Cement Rock Mineral Resources of the Niobrara Formation in Northeastern North Dakota

By Fred J. Anderson

Introduction

The recent shortages of cement in North Dakota, and how these shortages affect construction activities in our State, has received much attention. Cement is one of the basic components of concrete. Concrete is used in almost every type of contemporary construction and as a result is in extremely high demand. Currently all of the cement used in North Dakota for construction purposes has to be brought in from out-of-state producers. At the time of writing, the majority of cement used in North Dakota is obtained from producers in Iowa and from our Canadian neighbors in Alberta (Grand Forks Herald, 2005). This article will highlight some recent NDGS investigative work associated with the cement rock mineral resources of northeastern North Dakota.

The terms ***cement*** and ***concrete*** are often used interchangeably. This can be confusing. Simply speaking, cement is a mixture of lime and silica which forms the *binding component* of concrete. There are several different types of cement, but the most common variety is Portland. Portland Cement or *Portland Grade Cement*, is a cement material made by the grinding of a composite mixture of calcium, silicon, aluminum, iron and other minor constituents, typically found in limestone and shale - or equivalent raw materials. The mixture is heated to incipient fusion (melting) in a rotary kiln, followed by fine-grinding of the resulting clinker into a fine powder with the addition of gypsum (hydrous calcium sulfate) as a binding agent.

Practically all cement produced today is Portland-grade cement. The moniker of "Portland" was derived from its original source of production, the Isle of Portland in England. It was named for its resemblance to Portland stone, which was a "yellowish-white, oolitic limestone widely used for building purposes." (Jackson, 1997). Common source materials for the manufacture of Portland Cement are limestones or marls (combined with shale, clay, silica sand, and iron ore) (PCA, 2005). Lime and silica make up about 85% of the overall mass of the cement mixture.

With clear definitions in mind we can then understand a definition of ***cement rock*** as a rock that consists of all of the mineralogical constituents required for use as a cement *in situ* (meaning in place). It is formally defined as: "any rock that is capable of furnishing cement when properly treated, with little or no addition of other material; specifically a massive (meaning non-bedded), sparsely fossiliferous, clayey limestone that contains the ingredients (alumina, silica, and lime) for cement in approximately the required proportions." (Jackson, 1997).

Previous Investigations of Cement Rock in North Dakota

The possibility of using portions of the Niobrara Formation as a raw material for the creation of Portland Cement was formally investigated in 1962 and reported in 1964 by NDGS geologist Clarence G. (Kelly) Carlson. Interestingly, the investigative costs; including drilling and laboratory analytical work, were borne not by the Survey budget, but by the then existing North Dakota Economic Development Commission. Earlier work and comment on the cement rock mineral resources of North Dakota dates back over a century to E.J. Babcock in his first annual bulletin of the NDGS completed in 1901 (Babcock, 1901). An excellent historical treatment as well as an overview of cement rock mineral resources in other parts of North Dakota can be found in Volume 21 of the NDGS newsletter as penned by E.C. Murphy, current ND State Geologist (Murphy, 1994), and on the NDGS website at: http://www.state.nd.us/ndgs/minerals/nd_cemen_h.htm.

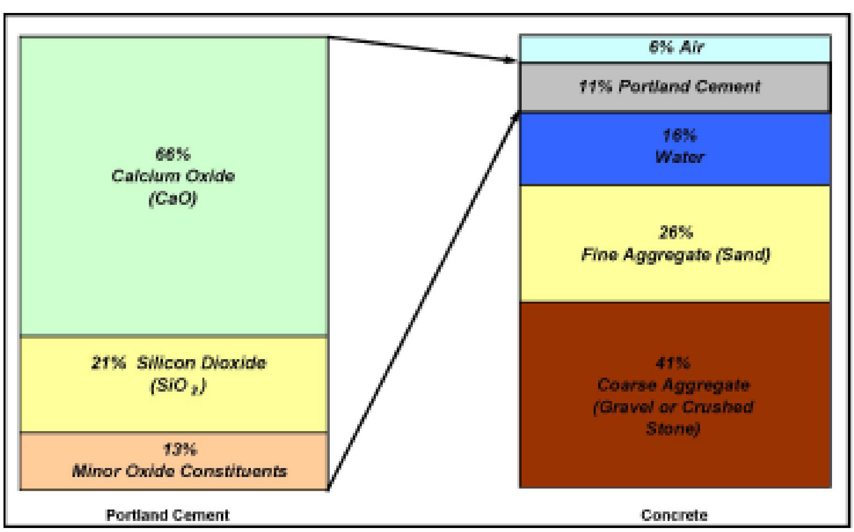


Figure 1. Typical compositions and relationships of Portland Cement (left) and concrete (right).

