NORTH DAKOTA CLAYS

A Historical Review of Clay Utilization in North Dakota

by

Edward C. Murphy

MISCELLANEOUS SERIES NO. 79

NORTH DAKOTA GEOLOGICAL SURVEY

John P. Bluemle, State Geologist

1995

NORTH DAKOTA CLAYS A Historical Review of Clay Utilization in North Dakota
Edward C. Murphy North Dakota Geological Survey M.S. 79

1895 - North Dakota Geological Survey's Centennial Year - 1995

The North Dakota Geological Survey was created by an act of the North Dakota Legislature in 1895, six years after statehood. The Geological Survey was directed to make a

> ... *complete account of the mineral kingdom ... including the number, order, dip and magnitude of the several geological strata, their richness in ores, coals, clays, peats, salines and mineral water, marls, cements, building stones and other useful materials, the value of said substances for economic purposes, and their accessibility.*

Such studies continue, but over the years the Geological Survey's mission has grown and is now three-fold: to investigate the geology of North Dakota; to administer regulatory programs and act in an advisory capacity to other state agencies; and to provide public service and information to the people of North Dakota.

The Geological Survey serves as the primary source of geological information in the State. A large amount of geological information can be obtained from NDGS publications; comprehensive collections of cores, samples, and fossils; oil and gas records; coal and subsurface mineral records; and through our affiliate office of the nationwide Earth Science Information Center.

ISSN: 0078-1576

NORTH DAKOTA CLAYS
A Historical Review of Clay Utilization in North Dakota

by

Edward C. Murphy

MISCELLANEOUS SERIES NO. 79

NORTH DAKOTA GEOLOGICAL SURVEY

John P. Bluemle, State Geologist

1995

CONTENT

ILLUSTRATIONS

ABSTRACT

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 in the manufacture of pottery, kitty litter, sewer pipe, lightweight aggregate, soaps, filters, as a source of alumina, and the in the manufacture of natural cement. The clay resources of North Dakota have played an important role in the economic development of North Dakota. The numerous studies of this resource have created a an important data base which will help identify the future usefulness of these deposits as technology changes.

ACKNOWLEDGEMENTS

Clarence Elder and Jim Laske provided a tour of the Hebron Brick Company facility and information on the plant's history and current operation procedures. Oscar Manz provided additional history and insight into the development of clay and claystones in North Dakota. Oscar Manz (Professor Emeritus) and Nels Forsman (Professor of Geology and Geological Engineering), University of North Dakota, Bob Biek (ND Geological Survey) critically reviewed the manuscript. Todd Strand, State Historical Society of North Dakota, graciously provided the historical photographs for the article.

AUTHORS NOTE

In this report, I have referred to the unlithified (soft) Pleistocene and Recent sediments as clays and the lithified bedrock units as claystone.

INTRODUCTION

The clays and claystones present at the surface in North Dakota can be grouped into three general categories: bedrock (which includes Cretaceous through Miocene units), glacial deposits, and alluvium (Recent) (Figure 1). They can also be grouped into several general types in relation to desired properties: swelling, nonswelling, calcareous, bleaching ability, and alumina content. Since three quarters of North Dakota is covered by glacial sediments, glacial clays are the most prevalent in the state. The bedrock claystones however, have proven to be the most versatile for utilization and as a result have been important in the manufacture of products. As with many other products of North Dakota, the successful utilization of North Dakota claystones has been hampered by the lack of sufficient local markets and by transportation costs.

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. In 1892, Earle J. Babcock, Dean of the Chemistry Department and Mining Department at the University of North Dakota and State Geologist from 1895 to 1902, published the first article on the various types of clays and claystones in the state. Later, Babcock and C.H. Clapp did the first comprehensive study of North Dakota claystones, and published the results in 1906 as part of the Geological Survey's Fourth Biennial Report. In this report, Clapp and Babcock (1906a and b) obtained 122 clay samples from throughout the state for physical analysis. The analyses included a determination of plasticity, chemical composition, and the results of test burning of samples. They also determined the influence of natural chemical variations in the claystones on the final fired product.

The "Tertiary" clays of Leonard (1906) and Clapp and Babcock (1906b) are claystones that are now placed in the Golden Valley, Chadron, Brule, or Arikaree Formations (Figure 1). The "high grade white clays" of Leonard (1906) and the "white clays" of Clapp and Babcock (1906b) were

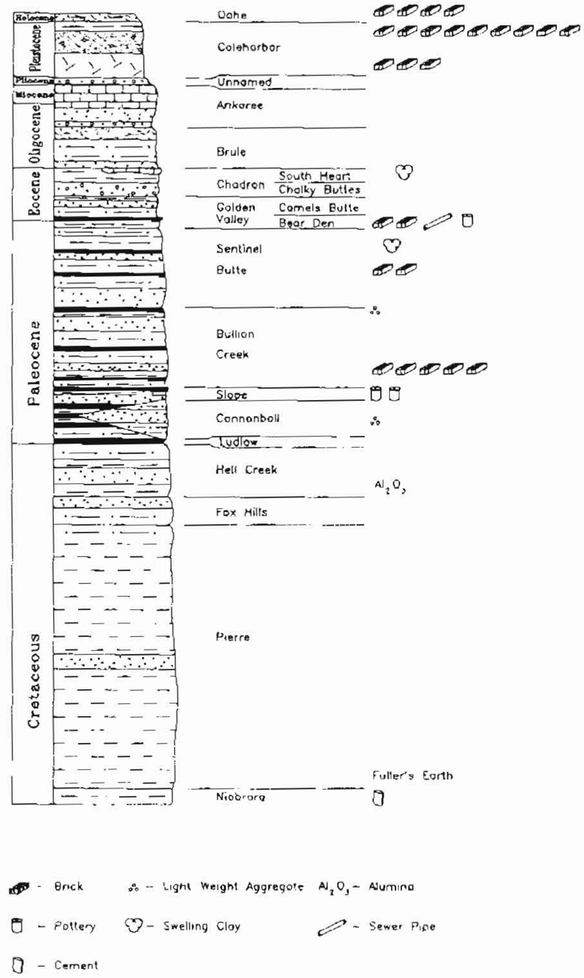

Figure 1. The upper portion of the generalized stratigraphic column of North Dakota. The symbols indicate the general stratigraphic position of clay and claystone utilization in North Dakota.

later recognized to be part of a distinct stratigraphic unit named the Golden Valley Formation by Benson and Laird (1947) and later identified as the Bear Den Member of the Golden Valley Formation by Hickey (1977) (Figures 1-3). Clapp and Babcock (1906b) measured several geologic sections and provided the first detailed map of this unit. They noted that the "white clays" occurred at the same general horizon throughout parts of Stark, Dunn, Mercer, and Hettinger Counties in the western part of the state. In addition to their mapping, Clapp and Babcock analyzed the chemical and physical properties of several samples taken from the Bear Den Member. Leonard placed

