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SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

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REPORT OF INVESTIGATIONS

No. 35

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BENTONITES

of the

BELLE FOURCHE DISTRICT

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by

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Vermillion, S. Dak.
April, 1940

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M. E. WING

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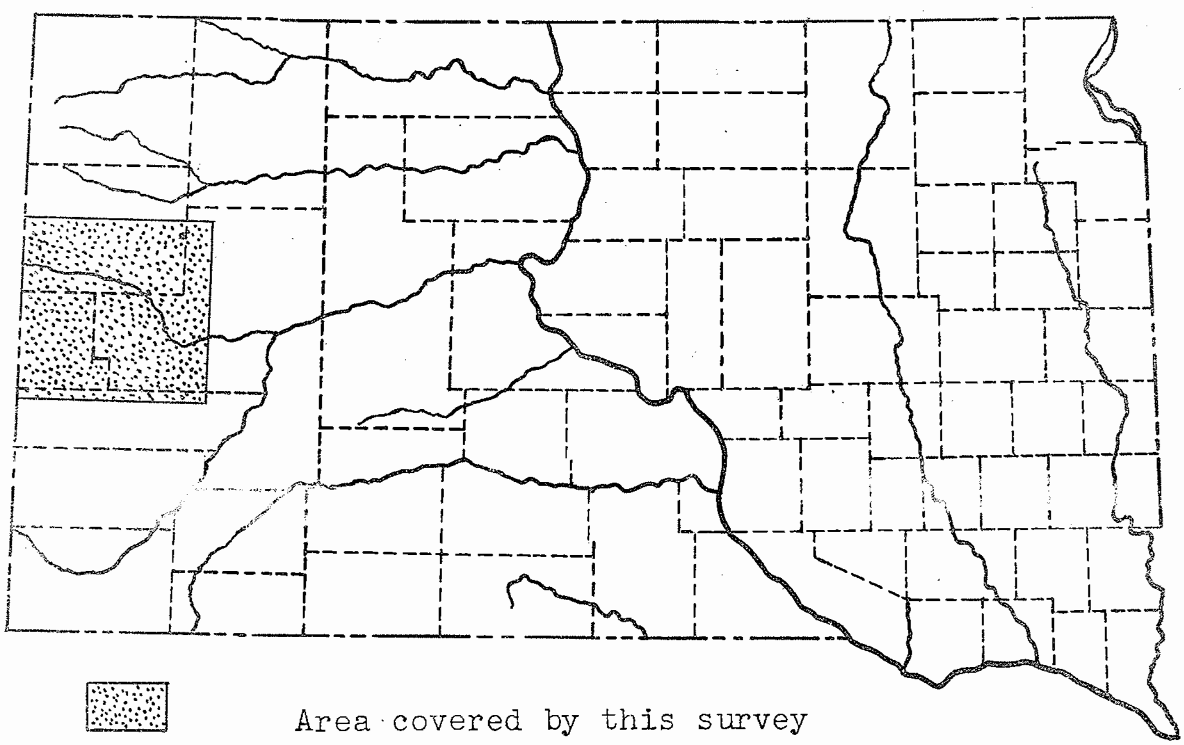

Area covered by this survey

INTRODUCTION

Bentonite is a clay-like material that has attracted much attention in recent years because of its origin, unusual properties and hundreds of uses. It was first discovered in Wyoming and was called Taylorite. Later, because of its occurrence in rocks of the Fort Benton series of the Cretaceous System, the name was changed to bentonite. While bentonite is now produced in many states, the deposits encircling the Black Hills and occurring in South Dakota as well as Wyoming supply the greater part of high grade bentonite produced in the United States.

At present there are two bentonite processing plants at Belle Fourche, South Dakota. One is owned by the American Colloid Company of Chicago, and is located at the end of the Chicago and Northwestern Railroad spur, approximately one and one-half miles northwest of the city. The other plant is owned and operated by F. E. Schundler & Co., Inc. of Joliet, Illinois, and is located in Belle Fourche.