Geology of the Niobrara Formation

The Niobrara Formation subcrops in the eastern portion of the state beneath a blanket of glacially deposited sediment. The Niobrara subcrops in 14 North Dakota counties, including: Pembina, Walsh, Grand Forks, Steele, Barnes, Ransom, LaMoure, Dickey, Sargent, Ramsey, Benson, and Nelson (Figure 2). The majority of the subcrop is within the eastern one-third of the state with a smaller portion located 40 miles west, of the westernmost extent of the main subcrop in Ramsey County. This subcrop, based on the 1983 interpretation of the bedrock geology of North Dakota completed by Bluemle (1983), extends over an area of approximately 1,629 square miles (4,219 square kilometers). This translates to an area equal to roughly 2.5% of the entire land area of North Dakota (Figure 2).

Figure 2. Distribution of the subcrop (formation exposed directly beneath the glacial cover) of the Niobrara Formation in eastern North Dakota (Modified from Bluemle, 1983).

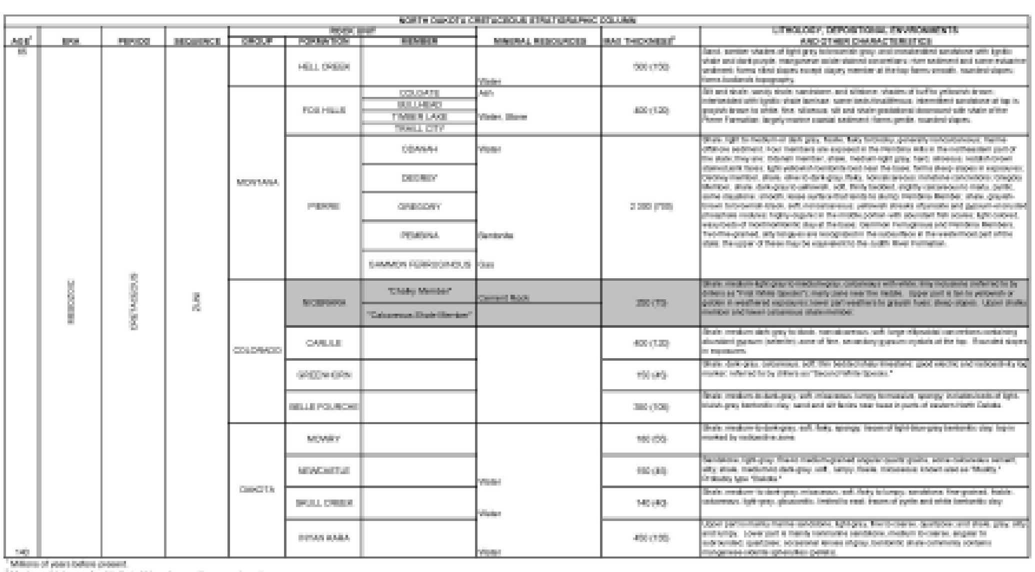
The Niobrara Formation ranges in lithology from limestone to chalk to a slightly calcareous shale of Late Cretaceous age that was deposited in a shallow epicontinental sea during Late Cretaceous time (Shurr and Rice, 1987). The Niobrara outcrops in minor localities in the northeastern part of the state. The Niobrara is underlain by the Carlile Shale of the Colorado Group and, in turn, is overlain by the Pierre Formation of the Montana Group (Figure 3).

The Niobrara Formation was named for outcrops located near the mouth of the Niobrara River in Knox County, Nebraska (Lerud, 1982). The Niobrara Formation in eastern North Dakota was deposited as a relatively shallow-water sediment during a major transgression and regression of the late Cretaceous interior seaway which stretched, at its maximum extent, all the way from the Gulf of Mexico to Hudson Bay (Sieverding and Shurr, 1982). The Niobrara in northeastern North Dakota can be further stratigraphically subdivided into two distinct lithostratigraphic units, referred to as ***members***, an upper chalky member and a lower calcareous shale member (Reiskind, 1986).

Formation A rank of formal lithostratigraphic nomenclature that is the fundamental unit in lithostratigraphic classification**.** It is a body of rock identified by lithic characteristics and stratigraphic position; it is prevailingly but not necessarily tabular and is mappable at the Earth's surface or traceable in the subsurface.

Member A rank of formal lithostratigraphic nomenclature that is below a formation and is always a part of some formation. It is recognized as a named entity within a formation because it possesses characteristics distinguishing it from adjacent parts of the formation.