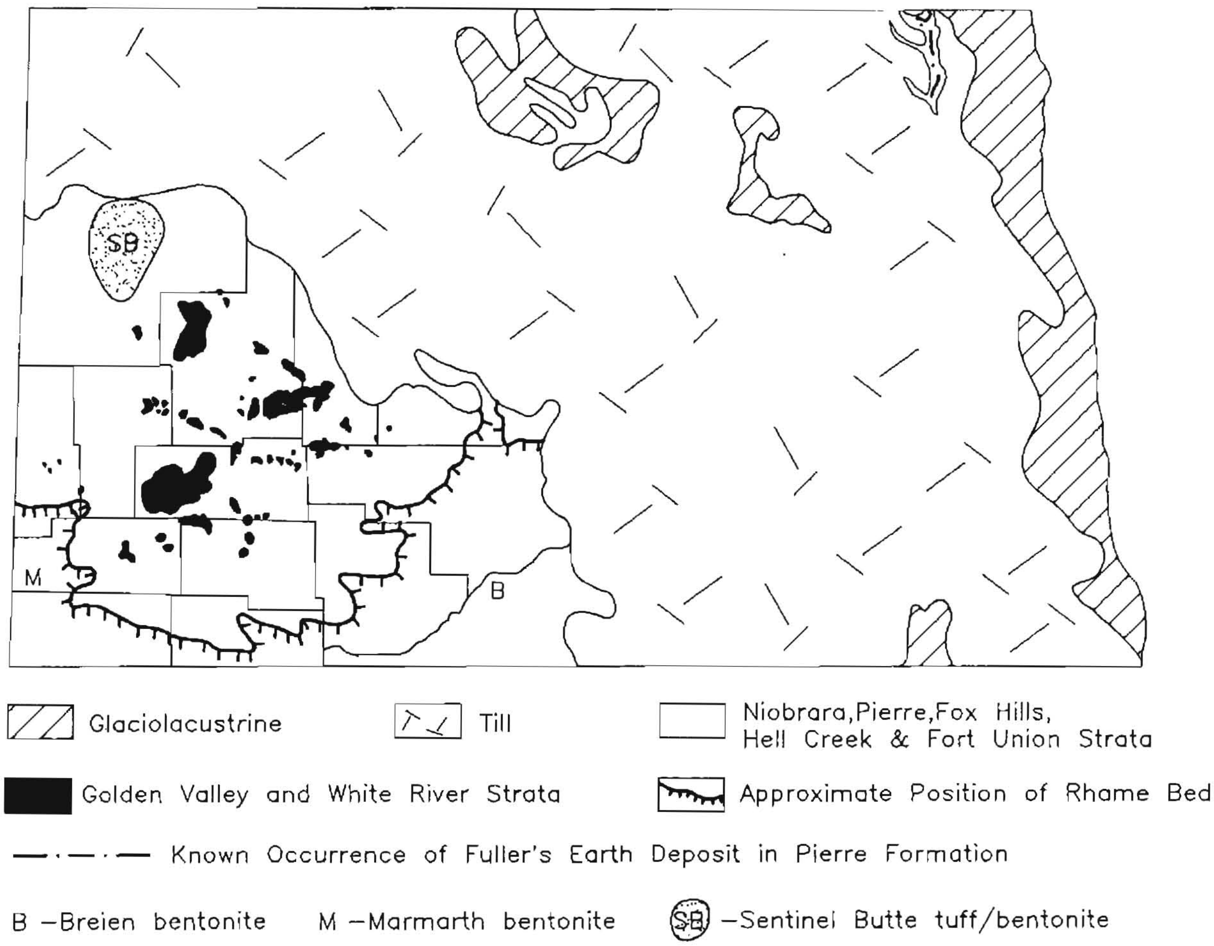

Figure 2. A generalized geologic map of North Dakota (modified from Bluemle, 1977 and Clayton, 1980).

these claystones at the base of the Tertiary, but today we recognize that they are latest Paleocene in age and are overlain by the Eocene Camels Butte Member of the Golden Valley Formation (Figure 1).

Clapp and Babcock (1906b) determined that the North Dakota clays best suited for brickmaking were taken from either the Bear Den Member or glaciolacustrine deposits. They also recognized that the Bear Den claystones could be used in the manufacture of stoneware. Their analysis revealed that an outcrop of the Bear Den Member at Black Butte, Hettinger County, contained a higher percentage of kaolinite than any other sample they tested and was "in a class by itself...which could be worked by almost any process and molded into any desired form"(Clapp and Babcock, 1906b, p. 175). The brick plants at Hebron and Dickinson utilized clays from the Bear Den Member. Babcock and Clapp determined from their tests that the Hell Creek and Fort Union claystones (which they included in the "Laramie") were "not of great economic importance" because the majority of them were too sandy and could not be worked (Clapp and Babcock, 1906b, p. 130).

Babcock established kilns in the School of Mines at the University of North Dakota to test the workability of the clays from the Bear Den Member and to promote use of these clays by demonstrating the quality of earthenware that could be produced from them (Babcock, 1906). Several sets of this earthenware, ranging from cups and

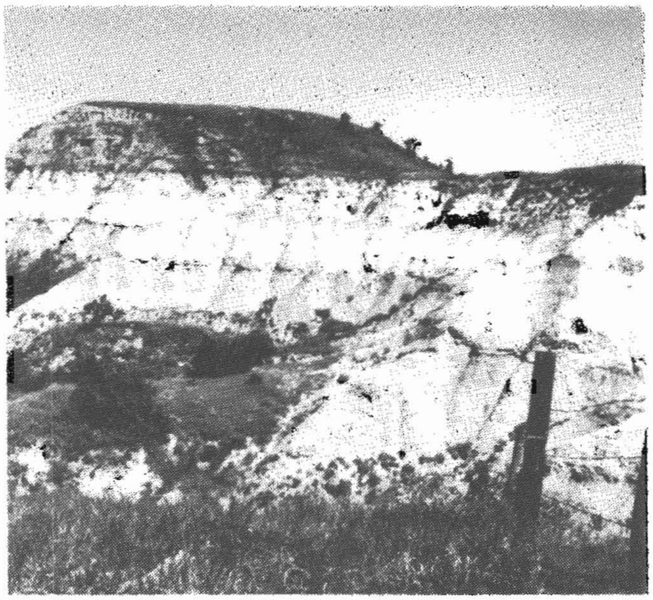

Figure 3. The Bear Den Member of the Golden Valley Formation in west-central Dunn County. The brightly colored Bear Den Member is prominently exposed and is overlain by the Camels Butte Member in the background.

Figure 4. The Rhame Bed at the top of the Slope Formation along the drainage of Deep Creek, Slope County. This "dazzling" white bed forms a prominent marker horizon throughout many areas in western North Dakota.

saucers to tea sets and pitchers, were displayed at the 1904 Worlds Fair in St. Louis. Babcock sent samples of the Bear Den claystone to manufact-urers of earthenware all over the country in an attempt to interest others in these deposits.

In the 1930s, William Budge, a professor of ceramic engineering at the University of North Dakota, authored several reports on the clay deposits of North Dakota (Budge, 1931, 1932, 1935, and 1936). Budge focused his studies on the swelling claystones of western North Dakota. These deposits have historically been referred to as bentonites, but are more correctly termed swelling claystones; the term bentonite is restricted to clays that formed from the alteration of volcanic glass (Forsman, 1984a). Although some beds, such as the "blue bed" in the Sentinel Butte Formation, have been proven to be bentonites, it is best to avoid that term when talking in general about swelling claystones in North Dakota in order to avoid misleading workers who are looking for stratigraphic marker beds (Figure 4). Fremont Clarke (1948) expanded on Budge's work in his study of swelling claystones in the southwestern portion of the state.

In the 1950s and 1960s, Oscar Manz, a professor of engineering at the University of North Dakota and a part-time employee of the Geological Survey, continued Babcock's work and conducted several studies of the properties of North Dakota clay deposits (Manz, 1953, 1954, 1956, 1961, and 1968). Manz determined from the engineering properties and the results of test firing of clay samples that numerous claystones within the Fort Union Group were suited for the manufacture of stoneware, sewer pipe, and other semi-refractory products (Manz, 1953). Manz (1954) tested Fort Union claystones and Lake Agassiz clay to determine their usefulness as lightweight aggregate. Manz (1956) also determined that good common brick, building or drain tiles, and even some good face brick could be manufactured from glaciolacustrine clays in the Red River Valley. Clays from the Bear Den Member were found to meet most of the criteria needed for electrical insulators, with the most suitable deposit occurring near the town of Taylor in Stark County (Manz, 1968). Manz (1971) determined that 860,000 tons of Bear Den claystone were available from two deposits near Taylor, enough to supply an average size insulator plant for 100 years.

Several studies have used x-ray analysis to determine the mineralogy of clay and claystones in North Dakota. Royse (1967), Jacob (1975), and Moran and others (1978) determined that the dominant clay mineral group in the Fort Union is smectite and the dominant clay mineral sodium montmorillonite. Brekke (1979), Groenewold and others (1983), and Forsman (1985) further determined that Fort Union claystones were primarily composed of sodium montmorillonite with secondary mica-illite and iron chlorite with minor amounts of kaolinite. There are two primary exceptions to this rule within the Fort Union--the Rhame Bed at the top of the Slope Formation and the Bear Den Member of the Golden Valley Formation (Figures 3 and 4). Both of these stratigraphic units consist primarily of kaolinite with secondary amounts of montmorillonite and illite (Hickey, 1977; Wehrfritz, 1978; and Prichard, 1980).