The South Dakota Geological Survey had several motives in mind in conducting a survey of the bentonite deposits north of the Black Hills. The first was to boost the present industry as much as possible. It was though that this could be done by surveying the one known deposit, and pointing out its extent, the enormous tonnage available, and the high quality of the product. Second, to extend the present field, if possible, by careful field study, drilling, etc. Third, to locate other bentonite beds of possible commercial importance, that is--at other geologic horizons, and to make known the properties of these other deposits so as to encourage their development. Fourth, to study the bentonite horizons northeast and east of the Black Hills so as to be in a position to advise in case developments are contemplated in those sections.

The writer spent the summer of 1939 in the field with two assistants carrying on the survey. The deposit from which bentonite is now produced was mapped from the Wyoming boundary line to Belle Fourche, where it thins so as to be unworkable. A new bed of bentonite having about the same extent was mapped and sampled. All formations from the top of the Dakota sandstone to the top of the Pierre were carefully studied to find whether there were other beds which might be of commercial value. Finally, all horizons where bentonite was known to occur were carefully searched east to Sturgis and south as far as Rapid City.

The author wishes to express his sincere appreciation of the help given by two producers of bentonite in the Belle Fourche district. Both the American Colloid Company and the Schundler Bentonite Corporation furnished copies of commercial bulletins, maps, and samples, and gave every bit of assistance possible. To Mr. Edward Bussfield, manager of the Middle Creek Plant of the American Colloid Company and to Mr. Dan Marchent, manager of the Schundler plant, the writer is especially grateful for very friendly assistance.

Many interesting facts concerning the history of the Belle Fourche bentonite industry were learned from two of the pioneers in its development, Mr. W. I. Smith and Mr. T. W. McClanahan, president and secretary, respectively, of the Belle Fourche Bentonite Products Corporation. This corporation holds most of the leases and claims in the district and subleases to the American Colloid Company.

The writer was ably assisted in the field by Mr. John McKeever of Aberdeen and Mr. Paul Drickey of Rapid City. To the valuable assistance of these men is due much of the success of the survey.

To Dr. E. P. Rothrock, Chief of the South Dakota Geological Survey, the author wishes to express his thanks for generous cooperation. Dr. Rothrock consulted with the field party twice during the summer, and made available his extensive knowledge concerning the geology of the district.

The State Geological Survey furnished the field party with equipment, maps, and reference material.

GEOLOGIC FORMATIONS

Bentonite beds studied in the field and described in this report occur in the Graneros and Pierre formations of the Cretaceous System. Those in the former are the more important because all of the bentonite produced near Belle Fourche comes from this formation. Since these formations dip toward the northeast or away from the Black Hills, the Graneros outcrops occur nearest the Hills and the Pierre farthest away. This is the order in which exposed formations are described.

The Graneros

The Graneros formation consists of about 1000 feet of light to dark gray shale containing one prominent sandstone member, one persistent but thin limestone layer, and numerous concretions lying at various levels. It is bounded below or underlain by the Fall River (Dakota) sandstone and is overlain by the Greenhorn limestone. Three shale divisions have been widely recognized, the lower and upper ones are principally dark in color while the middle division consists of light or silvery gray siliceous shale.

Lower Graneros: The lower shale division consists mainly of dark shales. It contains scattered lense-shaped concretions. Its thickness was not measured, but it is estimated at between 250 and 300 feet. Bentonite was found in this division in the northeastern corner of Sec. 30, T.8 N., R. 3 E. and in the north-western corner of Sec. 11, T.7 N., R. 3 E. At the former location the bed was 18 inches thick and at the latter two feet. At both places there was a distinct zone of septarian concretions, ranging from 3 to 8 feet in diameter and covered with brownish yellow cone-in-cone structure lying approximately 30 feet above the bentonite.