North American Stratigraphic Code, 1983



NORTH DAKOTA CRETACEOUS STRATIGRAPHIC COLUMN

Group	Formation	Member	Mineral Resources	Max Thickness	Lithology, Depositional Environments and Other Characteristics
	HELL CREEK		Water	500 (150)	[illegible]
MONTANA	FOX HILLS	COLGATE	Ash	400 (120)	[illegible]
		BULLHEAD			
		TIMBER LAKE	Water, Stone		
		TRAILL CITY			
	PIERRE	ODANAH	Water	2 300 (700)	[illegible]
		DEGREY			
		GREGORY			
		PEMBINA	Bentonite		
		GAMMON FERRUGINOUS	Gas		
COLORADO	NIOBRARA	"Chalky Member"	Cement Rock	250 (75)	[illegible]
		"Calcareous Shale Member"			
	CARLILE			400 (120)	[illegible]
	GREENHORN			150 (45)	[illegible]
	BELLE FOURCHE			350 (105)	[illegible]
DAKOTA	MOWRY			180 (55)	[illegible]
	NEWCASTLE		Water	150 (45)	[illegible]
	SKULL CREEK		Water	140 (43)	[illegible]
	INYAN KARA		Water	450 (135)	[illegible]

Age: 65 (top) to 140 (bottom); Era: MESOZOIC; Period: CRETACEOUS; Sequence: ZUNI.

[illegible]

Figure 3. Cretaceous stratigraphic unit nomenclature in North Dakota (modified from Bluemle and others, 1986), and incorporating the stratigraphic members of Reiskind (1986).

Cement Rock Mineral Resource Potential Areas

The fact that the Niobrara Formation in the northeastern part of the state is calcareous (> 50% calcium carbonate) spurred the initial interest in its utilization as a potential cement source rock. In the late 1800's and early 1900's, a natural cement manufacturing plant operated near Concrete, North Dakota (Figure 4). The plant operated for 17 years, from 1892 to 1909, but discontinued operations due to problems with production and marketing (Grand Forks Herald, 1957).

During later investigations conducted in the early 1960's in northeastern North Dakota, several areas were selected as candidate sites, marked for further investigative drilling, based on field evidence gathered from previous field reconnaissance and geologic mapping work. The information from this investigation was summarized in NDGS Report of Investigation No. 41 (RI-41). RI-41 was completed by Survey geologist Clarence (Kelly) Carlson (Carlson, 1964). Carlson identified five areas or "prospects" in his report that were identified and further investigated (Figure 4). Drilling investigations were conducted in the Edinburg area (northeast central Walsh County), the Park River area (east central Walsh County), the Lankin-Fordville area (southeast central Walsh County), the Shawnee-McCanna area (east central Grand Forks County), and the Northwood area (southeastern Grand Forks County). From these investigations, the Shawnee-McCanna area was deemed most favorable at the time, due to its relatively thin overburden, rock quality, and proximity to favorable markets and transportation systems existing at the time.

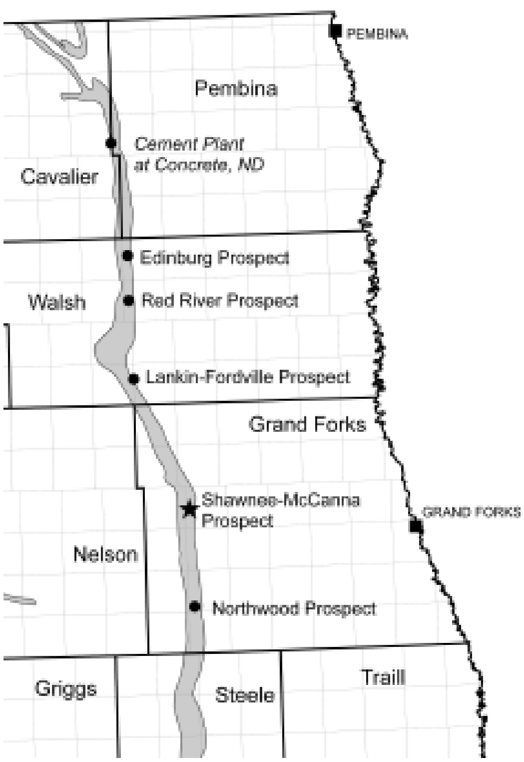


Figure 4. Location of previous areas of interest or "prospects" investigated as a part of cement rock potential studies in the early 1960's by Carlson (1964).