Studies of tills in North Dakota routinely include textural analysis, but do not generally determine clay mineralogy. Groenewold and others (1983) analyzed the clay mineralogy of till from five samples at the Center Mine in Oliver County and 29 samples from the Falkirk Mine in McLean County. They determined that these tills were composed primarily of montmorillonite with secondary amounts of mica-illite and chlorite, the same mineralogy as the bedrock claystones.

BRICK MAKING

The primary use of claystones in North Dakota has been for brick making. Bricks were produced as early as 1868 by soldiers who replaced log buildings with brick at Fort Ransom (Figure 5). Bricks were first produced for commercial use in North Dakota at Fargo in the 1870s. Brick making quickly spread through the Red River Valley and by 1885 plants were operating at Minto,

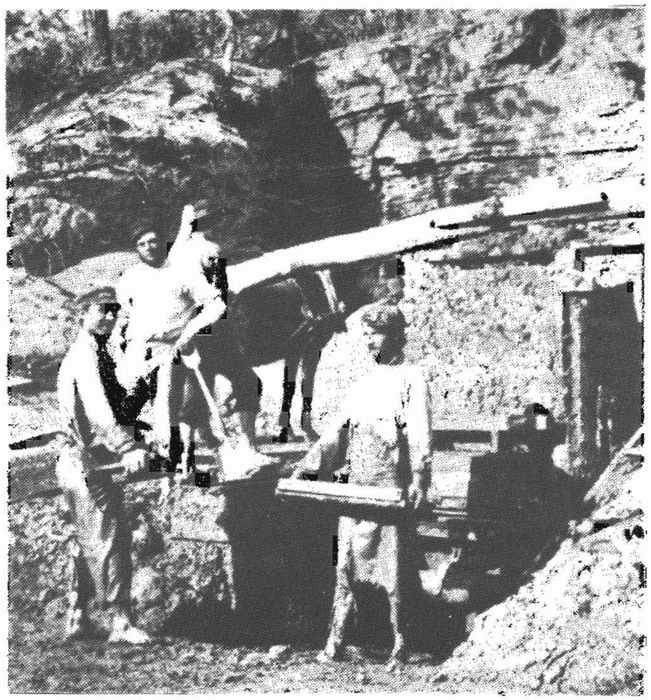

Figure 5. Soldiers making pressed brick at Fort Totten circa 1870. Photo by S.J. Morrow courtesy of the State Historical Society of North Dakota.

Walhalla, Grafton, and four plants in Grand Forks (Figure 6). Grand Forks, with its four plants, was the center of brick making in North Dakota during these early years (Bluemle, 1987). By 1906, 26 sites operated in North Dakota mining claystone, primarily for the manufacture of brick for local construction (Babcock, 1906). Most of the plants produced common brick, but pressed brick, facing brick, and fire brick were also produced at a few sites. Throughout North Dakota, bricks were made from clays of different geologic origins. One brick plant at Mayo used Cretaceous shales while brick plants at Kenmare, Donnybrook, Burlington, Velva, New Salem, Hebron, Dickinson, and Wilton used claystones from the Fort Union Group (Figures 6-8). Brick plants at Bismarck, Rolla, and Richardton produced bricks from till whereas glacial Lake Agassiz clay was used at four plants at Grand Forks, two at Fargo, and one each at Drayton and Abercrombie. Another plant at Omemee used glaciolacustrine clay from Lake Souris. Plants at Mandan, Williston, Minot, and

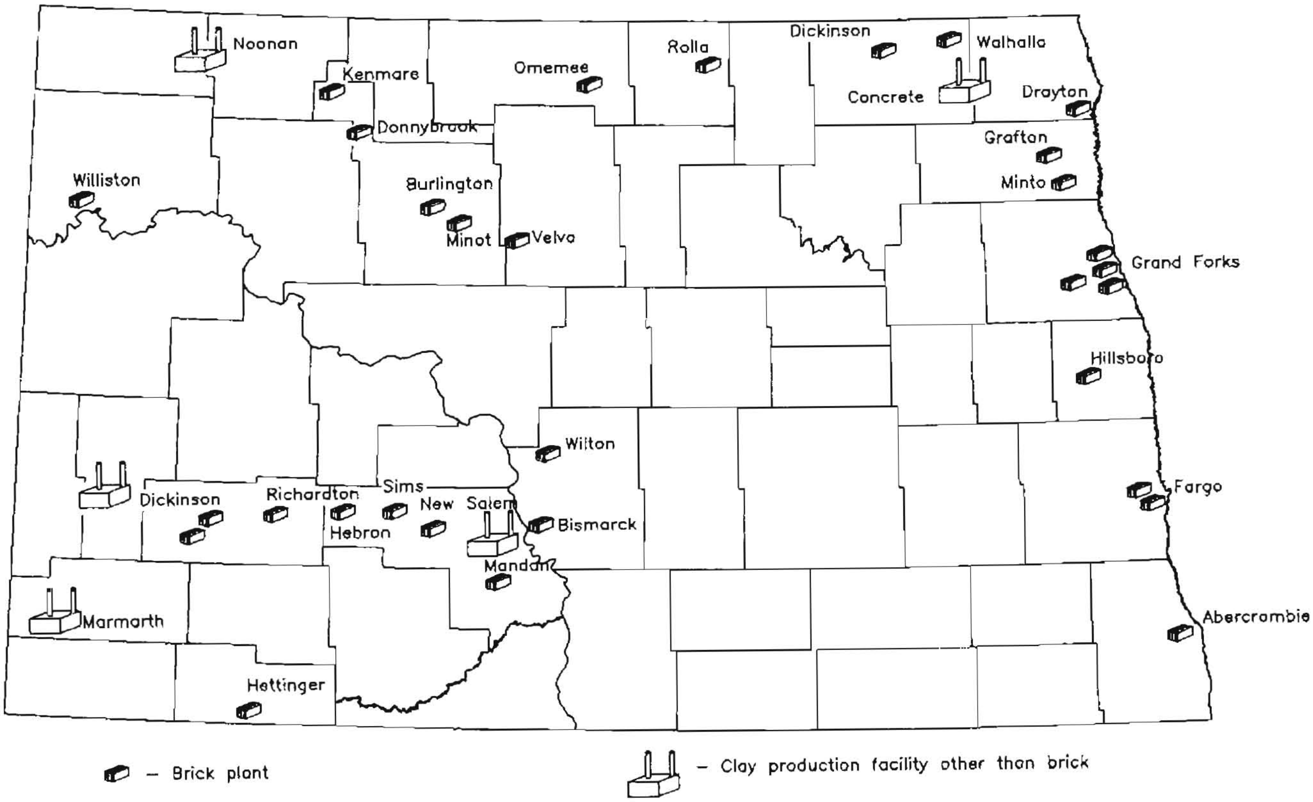

Figure 6. The locations of clay production facilities that have operated in North Dakota. Most of the commercial brick-making facilities shown operated in North Dakota during the late 1800s and/or early 1900s.

Hillsboro used alluvial clays to make bricks (Clapp and Babcock, 1906b). The State Brick Yard plant operated near the State Penitentiary at Bismarck and used convicts as laborers (Leonard, 1912).

Most of these operations obtained clay or claystone from shallow pits at or near the brick plants. Several brick plants in western North Dakota were situated adjacent to coal mines and used the claystone overburden or underburden as raw material for the bricks and burned the coal to fuel the kilns. For example, at the Washburn Company's Wilton Mine, the claystone beneath the coal was used to manufacture the brick (Babcock, 1906). Clapp (1906) noted that many of these plants had been established with no prior prospecting of the clay deposits and some were using clay that was inferior to other deposits in that area.