In the Belle Fourche folio[1], there is reported a

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1. Darton, N.H. and O'Harra, C.C., The Belle Fourche Folio, U.S.G.S. Folio 164, p. 4, 1909.

gray to buff, massive, coarse-grained sandstone in the upper part of the lower Graneros. Its thickness near St. Onge Park is given as 8 feet, but the bed either weathers rapidly or is not persistent, for it is not exposed at many places in the area. It is believed that the bed is the New Castle sandstone. Rothrock reports the same sandstone as occurring 30 feet below the top of the Lower Graneros in the Chilson and Cascade anticlines south of the Black Hills.[2]

Middle Graneros: The Mowry division of the Graneros consists of the light to dark siliceous shales, although as a whole the shales are light gray in appearance and easily distinguishable from those above and below. Because of greater hardness and greater resistance to erosion these shales form steep sided hills. At places deep gorges are cut through them. They do not become sticky when wet, and roads across them are much better than the average even in wet weather. Small pines and scrubby oaks grow in great numbers on the Mowry shale, but not on the Upper Graneros unless the latter is covered with alluvium. Thus, trees serve to a considerable extent to mark the upper surface of the Mowry. The Mowry contains numerous fish scales in most places. Joints and bedding planes contain much yellow dust which has resulted from weathering of numerous thin seams of bentonite.

The principal bed of bentonite northwest of Belle Fourche is reported by some writers as occurring just above and by others as eight feet above the Mowry. In much of the district near Belle Fourche, gray-white siliceous shale containing fish scales extends to 2 or 3 feet above the thick bed of bentonite. The lowermost oligonite concretions occur at least 3 feet above the thick bed of bentonite. Consequently it is believed that this bed of bentonite, from which production in the Belle Fourche region comes, lies in the top of the Mowry.

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1. Rothrock, E. P., The Cascade Anticline, R.I. # 8, and The Chilson Anticline, R.I. # 7, S. Dak. State Geological Survey, 1931.

The Mowry Member of the Graneros Formation
In Cut Along Belle Fourche River
NW$\frac{1}{4}$ of the NW$\frac{1}{4}$ of Sec. 23, T. 9 N., R.1E.
Butte County, S. Dak.

Feet	Inches	
3		Big Bentonite
35		Gray shale, weathers light gray, contains much yellow dust along joints
	4	Bentonite; gray to light pink with rust stains
2		Gray shale
	4	Bentonite
22		Gray-black shale
	5	Bentonite
41		Gray shale; much yellow powder along joints
	7	Bentonite
	10	Gray shale
	9	Bentonite; light cream to ivory color with some rust stain
6		Gray-black shale
	4	Bentonite
1	6	Gray shale
	5	Bentonite; olive-gray
	5	Bentonite, light pink and rust colored
	9	Gray shale
	6	Sandy shale with gypsum; rust colored
4		Gray-black shale
	5	Bentonite, salmon pink and rust colored.
14		Black shale, yellow dust along joints
	11	Bentonite
3		Gray shale
		Large flat limestone concretion with algal structure over upper surface
1		Gray shale containing sandstone lenses. Rust colored.
4		Gray shale with numerous thin seams of light gray bentonite
	4	Bentonite; gray to rust color
2		Gray shale with thin seams of bentonite
-	-	River bed.

Attention is called to the fact that the section measured is 145 feet thick, but this is not the full thickness of the Mowry. This part of the Mowry contains 10 beds of bentonite in addition to the thick bed in the upper part and numerous thin seams and much dust-like material. The ten seams have a total thickness of 56 inches and adding the 3 feet thickness of the bed in the upper Mowry, there is a total of about 8 feet of bentonite in the section measured.

Upper Graneros: The upper division of the Graneros near Belle Fourche consists of dark shales approximately 600 feet thick. Beginning 3 feet above the top of the thick bentonite bed found in the upper part of the Mowry and just above a 4 inch seam of bentonite, there is a zone of dark brown to black concretions approximately 12 feet thick. Above this there is a 4 foot zone of light shale containing some bentonite and above this a zone 10 feet thick of light chocolate brown concretions. The 4 foot zone of light shale and bentonite serves to show where the thick bentonite bed lies not more than 16 feet beneath the surface.