Recent Investigations

A contemporary look at this area was recently completed by the NDGS in 2005. Existing data sources were compiled using contemporary methods. These methods were focused on the stratigraphic distribution of the cement rock minerals in the vicinity of the Shawnee – McCanna. The information is presented in a set of 1:24,000 scale maps, geologic cross-sections, and a core summary. The original prospect boundary was included on the maps in order to enable a comparison of current information with previous data. Geologic contacts of surficial units were compiled and modified from previous small-scale mapping (Anderson, 2005).

The location of drillholes with a set of modified thickness of glacial drift contours are shown on the map, which delineate areas of uniform glacial drift thickness (Figure 5).

Cement rock minerals resources information and relationships of the subcrop of bedrock geologic units in the area were also compiled into a second map. The geologic contacts of middle Cretaceous strata (Pierre, Niobrara, Carlile, and Greenhorn Formations) that subcrop in the map area are shown along with a modified isopach of Carlson's "high lime zone" (Figure 6).

Regional dip on these Cretaceous units is 5° to the west/southwest. The Cretaceous sediments are overlain by a relatively uniform thickness of glacial sediments of subglacial and glaciolacustrine origin that are depicted on the surficial map.

The relationships between contemporary land use, vegetative cover, local hydrology and proximity of existing

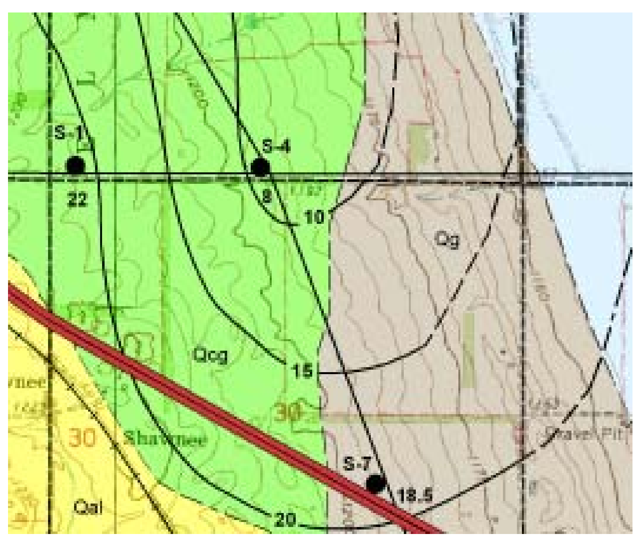


Figure 5. Section of the surficial geologic map of the Shawnee-McCanna area depicting the relationship of surficial geologic units and locations of drillholes along with thickness of glacial drift. A map like this is useful for understanding the relationship between points of drillhole investigation and different geologic materials exposed at the surface in addition to the interpreted thicknesses of glacial sediment cover.

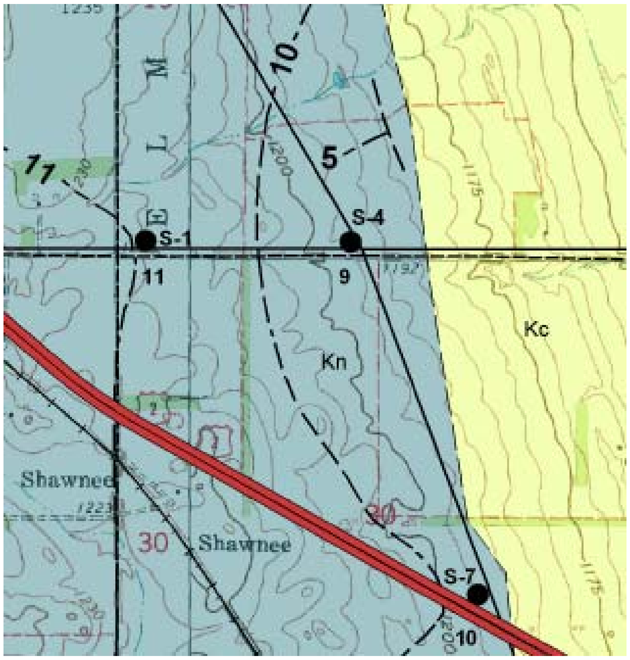


Figure 6. Section of the bedrock geologic map of the Shawnee-McCanna area depicting the relationship of generalized bedrock geologic units present in the subcrop and locations of drillholes along with the thicknesses of the "high lime zone."

Figure 7. Portion of the mineral resource planning map showing the relationships between current land use, local hydrology, and transportation routes with included overburden thickness contours.

major transportation routes were mapped from 1993 Digital Color Orthophotography in the area and depicted on a third map. Overburden thickness contours delineate areas of uniform overburden thickness across the mineable portions of the area. Overburden was defined as the sum of the thickness, in feet, of glacial drift in addition to the drilled thickness of the Cretaceous Niobrara Formation to the top of the "high lime zone" (Figure 7).