The output of bricks gradually increased from 1895 to 1904. In 1902, North Dakota produced approximately 21 million bricks worth $157,000. By 1905, approximately 26.5 million bricks were produced, 24 million of which were common bricks, with an estimated value of $215,000. In 1914, the estimated value of bricks produced in North Dakota increased to $260,000. These were the glory days of brick making in the state; by 1951 the volume had decreased and the net value of the product was only $40,000 (Hainer, 1956). The Dickinson plant ceased operation in the late 1930s. By the early 1950s, the Hebron Brick Company and a plant at Hettinger were the only two brick plants still in operation (Manz 1954). Of the two dozen plants operating within North Dakota in 1906, only the Hebron Brick Company has survived to the present time.

Several more recent attempts have been made to establish additional ceramic production in North Dakota. In the 1960s, the Dickinson Clay

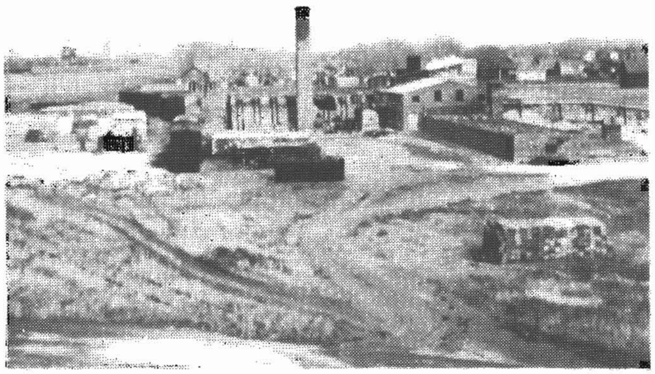

Figure 7. The Dickinson Fire and Pressed Brick Company. Photo by Presthus Studio in Dickinson circa early 1900s courtesy of the State Historical Society of North Dakota.

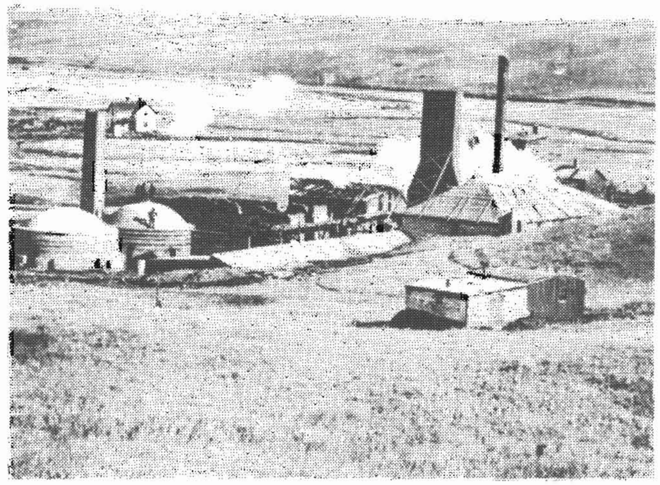

Figure 8. The Kenmare Hard Coal and Brick Company Plant. Photo by E.H. Gross circa early 1900s courtesy of the State Historical Society of North Dakota.

Products Company began producing ceramic sewer pipe and tiles, but closed due to competition from plastic sewer pipe products (Dickinson Centennial Comm., 1982). In the summer of 1960, clay near Williston was analyzed and compared to the clays used by the Hebron Brick Company to determine the feasibility of establishing a brick plant in that city (Manz, 1961). The plant was never built. In 1991, the Economic Development Commission held a meeting in Fargo to determine the feasibility of establishing a commercial facility to manufacture ceramic tile in North Dakota. The consensus of the meeting was that production of ceramic tile in North Dakota was not economically feasible at that time (Govig, 1991).

Hebron Brick Plant

The brick plant at Hebron was established in 1904 by the Hebron Pressed and Fire Brick Company. In 1923, the company was renamed the Hebron Brick Company (Hebron Centennial Corp., 1984). The plant is unique in that it was located adjacent to the railroad for transportation purposes and is some distance from its clay source (Figure 9). In contrast, most brick plants were built directly on their clay sources. Ironically, over 90% of Hebron brick is now transported to market by semi-trailer. In 1906, a steam tram was built to haul the clay from pits 5 miles north of the plant site. This had previously been done by wagon. The company no longer uses the tram and instead transports the sand and clay to the plant site by truck. In 1926 a fire in the grinding room destroyed a major portion of the plant. The devastating effects of the fire are still visible in the twisted steel beams and smoke-stained walls of that building.

The plant uses four primary ingredients in its manufacture of brick: white plastic claystone, gray plastic claystone, sandstone, and reground or recycled brick. Both the white and gray claystones are obtained from the Bear Den Member of the Golden Valley Formation. The sandstone is mined from the same pits as the claystones and is obtained from either the Camels Butte Member of the Golden Valley Formation or the Sentinel Butte Formation. The Hebron Brick Company has mined claystone from at least three separate pits located approximately five miles north of the plant. From 1906 to 1939, the company also mined coal from this area to fuel the plant (Hebron Centennial Corp., 1984). Early underground mining of both the coal and claystone was eventually replaced by surface mining. Small amounts of clay from out of state are currently being mixed with North Dakota clays to obtain special colors.

The brick making process at the Hebron Brick Company can be divided into the following steps: 1) mining of the sandstone and claystone, 2) grinding and sizing of the sandstone, claystone, and reject bricks or "seconds" called grog, 3) wetting and proper mixing of the four primary ingredients, 4) molding and cutting of the sand/clay mixture, 5) drying and firing of the brick, and 6) loading and transportation of the brick to market. The plant has undergone several changes since it first began production 90 years ago; however, the first two processes have changed little over the years. The ingredients are transported from the grinding room by a series of conveyor belts and stored in four metal hoppers. The materials are then released in the appropriate amounts from the hoppers and run through a series of augers that mix the materials while binding agents are added. The plant originally produced brick by the dry-pressed method, which required less mechanization, but was labor intensive. About 1913, the plant switched over to an extrusive method which forces the moistened sand and clay mixture into a long slug (Johnston, 1992). Textures and finishes are added to the slug just before it is cut into 16 individual bricks by a machine that passes wire through the clay.

The bricks are automatically stacked on carts (3,000 bricks to a cart) and rolled on rails though the rest of the plant. The carts are first rolled into an open room where the bricks slowly dry for 24 hours. From there the bricks are rolled into the drying room for 48 to 72 hours, and finally into a tunnel kiln where they are rolled past a series of gas-fired furnaces. Every hour a cart is advanced from the drying room into the 317-foot-long kiln. The tunnel kiln was constructed in 1960. Prior to that time, the bricks were baked in periodic kilns. The cars remain in the kiln for 24 hours during which time they are slowly advanced through a series of gas-fired furnaces that reach a

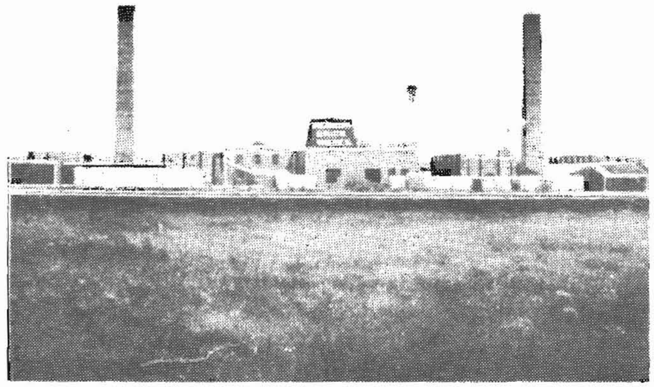

Figure 9. The Hebron Brick plant circa early 1900s. Photo courtesy of the State Historical Society of North Dakota.

maximum temperature of over 2,000 degrees Fahrenheit. The bricks exit the kiln at a temperature of approximately 800 degrees. The proper firing of the brick is critical in obtaining the desired strength and to prevent cracking. This requires that the brick be slowly brought to the desired maximum temperature and slowly brought back down. The temperature in the kiln is carefully monitored and regulated by a recently installed computer system. The kilns are currently heated by natural gas, but in the past a variety of fuel sources were used including coal, gas produced from the coal, and fuel oil.