Approximately 200 feet below the Greenhorn limestone which overlies the Upper Graneros is a thin but persistent limestone ledge. This limestone ledge, herein called the Middle Creek, caps and causes the escarpment trending northwest from Belle Fourche along the northeast side of Middle Creek Valley. It causes also a dip slope toward the north and east into Crow Creek valley. It is a semicrystalline limestone with a somewhat sandy texture on the weathered surface. It contains many black grains and flakes of organic material, and emits a strong petroleum odor when broken. It contains many shark teeth, fossil shells of Inoceramus, and a large, ribbed ammonite, probably Prionocyclus.

Northeast of Belle Fourche there is a bed of bentonite ranging from 2-4 feet thick lying about 8 or 9 feet below the crest of the escarpment. This bentonite varies in color from olive-gray-green to a white, and is probably quite white in color back from the face of the escarpment where it has not weathered. It is described more fully on a section dealing with description of bentonite resources in the region.

The Greenhorn Limestone

The Greenhorn limestone member consists of thin gray colored beds alternating with light colored, chalky shale layers. This is particularly true of the central 15 feet, for both above and below this central zone the member consists principally of light colored shale, and contains only an occasional thin limestone. The total thickness of the formation is between 25 and 35 feet.

The Greenhorn limestone is only moderately resistant to erosion and does not form a prominent escarpment except north of Snoma. Individual slopes of limestone harden, however upon exposure, and the outcrop is always marked by numerous fragments of limestone, seldom more than an inch thick and a few inches across. The Greenhorn limestone caps Susie Peak and causes a slight bench along the northeast slope of Crow Creek between R. 3 E. and the state line. It contains some fragments of shells of the pelecypod Inoceramus labiatus, but these are not particularly numerous.

A typical section of the Greenhorn limestone occurs in a roadcut along highway 85 north of Belle Fourche, near the northwestern corner of Sec. 14, T. 9 N., R. 2 E. This section is given below. The contact of the formation with the Graneros below could not be determined. There is a moderately sharp contact with the Carlile above, however, as evidenced by the abrupt change near the top of the hill from light to dark shale. The thickness of the Greenhorn exposure is 32½ feet. Its thickness appears to be much greater in the roadcut because of the fact that the upper 17 feet is duplicated as a result of faulting.

Greenhorn Limestone
NW corner, Sec.14, T.9 N.,R.2 E.
Butte County, S.Dak.

Feet	Inches	
7		Gray shale, overlain by black Carlile shale
	8	Limestone; light gray, thin-bedded
1	4	Chalky shale

	6	Limestone; gray-buff
	3	Brown shale
	6	Bentonite; rust-colored with white streaks at base
1	4	Gray shale with thin seams of limestone
	8	Limestone; buff-colored, thin bedded. Thin seam of brown bentonite near base.
1	2	Shale with thin seams of limestone
	6	Limestone; buff, thin-bedded.
1	8	Shale; light gray
	6	Limestone; thin-bedded
2	6	Shale; gray, containing thin limestone fragments.
	4	Limestone; light buff-gray.
1		Gray shale
	2	Limestone, light buff, fragmental.
	8	Shale
	2	Limestone, gray, impure
	2	Clay; yellow, bentonite
	4	Shale; gray
	2	Limestone; thin-bedded
10		Gray shale with few thin limestone fragments.
32	6	Total thickness of exposure.

The Carlile

The Carlile shale outcrops north of Belle Fourche between Owl and Crow Creeks and in ranges 3 and 4 E. between Indian and Crow Creeks. It varies between 600 and 800 feet in thickness and consists principally of gray to black fissile shale. Two very conspicuous features of this formation, however, are the persistent sandstone layers approximately 100 feet above its base and the numerous biscuit-shaped concretions, some of which are more than 5 feet in diameter. Most of the latter show dark calcite veins which have filled cracks radiating from the center, and are covered with cone-in-cone structure. Many of them are highly fossiliferous.