Four geologic cross sections were drawn on the surface and near-surface units present. A portion of geologic cross section A-A', drawn from west to east across the northern portion of the study area, depicts the stratigraphic relationships of surficial (undifferentiated glacial deposits) and bedrock geology. Geologic and geochemical information from well control data was incorporated into the sections with a delineation of a "high lime zone" shown (Figure 8).

As a final component of this work, a core summary containing all of the descriptive and analytical data available for the drillholes conducted as a part of the 1964 investigative work, was also completed. New geologic logs were constructed using descriptive stratigraphic information compiled with carbon dioxide and calcium carbonate analysis with depth logs. Cores from the drillholes were photographed and included in each log. Photographs were obtained of relatively high and relatively low calcium carbonate zones and included in each log in order to depict the relationship between the mineralogical characteristics of the core visible macroscopically, with the corresponding value of calcium carbonate content.

Previously completed paleontological descriptions completed by Reiskind (1986) were also compiled into each log in order to enhance paleoecologic and paleogeographic understanding of the geologic setting (Figure 9). Where available, electric logs of the drillholes were included, along with X-Ray Diffraction data for phases of clay minerals present within selected portions of the core.

Potential End Use

Previous work has indicated that the calcareous shales of the Niobrara Formation are of marginal quality, with calcium carbonate concentration values around only 63%. These values are below the 80% concentrations typically required for a sole source cement rock to be used for Portland Cement (Carlson, 1964).

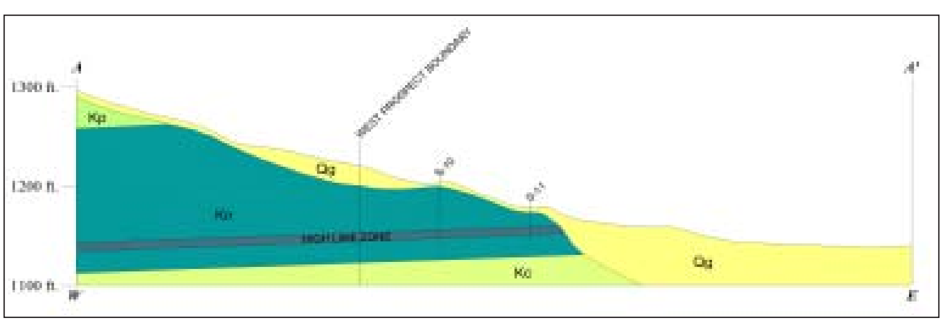


Figure 8. Section of geologic cross section A-A' depicting the vertical and horizontal relationships of Cretaceous age sedimentary strata and glacial sediments present in the surface and subsurface of the Shawnee-McCanna area.

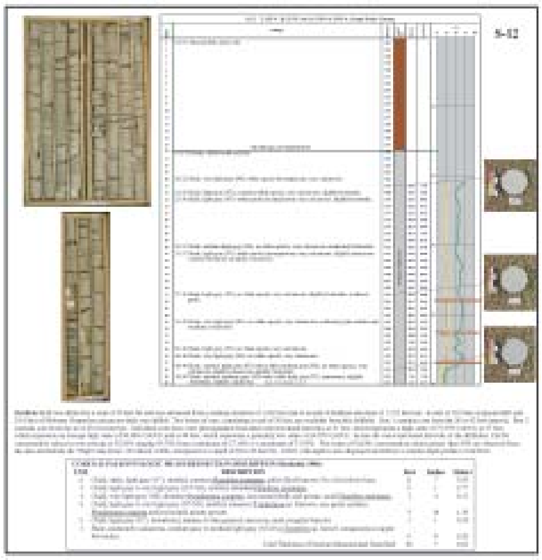


Figure 9. Core summary of drillhole S-12 drilled within the Shawnee-McCanna area.

It is likely, although speculative, that with some additional degree of beneficiation (i.e. limestone addition), portions of the upper-Niobrara Formation in northeastern North Dakota *could* be utilized as a cement rock source. One key to developing the Niobrara shale, as well as other geologic resources throughout the state, will be to develop a multi-resource development approach to candidate areas which, along with other more recent technological advances in mineral processing, may turn previously determined marginal-use areas into developable mineral resources.

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Web Sites of Interest

Cement Rock Mineral Resources of North Dakota
http://www.state.nd.us/ndgs/minerals/nd_cemen_h.htm

Portland Cement Association
http://www.cement.org

Understanding-Cement
http://www.understanding-cement.com/index.html