1:100000
Luther, M.R., Christensen, R.	NDGS/NDDOT	SW	North Dakota	GA,MN	flakable lithic resources	1:1000000
Luther, M.R.	NDGS	PE,WA,CV, GF,NE	ne North Dakota	QG,GM	Atlas Area #1, surficial geologic map	1:250000
Luther, M.R.	NDGS	GF	west-central GF County	GS,GM	GIS prototype project	- 0 -
Luther, M.R., Brekke, D.W.	NDGS/EERC	SW	eastern ND	NF,GH, GC,ST	Trace elements in Cretaceous shales	1:1000000
Luther, M.R., Cluer, J.K.	NDGS/Blue Lead Expl.	DU,SR,BI,MK	western ND	NF,MN	Near surface metaliferous deposits	1:2400 1:1000000
Martin, J., Sawyer, J.F.	SDGS	BW,AD,SI,EM SD	Lemmon and McIntosh 1x2° quads	GM	Geologic maps	1:250000

Investigator(s)	Organization(s)	County(s)	Location	Type of Study	Title/Subject	Scale of Map
Martin, J., Sawyer, J.F.	SDGS	BW,AD,SI,EM	ND-SD border	GM	Geologic map of SD	1:500000
Martiniuk, C.D. Barchyn, D.	MEM	MB	Southwestern Manitoba	PG	Petroleum potential of the pre-Mississippian	- 0 -
McClellan, W.A.	NDGS	SW	western ND	PG	Sherwood Shoreline play	- 0 -
McClellan, W.A.	NDGS	BW	western Bowman Co	PG	Red River Fm.	- 0 -
Melchior, R.C.	Bemidji State Univ	GV	Wannagan Creek area	PA	Paleocene flora	- 0 -
Murphy, E.C.	NDGS	DU	county wide	GM	Geologic map	1:125000
Murphy, E.C., Hoganson, J.W., Nichols, D.J., Forsman, N.F.	NDGS/USGS/UND	BL,MO,EM, GR,SI	south-central ND	ST,PA,PY, MN	K/T boundary	- 0 -
Oreskovich, J.A., Toth, T.A.	NRRI	MN	Kittson County	EC	Bloating clays/uses	- 0 -
Oreskovich, J.A., Hauck, S.A.	NRRI	MN	Kittson County	EC	Bloating clays/lightweight aggregate	- 0 -
Pigg, K.B.	AZ State Univ	MO	Almont	PY	Paleocene flora	- 0 -
Redly, P.	Univ of Saskatchewan	SW,MT,MB,SK	Williston Basin	GP,ST,SG	Seismic/sequence strat/structure of WB	- 0 -
Reid, J.R.	UND	ML,ME	Lake Sakakawea	EG,GO	Shoreline erosion, mechanisms, rates	- 0 -
Reid, J.R.	UND	ML	N shore, Lake Sakakawea	GO,SO	Interpretation of 16 paleosol sites	- 0 -
Reid, J.R.	UND	TR,MN	Halstad, MN area	GO	Geomorph of archaeological sites	- 0 -
Richardson, J.L.	NDSU	BO,CA,CV,DV, RN,RA,SM,TR, WA,FO	Statewide	GO,SO,HG, GC	Wetland soils, saline soils	- 0 -
Rowland, T., Flores, R. Keighin, B.	Coteau Properties Co/ USGS	ME	Freedom Mine	CG	Beulah Bed concretions	- 0 -
Schoenberg, M.E.	USGS-WRD	RI, MN	Wahpeton - Breckenridge	HG	Sources of groundwater	1:222000
Shurr, G.W.	St Cloud St Univ	BI,GV,MK,SR	sw Williston Basin	PG,SG,SK	Tectonic setting Bakken production	- 0 -
Shurr, G.W.	St Cloud St Univ	SW	North Dakota	SG	Surface expression of local structural anomolies	variable
Shurr, G.W.	St Cloud St Univ	SW	Western ND	PG,ST,SG	Shallow gas potential	1:250000 1:500000
Shurr, G.W.	St Cloud St Univ	BI,GV,MK SR,MR,WI,BU	Williston Basin	SG	Tectonic blocks/lineaments	1:250000 1:1000000
Soil Survey Staff	USDA-SCS	RI,ED,MK,BI	county wide	SO	Soil survey	1:24000 1:12000
Starr, E.	Valley City State Univ	BA	Valley City area	PA	Microfossils of the Pierre Fm	- 0 -
Strobel, M.L.	USGS-WRD	GF,WA	Red River Valley	HG	Saline seeps	- 0 -
VanNest, J.	Univ of Iowa	DU,ME	Spring Cr drainage basin	GA,GO,QG, SO	Knife River Flint/Leonard paleosol	- 0 -
Vuke-Foster, S.	MBMG	BW	Ekalaka 30x60 quad	GM	Geology of Ekalaka quad	1:100000
Vuke-Foster, S.	MBMG	BW	Ekalaka 1x2 quad	GM	Geology of Ekalaka quad	1:250000
Vuke-Foster, S.	MBMG	BW,SL,GV	Miles City 1x2 quad	GM	Geology of Miles City quad	1:250000
Vuke-Foster, S.	MBMG	GV,MK	Glendive 30x60 quad	GM	Geology of Glendive quad	1:100000
Young, G.	MMMN	MB	Southern Interlake Region	PA	Ordo. Stony Mtn Fm corals	- 0 -
Zwilling, D.	MNDNR-DW	RI,MN	Wahpeton/Breckenridge area	HG	Groundwater monitoring	- 0 -