In 1952, the plant used 20,000 tons of claystone to produce almost 10 million bricks and tiles (Manz, 1954). In the 1960s, the plant had an average annual production of 12 million bricks utilizing 36,000 tons of claystone a year (Manz, 1973). At present, the plant mines 40,000 tons of claystone a year and produces approximately 20 million bricks (approximately 80% of the state's annual production in 1905). The Hebron Brick Company presently manufactures only brick because of the large drying space required for tile production. The largest single order for Hebron bricks was for the exterior of the Fargodome, which required 1 million bricks representing approximately two weeks of production for the plant.

The Hebron Brick Company employs 55 workers and is a small to moderate size operation in comparison to other facilities across the country. It is one of only two brick plants in the four-state region of Montana, North and South Dakota, and Minnesota; the other is located in Springfield, Minnesota. The Hebron Brick Company sells approximately 80% of its brick out of state (Johnston, 1992). Their primary market includes North and South Dakota, Montana, Wyoming, Minnesota, Wisconsin, and Canada, but the plant has shipped bricks to both coasts. The Hebron Brick Company has managed to stay in business and thrive by making its size an asset rather than a detriment. As a smaller plant they can profitably handle smaller specialized jobs. They specialize in matching brick for existing buildings because often the original brick manufacturer is no longer in business. It is easier for the Hebron Brick Company, with its older equipment, to match the old brick.

POTTERY

The ceramics department in the School of Mines at the University of North Dakota produced ceramic products from North Dakota clays and claystones from 1904 through the 1940s, some of which were sold to the public. In a late-1940s brochure on the department, Associate Professor of Ceramics Margaret Cable stated that "two very plastic fine-grained clays from Morton and Mercer Counties are mixed that the ware may be easily shaped; a sandy open-grained clay from Adams County gives porosity so the ware will dry without cracking; a red iron-stained clay of low fusion from Mountrail County gives added hardness, densification, and ring to the fired ware; while a clay found in Stark County is used as a glaze ingredient". Claystone from the Rhame Bed (Slope Formation) was used in making pottery at the University of North Dakota during the late 1920s and early 1930s and may be the source for the Adams County clays noted by Cable in her brochure (Budge, 1932). The Dickinson Clay Products Company produced souvenir pottery, such as ash trays, under the names "Dickota", "Dickinson Clay Products", and "Badlands Pottery" from 1935 to 1937 (Dickinson Centennial Comm., 1982). Ceramic production occurred at the Wahpeton Pottery Company under the name "Rosemeade" using Slope Formation claystones from west of Mandan during the 1940s, but the company went out of business in the 1960s.

LIGHTWEIGHT AGGREGATE

Changes in building height and design and the use of structural steel necessitated the development of lightweight concrete that had sufficient strength, but would not add inordinately to the weight of the structure. Concrete made with lightweight aggregate has a unit weight 40 to 70% less than concrete made from sand and gravel (Hainer, 1956). At least three lightweight aggregate plants have operated in North Dakota. These plants formed the lightweight aggregate by expanding or bloating claystone or mudstone in a rotary kiln under high temperatures. In 1953, Molite Incorporated began producing lightweight aggregate from mudstones in the Cannonball Formation at Mandan. From 1954 to 1971, the Noonlite plant operated near Noonan utilizing claystone above the Noonan coal bed. A third plant began operating near Dickinson in 1968 (Manz, 1973). Manz (1954) determined that Cannonball mudstone samples taken from Molite Incorporated's pit were less suitable than other Fort Union Group claystones he sampled. Manz's study determined glaciolacustrine clays to be the most suitable clays for production of lightweight aggregate.

In recent years, state agencies in Minnesota have been studying several bloating clay deposits as potential lightweight aggregate (Hauck et al., 1990; Oreskovich and Hauck, 1993; Oreskovich and Toth, 1993). The Minnesota Natural Resources Research Institute determined that glaciolacustrine clays within the Sherack and Brenna Formations (Pleistocene) near Hallock, Minnesota were suitable as lightweight aggregate and for insulating concrete. The Sherack Formation is present within 10 feet of the surface

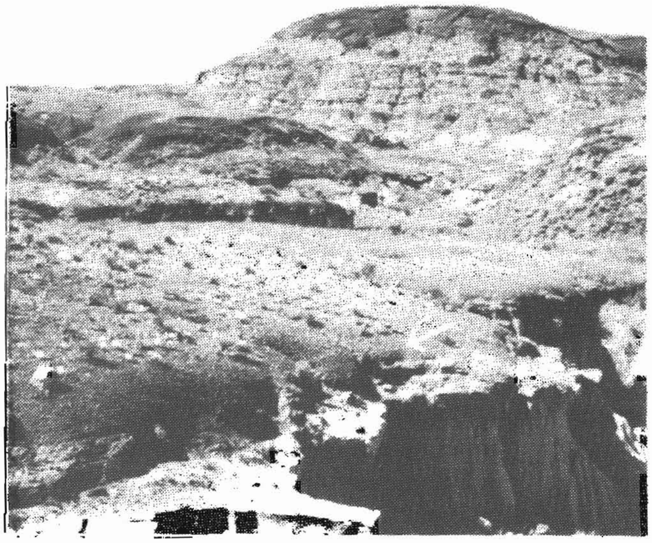

Figure 10. A swelling claystone (arrow) at the base of the Hell Creek Formation at the Crowghost Cemetery, Sioux County.

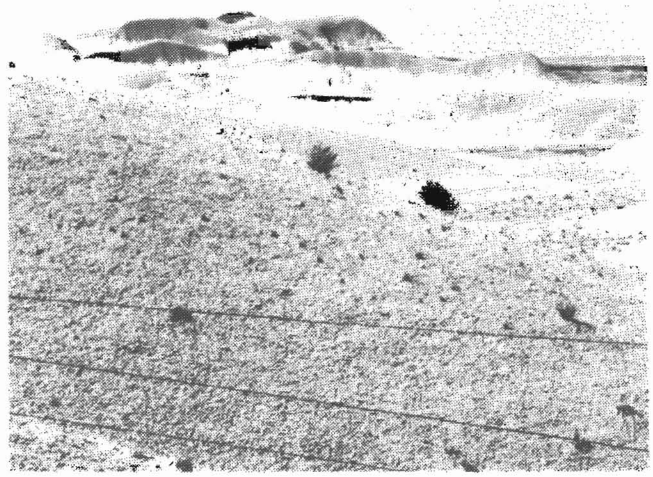

Figure 11. Swelling claystone in the South Heart Member, Little Badlands, Stark County.

throughout the Red River Valley and the Brenna Formation is present throughout the northern half of the Red River Valley in North Dakota, generally at depths of 10-30 feet (Arndt, 1977). The information obtained by the Minnesota NRRI from the testing of Glacial Lake Agassiz clays is valuable in assessing these geologic units on the North Dakota side of the Red River Valley.

In addition to its use in tall buildings, lightweight aggregate has also been used to increase the insulation value of concrete and in asphalt overlays to improve traction and reduce breakage of headlights and windows from rock thrown by passing vehicles. Lightweight aggregate has also been used as a decorative landscaping material, as a geotechnical bedding for sewer and water lines, and in concrete roofing tiles (Oreskovich and Toth, 1993).

SWELLING CLAYSTONES

Swelling claystones occur throughout the Hell Creek, Fort Union, and White River strata (Figure 10). A large deposit of swelling claystones within the White River Group (South Heart Member of the Chadron Formation) in the Little Badlands, Stark County was mapped as alkali bentonites by Budge (1931) and Hammers and Budge (1931) (Figure 11). In 1930, the Dakota Colloidal Products Company began mining a Sentinel Butte Formation claystone 7 miles north of Fryburg. The claystone was transported to facilities in Belfield and dried, pulverized, and bagged (Budge, 1932). The company was not able to find a market for the prepared swelling claystone, but secured an arrangement with the National Soap and Chemical Company in Minneapolis to prepare soaps and cleansers using the claystone in each of these products (Budge, no date). The Dakota Colloidal Products Company marketed Dakonite soap and switched to mining the South Heart Member of the Chadron Formation in the Little Badlands area when the company determined it was superior to the Sentinel Butte claystone they had previously been mining (Budge, 1935). Poor management resulted in foreclosure and a buyout of the plant by the Mineral Products Corporation. After a short period of operation, the plant was destroyed by fire and not rebuilt (Clarke, 1948).