It is noteworthy that the concretions in the lower part of the Carlile are rusty-yellow in color and are sandy, while those in the upper part are gray and composed of limestone. There are 3 or 4 layers of concretions in the upper part, separated from each other by 10-15 feet of shale.

The Niobrara

The Niobrara consists of light colored calcareous shale. The formation is soft and erodes easily, and consequently a principal valley (Owl Creek) has developed along its outcrop. The few exposures that occur show that the formation changes to a cream color when it weathers. Because the formation is so extensively covered with alluvium, it was impossible to describe it in detail. Its thickness is approximately 200 feet.

The Pierre

The Pierre shale is the youngest formation through which search for bentonite extended. It consists of light and dark gray shales approximately 1400 feet thick. Because of this great thickness and the lower dips that prevail where this formation outcrops several miles from the Black Hills, the outcrop band about the hills is very wide.

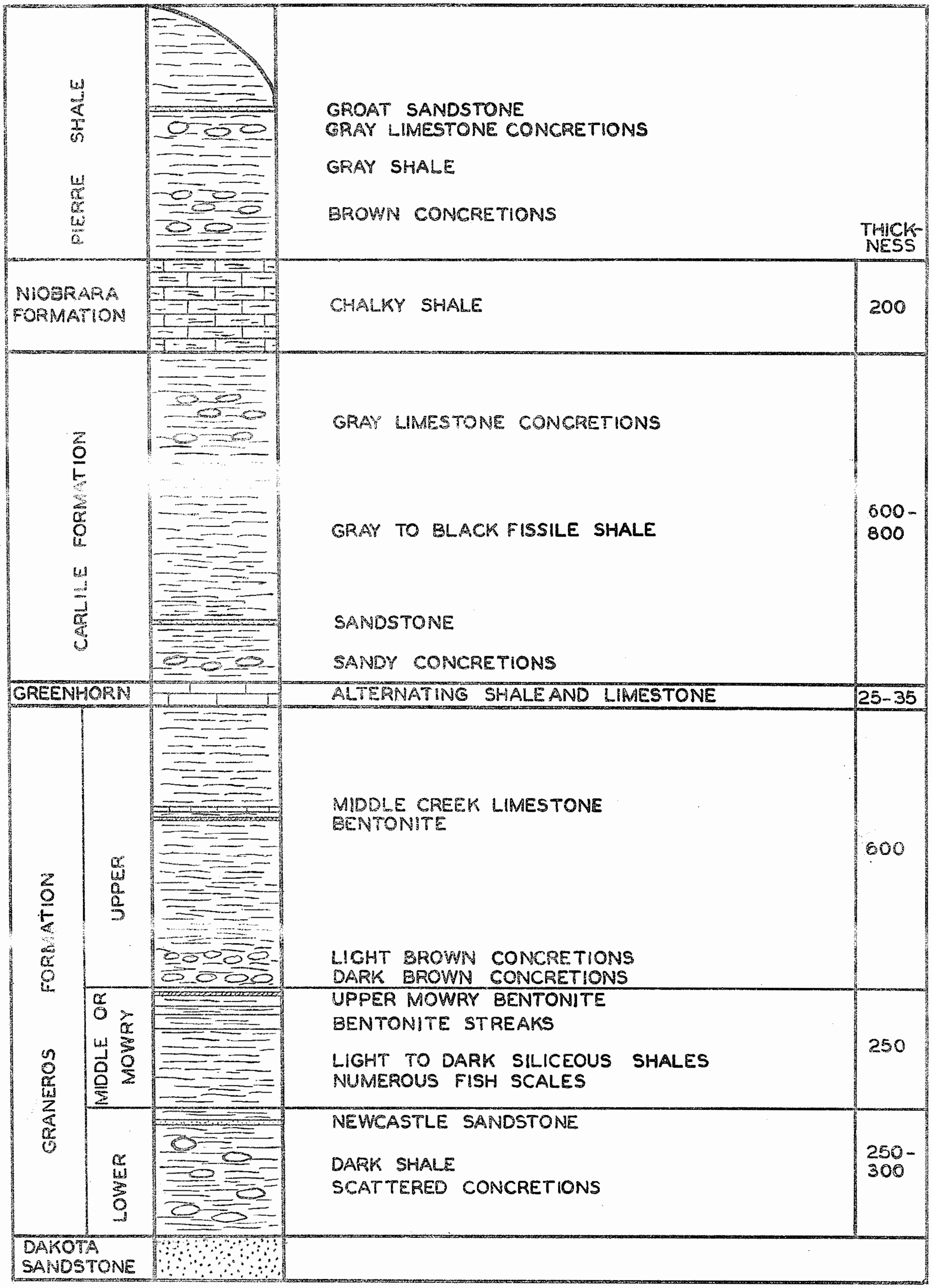
North of Belle Fourche, Pierre shale outcrops begin on the north side of Owl Creek and underlie the rolling plains many miles to the north. Mud Buttes are composed of approximately 300 feet of the lower Pierre while Antelope Butte, capped with Tertiary sandstone, is composed of the upper 300 feet. The intermediate portion of the formation is exposed on the north side of North Indian Creek between the two buttes mentioned.