Abbreviations

EERC - Energy and Environmental Research Center, Grand Forks
MBMG - Montana Bureau of Mines and Geology
MEM - Manitoba Energy and Mines
MGS - Minnesota Geological Survey
MNDNR-DM - Minnesota Dept of Natural Resources, Division of Minerals
MNDNR-DW - Minnesota Dept of Natural Resources, Division of Waters
NDPSC - ND Public Service Commission
NDSU - North Dakota State University, Fargo
NDSWC - ND State Water Commission
NRRI - Natural Resources Research Institute, Duluth
SDGS - South Dakota Geological Survey
SEM-PG - Saskatchewan Energy and Mines, Petroleum Geology Branch
UND - University of North Dakota
USBM - US Bureau of Mines
USGS-WRD - US Geological Survey, Water Resources Divison

by Bob Biek

Geological Highway Maps

When I go on vacation or short weekend trips, you'll always find a geological highway map at my side. Such a map not only shows the location of roads, towns, and other features, but also the geology of a region. There is perhaps no better way to make a long, otherwise tedious drive interesting, or to lend a new sense of awareness to even the most scenic routes.

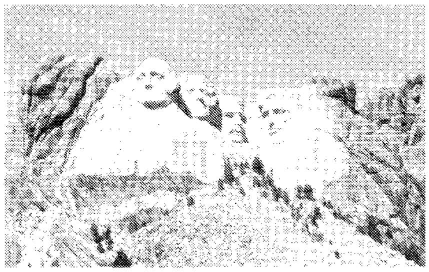
Typically, geological highway maps show the geology of an entire state - the distribution of geologic formations, their relative ages, and the structures they reveal - together with an easy-to-understand explanation of the state's geologic history and interesting or unusual geologic features. Many state (and provincial) geologic surveys or geologic societies have published such maps. State Geologist John Bluemle created such a map for North Dakota in 1988.

The Geological Highway Map of North Dakota contains a full-color, generalized geologic map (scale 1:1,000,000 - roughly the same scale as the Official State Highway Map), cross-section, and brief explanations of geologic formations shown on the map. The backside of the map shows the general locations and photographs of interesting geologic features, and an explanation of the geologic history of the state. Using this map will make any long drive more enjoyable, and may even prompt one to get a hold of a geologic roadlog or county geologic maps of particularly interesting areas. The North Dakota Geological Highway Map is available from the NDGS for $3.00.

Geological Highway Map

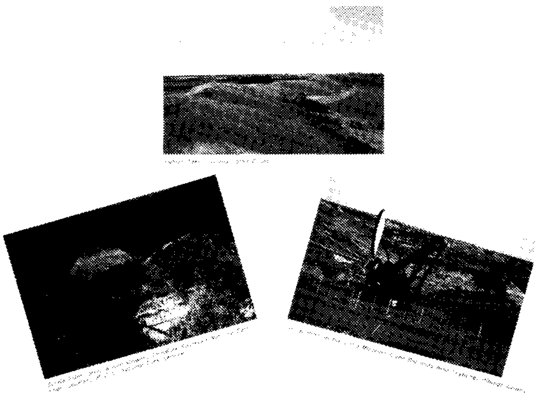
NORTHERN GREAT PLAINS REGION

NORTH DAKOTA NEBRASKA
SOUTH DAKOTA IOWA MINNESOTA



Published by
The American Association of Petroleum Geologists

NORTH DAKOTA



GEOLOGICAL HIGHWAY MAP

North Dakota Geological Survey
Grand Forks, North Dakota 1988

One other geological highway map that covers North Dakota (and South Dakota, Iowa, Nebraska, and Minnesota) was published by the American Association of Petroleum Geologists at a scale of about 1" = 30 miles. Although less detailed than the North Dakota map, it gives the overall picture of the northern Great Plains region. It is one in a series of twelve such AAPG maps that cover the entire U.S. It is available from the American Association of Petroleum Geologists, 1444 South Boulder, P.O. Box 979, Tulsa, OK 74101 (916-584-2555).

NEW PUBLICATIONS

List of Publications
of the
North Dakota Geological Survey,
(February, 1994), 63 pages, free on request.

This list of NDGS publications, and materials available from the Oil and Gas Division, updates the previous list published in January, 1992. The list contains only those materials currently available. A complete list of all NDGS publications ever printed is also available.

Proceedings of the **Second International Williston Basin Horizontal-Well Workshop**, April, 1994, compiled by William A. McClellan, approximately 240 pages in a three-ring binder, $6.00 plus shipping and handling.

This volume contains 13 papers and 7 poster abstracts presented at the Second International Williston Basin Horizontal-Well Workshop co-sponsored by the NDGS and Saskatchewan Enery and Mines. See page 3 for further information.

Outside Publications

Wood, Robert H. II and Biek, Robert F., 1994, *The mineral industry of North Dakota*: U.S. Bureau of Mines 1992 Annual Report, 6 p.

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*: *in* Garvey, R., ed., Proceedings of the North Dakota Academy of Science, v. 48, p. 95.

Forsman, N.F., Murphy, E.C., and Hoganson, J.W., 1994, *Sandstone petrography as a tool in mapping Cenozoic rock units in southwestern North Dakota*: *in* Garvey, R., ed., Proceedings of the North Dakota Academy of Science, v. 48, p. 76.

Luther, M.R., 1994, *GIS progress in North Dakota*: *in* Garvey, R., ed., Proceedings of the North Dakota Academy of Science, v. 48, p. 52.

NDGS publications and USGS topographic maps are available at our sales office (1022 E. Divide Ave, Bismarck), by telephone (701-224-4109), by FAX (701-224-3682), or by mail (see address below). 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.

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