Figure 12. The Marmarth bentonite a few miles north of Marmarth, Slope County. Two bentonites are separated by 5 to 16 feet of grey to white tuff.

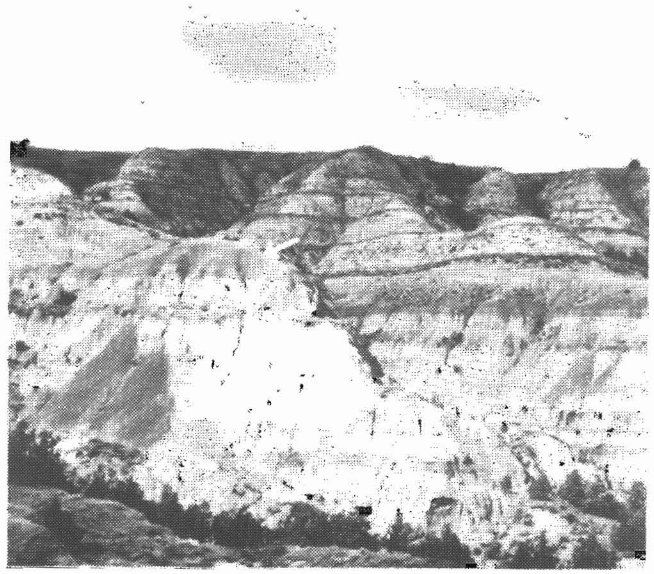

Figure 13. Outcrop of the Sentinel Butte Formation containing the Sentinel Butte tuff/bentonite ("blue bed") (arrow) in the North Unit of the Theodore Roosevelt National Park.

The early uses of North Dakota swelling claystones were as bases in cleansers and soaps and in reclaiming fouled motor oils (Budge, 1932). Clarke (1948) determined that these claystones were not equal to Wyoming and South Dakota bentonites in forming gels and were therefore inferior as drilling mud additives. He did determine that they were just as good as these other bentonites for use in acid-activated bleaching clay, as binders of foundry sands, and as fillers and possibly as detergents.

In 1971, Dakota Industries, Inc. established a plant at Belfield and began producing kitty litter and floor adsorption material from a mixture of local swelling claystones and volcanic ash from Linton. The plant made use of the rotary kilns that had previously been used in this area by Union Carbide to reduce uraniferous lignite to ash. Initial testing indicated that the claystones were equal or superior to the three leading brands of absorbent clays being used in the U.S. at that time. Unfortunately, the plant had some operating problems and also had trouble competing with some of the larger manufacturers of these products and ceased operations after only a couple of years (O.E. Manz, personal communication, 1994).

Bentonites in North Dakota

Geologists familiar with upper Cretaceous and Fort Union strata in North Dakota generally believe that many of the swelling claystones in these units are bentonites (ie., derived from the alteration of volcanic ash). Actually, only a few claystones in the state have been scientifically demonstrated to be true bentonites. These are associated with the following tuffs; the Marmarth tuff, the Breien tuff, and the Sentinel Butte Formation tuff (the blue bed).

Bentonite near Marmarth was first reported by Frye (1967) to occur in the lower portion of the Ludlow Formation (Frye used the term Tullock) approximately 4 miles northeast of Marmarth in T.133N., R.105W., secs. 4 and 5, Slope County (Figure 12). Subsequent workers have placed this bed in the Hell Creek Formation, approximately 14 feet below the Hell Creek/Ludlow contact

(Forsman, 1984b, 1985; Murphy and others, 1991). The Marmarth bentonite is actually two bentonites separated by 5 to 16 feet of tuff. The upper and lower bentonites are approximately 2 and 6 feet thick, respectively. An evaluation of outcrops in this area indicates that the Marmarth bentonite is restricted to the northeast quarter of section 5 and the south half of section 4. Frye (1967) traced the bentonite into sections 3 and 9 in this same township indicating that it may have an areal extent of up to 5 square miles.

Bentonite near Breien was also discovered by Frye (1967) and reported by him to occur in the upper part of the Fox Hills Formation approximately two miles east of the town of Breien in T.134N., R.81W., sec. 31, Sioux County. The presence of sequoia stumps in the middle of an associated tuff indicates this bed likely occurs at or near the base of the Hell Creek Formation. In addition, dinosaur bones are present approximately 5 feet above the bentonite. The Breien deposit consists of 2-3 feet of bentonite underlain by white tuff. The bed has been traced from the northwest quarter of section 31 into the northwest quarter of section 36 in the adjoining township. This bentonite may extend into the Crow Ghost Cemetery in section 33 where a similar swelling claystone occurs at the base of the Hell Creek Formation. The claystone in section 33 also contains sequoia stumps.

A prominent bench-forming claystone near the middle of the Sentinel Butte Formation in the North Unit of the Theodore Roosevelt National Park has long been referred to by geologists working in this area as the blue bed (Figure 13). Forsman (1984b, 1985) suggested the name Sentinel Butte Formation tuff/bentonite be substituted for the name blue bed due to the confusion that was resulting from the presence of many gray-blue claystones in the Sentinel Butte Formation. Although geologists had long suspected that this bed was a bentonite, Forsman and Karner (1975) were the first to scientifically confirm this. The Sentinel Butte Formation tuff/bentonite is up to 23 feet thick and consists of a lower layer of bentonite up to 12 feet thick and an upper bentonite up to 7 feet thick, separated by tuff. Forsman (1992) expanded the known extent of this bed to an area encompassing approximately 600 square miles from the North Unit of the park to northern McKenzie County. The Sentinel Butte Formation bentonite is the most extensive deposit known.

FULLER'S EARTH DEPOSIT

In 1936, a "fuller's earth" deposit was identified in eastern Cavalier and western Pembina Counties. The term fuller's earth originated from the material's historic use in the cleansing and fulling of wool by the removal of lanolin and dirt (Murray, 1983). Fuller's earth is defined as a fine earthy material containing predominantly montmorillonite that has the ability to bleach or absorb coloring matter from oils and fats. The northeastern North Dakota deposit consists of a 4- to 8-foot bed of interbedded yellow and gray claystones located at the base of the Pierre Formation in this area (Figures 2 and 14). The yellow, bleaching clay is present in thin layers, which are interbedded with thin layers of gray, nonbleaching claystone. The School of Mines at the University of North Dakota widely publicized the presence of this deposit which caught the interest of the Filtrol Corporation of Los Angeles. In the late 1930s, following a field investigation of the area, the Filtrol Corporation obtained leases on two areas near the towns of Walhalla and Concrete. However, no development took place because the company could not determine how to economically concentrate the thin beds of yellow claystone (Cooley and Manz, 1972). In the 1940s, Pembina Mountain Clays Ltd. began mining from a similar bed approximately 30 miles to the north near Morden, Manitoba, Canada. The clay is sold under various trade names and is used for bleaching mineral oils and waxes, re-refining used lubrication oils, and for decoloring animal fats and tallows.