While the Pierre has not been adequately described north of Belle Fourche and the subdivisions made along the Missouri River do not apply in this locality, nevertheless certain horizons seem to be distinctive. The lower 260 feet as exposed on Mud Buttes consist of gray shales and contain reddish and yellow-brown concretions, above which is 40 feet of light colored shale containing limestone concretions.

Just above this horizon and outcropping along the Albion road approximately 5 to 7 miles from its junction with highway 85 occurs a gray argillaceous sandstone which has been tentatively identified as the Groat sandstone of Wyoming. This division of the Pierre contains gigantic sandstone concretions and much greensand. It is also calcareous. This sandstone is apparently not extensive in South Dakota, since it was found in only this one locality.

Above the Groat sandstone and near the middle of the Pierre there is a zone which is similar over a wide area. From bottom to top it is described as follows:

Feet	Inches	
27		Gray shale, containing numerous limestone concretions which break up on exposures and accumulate on surface as small irregular, angular fragments. These are so numerous as to cause the slopes at this horizon to be distinctly reddish in appearance. Numerous Baculites are contained in the concretions.
13		Light colored sandy shale; large, yellow limestone concretions at top of this zone.
1		Bentonite; greenish-yellow
10		Shale
1		Very yellow bed, weathered bentonite with considerable volcanic ash. This bed is very noticeable and can be traced for many miles.
?		Shale; contains dark brown concretions.



GENERALIZED COLUMNAR SECTION

The upper part of the Pierre consisting of approximately 300 feet of dark gray shale is exposed on Antelope Butte. It contains many reddish brown concretions, and much gypsum as evidenced by numerous flakes on the weathered slope. About 200 feet from the top of the butte there is a zone of calcareous concretions which contain many fossils. These cause the tepee buttes farther east. There is at least one thin bed of bentonite just above these concretions.

It is noteworthy that the black shale zone containing the bentonite south of the Hills is absent north of Belle Fourche.