In the 1950s, the Great Northern Railway Company began a detailed investigation of this clay deposit (Reed, 1958). The investigation took place along a 50-mile front of the Pierre Formation outcrop and subcrop in Cavalier and Pembina

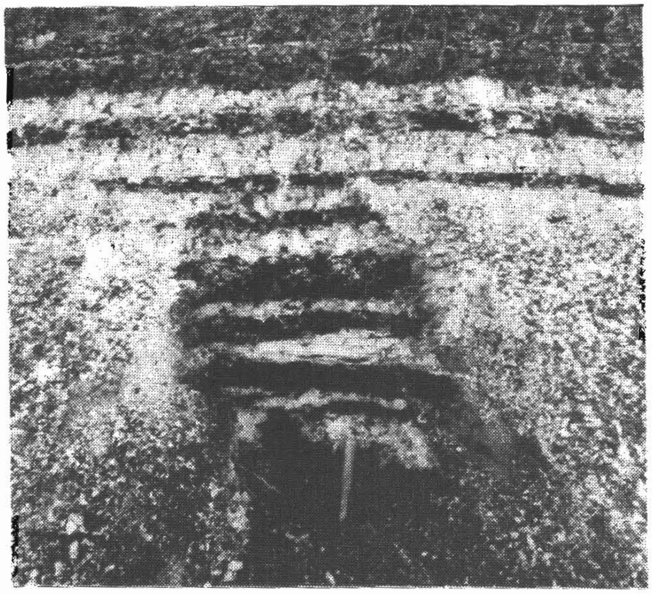

Figure 14. A fuller's earth deposit near the base of the Pierre Formation in the Pembina River Valley, Cavalier County.

Counties. Three small areas along this front were determined to contain 1,350,000 tons of fuller's earth under less than 65 feet of overburden (Great Northern, 1958). In 1978, Oscar Manz and the North Dakota Geological Survey drilled several holes to determine the amount of overburden covering the deposit in this area. Samples obtained from the drill holes indicated that the claystone was a sodium montmorillonite with a bleaching value of 35 to 40%. A calcium montmorillonite with a bleaching value of 100% was desired by industry so the deposit has gone undeveloped.

Although this deposit has historically been referred to as a fuller's earth deposit, it may be more accurate to refer to it as a nonswelling bentonite. Laboratory tests have determined that it does not readily swell. The stratified nature of the marine beds and the sharp overlying and underlying contacts suggests these light colored layers may have formed from the alteration of volcanic ash.

SOURCES OF ALUMINA

Both swelling and nonswelling North Dakota claystones have been investigated as potential sources of alumina. Interest in alumina during the Second World War prompted the Minerals Development Corporation to build an experimental plant at Marmarth in 1942 to produce alumina from swelling claystones. The experimental process was developed by chemistry and chemical engineering professors Ernest Coon and Abraham Max at the University of North Dakota. After several months of low alumina production, the plant was dismantled (Clarke, 1948). The interest in potential alumina sources also led to study of clay deposits in the Little Badlands, Chalky Buttes, and the Marmarth and Belfield areas (Clarke, 1948). These investigations determined that approximately 38 million tons of swelling claystone, with an average alumina content of 14% (South Heart Member), were present under less than 20 feet of overburden in the Little Badlands. Clarke (1958) determined that these claystones were generally too low in alumina to be considered as a favorable source for this metal.

Hansen (1959) investigated Cretaceous and Tertiary claystones in western North Dakota looking for a deposit of at least 50 million tons of clay with an alumina content of 20% or greater. Kaolinitic claystones in the Bear Den Member of the Golden Valley Formation were the only clays with an alumina content that exceeded 20 percent. Hansen did not investigate the Rhame Bed, which marks the top of the Slope Formation, but it is presumed that he would have found alumina values equal to the Bear Den Member due to the presumed similarities in their mineralogy. Hansen (1959) was unable to find a shallow deposit of claystone that would fit the needed criteria.

A chemical investigation of some North Dakota claystones by Stewart and Karner (1969) concluded that the alumina content of kaolinites had been under-reported by previous workers due to an average concentration of 25% quartz grains in each sample. Stewart and Karner determined that the alumina content of the clay samples rose to 30-40%

Figure 15. The Pembina Portland Cement Company plant at Concrete, North Dakota. Photo circa 1902-1909 courtesy of the State Historical Society of North Dakota (l). Recent photo of the abandoned site (r). The base of the kilns, building foundations, and scattered equipment are the only remains of the plant.

when the quartz was removed by grinding and settling.

CEMENT ROCK

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 15). 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....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. In 1909, it 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 upper Niobrara Formation is present in scattered outcrops along the valley of the Tongue River in the vicinity of the cement plant. 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 the 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.

The Geological Survey undertook several studies of the feasibility of cement production in both eastern and western North Dakota during the early 1900s and again in the 1940s, and 1950s (Babcock, 1901; Barry and Melstad, 1908; Powers, 1946; Hansen, 1953). 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 detected 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" offered the most suitable raw material for cement manufacturing. 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. A study was also undertaken by the North Dakota Geological Survey to determine the feasibility of mining Paleozoic carbonates in the Red River Valley of eastern North Dakota for the production of cement (Anderson and Haraldson, 1968). At least one cement company, Lehigh Portland Cement, evaluated the cement rock potential of northeastern North Dakota in the late 1950s-early 1960s but did not pursue it further (Carlson, 1964).

SUMMARY

The heyday of clay and claystone production in North Dakota occurred in the early part of this century when numerous brick plants dotted the state. Other than the short-lived plants at Belfield and Marmarth, no widespread use of swelling claystones has taken place in North Dakota. At the present time, the only major user of claystone in manufacturing within North Dakota is the Hebron Brick Company.

In recent years, the state of Minnesota has been actively pursuing study of its clay resources and potential markets for this resource. Many of the Minnesota studies have focused on lightweight aggregate as there is no production facility in the Upper Midwest (Mueller, 1993). Much of the information that has been gathered in Minnesota is applicable to eastern North Dakota. Studies and analysis of North Dakota clays and claystones should continue because as technologies change, new uses of these raw materials emerge. Through the diligent efforts of Earle Babcock, Charles Clapp, William Budge, and Oscar Manz, clays and claystones in North Dakota have been identified, chemically analyzed, and mechanically tested for their usefulness in many manufactured products. This valuable work has laid a strong foundation for any future studies of North Dakota clays and claystones.

REFERENCES

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

Arndt, B.M., 1977, Stratigraphy of offshore sediment Lake Agassiz--North Dakota, North Dakota Geological Survey Report of Investigation No. 60, 58 p.

Babcock, E.J., 1892, Clays of economic value in North Dakota, Department of Chemistry and Geology, State University, Grand Forks, North Dakota, 35 p.

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

Babcock, E.J., 1906, The uses and value of North Dakota clays, in the Fourth Biennial Report of the North Dakota Geological Survey, p. 191-244.

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

Benson, W.E. and Laird, W.M., 1947, Golden Valley Formation of North Dakota, abstract, Geological Society of America, Bulletin, Vol. 60, p. 1873-1874.

Bluemle, 1977, Surface geology of North Dakota, North Dakota Geological Survey Miscellaneous Map 18.

Bluemle, J.P., 1987, Brickmaking in Grand Forks, North Dakota Geological Survey Newsletter, December, p. 31-33.

Brekke, D.W., 1979, Mineralogy and chemistry of clay-rich sediments in the contact zone of the Bullion Creek and Sentinel Butte Formations (Paleocene), Billings County, North Dakota, unpublished Master's Thesis, University of North Dakota, 94 p.

Budge, W.E., 1931, Report of survey of clay deposits along main line of the Northern Pacific Railway, University of North Dakota College of Engineering Division of Mines and Mining Experiments, 17 p.

Budge, W.E., 1932, Report of surface of Tertiary clays in southwestern North Dakota, University of North Dakota College of Engineering Division of Mines and Mining Experiments, p. 21-38.

Budge, W.E., 1935, Report of bentonite survey, under Federal Emergency Relief Administration Project S-F2-48, University of North Dakota School of Mines, 15 p.

Budge, W.E., 1936, The bentonites of North Dakota, University of North Dakota School of Mines, 17 p.

Budge, W.E., no date, The bentonites of North Dakota, University of North Dakota School of Mines, 2 p.

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

Clapp, C.H., 1906, Methods of brick manufacture and description of the North Dakota Industry, in the Fourth Biennial Report of the North Dakota Geological Survey, p. 245-312.

Clapp, C.H. and Babcock, E.J., 1906a, Clay and its properties with special reference to North Dakota clays, in the Fourth Biennial Report of the North Dakota Geological Survey, p. 9-62.

Clapp, C.H. and Babcock, E.J., 1906b, Economic geology of North Dakota clays, in the

Fourth Biennial Report of the North Dakota Geological Survey, p. 95-190.

Clark, F.F., 1948, Southwestern North Dakota clay deposits Stark, Slope, and Billings Counties, North Dakota, United States Bureau of Mines Report of Investigations No. 4219, 32 p.

Clayton, Lee, 1980, Geologic map of North Dakota, United States Geological Survey, 1:500,000.

Cooley, A.M. and Manz, O.E., 1972, Benefication of bleaching clay near Walhalla, North Dakota, Proposal submitted to North Dakota Resources and Development Corporation, September 14, 5 p.

Dickinson Centennial Committee, 1982, Centennial roundup, a history of Dickinson, North Dakota, Assumption Abbey Press, Richardton, N.D., 173 p.

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

Forsman, N.F., 1984a, Misuse of the term "bentonite" for ash beds of Devonian age in the Appalachian basin: Discussion and reply, Geological Society of America Bulletin, v. 95, p. 124.

Forsman, N.F., 1984b, Durability and alteration of some Cretaceous and Paleocene pyroclastic glasses in North Dakota, Journal of Non-Crystalline Solids, v. 67, p. 449-461.

Forsman, N.F., 1985, Petrology of the Sentinel Butte Formation (Paleocene), North Dakota, Unpublished Doctoral Dissertation, University of North Dakota, 222 p.

Forsman, N.F., 1992, Tuffs in North Dakota, in Proceedings of the F. D. Holland, Jr., Geological Symposium, J.M. Erickson and J.W. Hoganson, eds., North Dakota Geological Survey Miscellaneous Series No. 76, 318 p.

Forsman, N.F. and Karner, F.R., 1975, Preliminary evidence for the volcanic origin of bentonite in the Sentinel Butte Formation, North Dakota, abs., North Dakota Academy of Science, Proceedings, V. 29, p. 10.

Frye, C.I., 1967, The Hell Creek Formation in North Dakota, unpublished PhD thesis, University of North Dakota, 411 p.

Govig, P.T., 1991, Memorandum on ceramic tile feasibility meeting, North Dakota Economic Development Commission, January 22, 2 p.

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

Groenewold, G.H.,Koob, R.D., McCarthy, G.J., Rehm, B.W., and Peterson, W.M., 1983, Geological and geochemical controls on the chemical evolution of subsurface water in undisturbed and surface-mined landscapes in western North Dakota, North Dakota Geological Survey Report of Investigation No. 79, 151 p.

Hainer, J.L., 1956, The geology of North Dakota, North Dakota Geological Survey Bulletin No. 31, 46 p.

Hammers, F.L. and Budge, W.E., 1931, Properties of some North Dakota bentonites, Journal of the American Ceramic Society, Vol. 14, No. 10, p. 742-746.

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

Hansen, Miller, 1959, Clays of North Dakota as a potential source of alumina, North Dakota Geological Survey Report of Investigation No. 33, 15 p.

Hauck, S., Heine, J., Zanko, L., Powers, B., Geerts, S., Oreskovich, J., and Reichhoff, J., LCMR Clay Project: NRRI Summary Report, Minnesota Natural Resources Research Institute, Technical Report No. NRRI/GMIN-TR-89-12A, October, 201 p.

Hebron Centennial Corporation, 1984, Hebron Brick Company, in Hebron our heritage, a history of the Hebron, North Dakota area, 600 p.

Hickey, L.J., 1977, Stratigraphy and paleobotany of the Golden Valley Formation (early Tertiary) of western North Dakota, Geological Society of America Memoir 150, 181 p.

Jacob, A.F., 1975, Criteria for differentiating the Tongue River and Sentinel Butte Formations (Paleocene), North Dakota, North Dakota Geological Survey Report of Investigation No. 53, 55p.

Johnston, E.P., 1992, Building it better, Hebron Brick is proof that good products sell, North Dakota Horizons, Fall, p. 4-7.

Leonard, A.G., 1906, The stratigraphy of North Dakota clays, in the Fourth Biennial Report of the North Dakota Geological Survey, p. 63-94.

Leonard, A.G., 1912, The geology of south-central North Dakota, in the Sixth Biennial Report of the North Dakota Geological Survey, p. 27-99.

Manz, O.E., 1953, Investigation of some North Dakota clays and shales, North Dakota Geological Survey Report of Investigation No. 13, 36 p.

Manz, O.E., 1954, Investigation of lightweight aggregate possibilities of some North Dakota clays and shales, North Dakota Geological Survey Report of Investigation No. 17, 48 p.

Manz, O.E., 1956, Investigation of Lake Agassiz clay deposits, North Dakota Geological Survey Report of Investigation No.27, 34 p.

Manz, O.E., 1961, Report on Williston clay deposit, unpublished report, University of North Dakota Department of Engineering, 6 p.

Manz, O.E., 1968, Feasibility study of the clays in the Golden Valley Formation of North Dakota--a potential constituent for the manufacture of electrical insulators, Final Progress Report to the North Dakota Economic Development Commission, June 24, 12 p.

Manz, O.E., 1971, Feasibility study of the Golden Valley clay deposit near Taylor, North Dakota, Final Progress Report to the North Dakota Business and Industrial Development Department, June 17, 8 p.

Manz, O.E., 1973, Clay and lightweight aggregate in Mineral and Water Resources of North Dakota, North Dakota Geological Survey Bulletin 63, p. 122-129.

Manz, O.E., 1994, personal communication, Professor Emeritus, University of North Dakota, May 14.

Mueller, M., 1993, Lightweight aggregate market study, in Ceramic tile and lightweight aggregate product development using Minnesota clays, Minnesota Natural Resources Research Institute Technical Report No. NRRI/TR-91/23, p. 244-248.

Moran, S.R., Groenewold, G.H., and Cherry, J. A., 1978, Geologic, hydrologic, and geochemical concepts and techniques in overburden characterization for mined land reclamation, North Dakota Geological Survey Report of Investigation No. 63, 152 p.

Murphy, E.C., Hoganson, J.W., Nichols, J.D., and Forsman, N.F., 1991, Mapping the Cretaceous/Tertiary boundary and associated rock units in North Dakota, COGEOMAP Report to the United States Geological Survey, December, 101 p.

Murray, H.H., 1983, Clays, in Industrial minerals and rocks, Lefond, S.J., ed., 5th edition, Society of Mining Engineers, New York, New York, p. 585-651.

Oreskovich, J.A., and Hauck, S.A., 1993, Testing of Kittson County bloating clays as lightweight aggregate in structural concrete, Minnesota Natural Resources Research Institute Technical Report No. NRRI/TR-93/17A, August, 49 p.

Oreskovich, J.A. and Toth, 1993, Evaluation of three Minnesota shales and clays for use as lightweight aggregate or other expanded product, with emphasis on the Kittson County clays, in Ceramic tile and lightweight aggregate product development using Minnesota clays, Hauck, S.A., ed., Minnesota Natural Resources Research Institute Technical Report No. NRRI/TR-91/23, p. 66-244.

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

Prichard, G.H., 1980, Authigenic kaolinite in the Bear Den Member (Paleocene) of the Golden Valley Formation, in southwestern North Dakota, unpublished Master's Thesis, University of North Dakota, 174 p.

Reed, Hank, 1958, Fuller' Earth deposit Pembina Mountains, North Dakota, Great Northern Railway Company Mineral Research and Development Department Report No. 6, 17 p.

Royse, C.F. Jr., 1967, A stratigraphic and sedimentologic analysis of the Tongue River and Sentinel Butte Formations (Paleocene), North Dakota, unpublished Dissertation, University of North Dakota, 312 p.

Stewart, J.A. and Karner, F.R., 1969, A mineralogical and chemical investigation of North Dakota clays--a potential source of aluminum, Final Report to the North Dakota Economic Development Commission, May 16, 6 p.

Wehrfritz, B.D., 1978, The Rhame Bed (Slope Formation, Paleocene), a silcrete and deep-weathering profile, in southwestern North Dakota, unpublished Master's Thesis, University of North Dakota, 158 p.

NORTH DAKOTA GEOLOGICAL SURVEY
600 EAST BOULEVARD, BISMARCK ND 58505-0840

1995