CHARACTER OF BENTONITE

Composition

Type 1 bentonite consists primarily of the mineral montmorillonite, a hydrous silicate of alumina for which the following formula has been given:[1]

$$Al_2O_3\ 4SiO_2XH_2O$$

The aluminum may be replaced by iron, calcium, magnesium, and to a limited extent by the alkalies. A chemical analysis of the high grade Belle Fourche bentonite shows the following constituents:[2]

SiO_2	60.64	per	cent
Al_2O_3	23.26	"	"
Fe_2O_3	3.92	"	"
TiO_2	.12	"	"
CaO	.59	"	"
MgO	2.19	"	"
K_2O	.37	"	"
Na_2O	4.33	"	"
H_2O	2.83	"	"

1. Ross, C. S. and Shannon, E. V., "The Minerals of Bentonite and Related Clays and their Physical Properties." Journ. Am. Ceram. Soc., Vol.9, pp. 77-79, 1926.
2. Bentonite-Private publication of the Belle Fourche Bentonite Products Co., Inc. Analysis by W. A. Selvig, U. S. Bureau of Mines.

Bentonite contains practically no organic material or free quartz. Brown limonite stains are seen in places on some deposits, but even this substance occurs in negligible quantities in the deposit as a whole. Gypsum crystals or flakes occur commonly in the beds but again in negligible quantities. At least one bed examined contained calcite, but this bed was not one from which bentonite is now being produced. Another thin bed contained unchanged volcanic ash.

Origin

Bentonite has developed principally from finely divided volcanic ash that settled at various times during the geologic past in shallow interior seas. Whether the water in these seas was any different from that of the present oceans cannot be determined. It is probable, however, that the ash of the various falls may have varied both in size of the particles and in composition. Further, the conditions which caused devitrification and other changes in the ash may have varied. Consequently, there are at least two main types of bentonite and many intermediate varieties.

The higher grades of bentonite, of which the Belle Fourche bentonite is an example, have the property of absorbing large quantities of water and swelling enormously. They will remain indefinitely in suspension in thin water dispersions. The lower grade bentonites are like the ordinary plastic clays and do not have the property of swelling, nor will they remain in suspension long.

Properties of Type 1 Bentonite

One of the outstanding characteristics of type 1 bentonite and one upon which many of its properties depend is its extremely minute grain size or texture. Bentonite is composed of flake-like crystals which are exceedingly small in diameter. Crystals of montmorillonite, the principal mineral found in type 1 bentonite, are between 1 and 0.1 micron in size. It is estimated that while English ball clay has an average of 3,400 grains per linear cm., bentonite has 20,000.[1] In other words, bentonite particles have a diameter of only 1/6 that of English ball clay.

Because of the shape of its particles and its extremely minute grain size, type 1 bentonite has a very large surface area per unit volume of material. Again comparing English ball clay with bentonite,[2] the former has an average area of 7,400 sq.cm. per gram, while bentonite has an area of 50,000 sq.cm. per gram.

Type 1 bentonite will take up 6 to 7 times its weight of water and in doing so will expand as much as fifteen times its dry volume. In this condition it forms gels which have the consistency of heavy grease. Water not only enters the lattice structure of the crystal, but a film of water covers the surface of each. Since the surface area per volume is extremely large, the amount of water absorbed by bentonite is very large and it swells enormously.

This power of swelling is reversible and is not diminished unless drying is done at over 400°F. It is not totally lost until bentonite is heated to 1200° F. Bentonite will not swell in alcohol, gasoline or similar liquids.

Another property of type 1 bentonite is that it will remain in suspension in distilled water even as dilute as 1 part in 10,000. This property is caused by the extremely minute character of the particles as well as by the electric charge carried by each particle.

Bentonite particles are negatively charged and when placed in turbid liquids particles attract positively charged impurities causing flocculation. Thus the liquid is freed of impurities held in suspension.

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1. Norton and Hodgdon. "Some notes on the nature of clay." Jour. Am. Ceram. Soc., Vol. 15, No. 3, 1932.
2. Norton and Hodgdon. "Some notes on the nature of clay." Jour. Am. Ceram. Soc., Vol. 9, pp.77-79, 1926.

Type 1 bentonite has base exchange properties also. In solutions the sodium and potassium of the bentonite are exchanged for calcium and magnesium, thus making a material which can be used as a water softener.

Other properties of this type of bentonite are its high degree of placticity, its great bonding strength, and its specific gravity of 2.65. It fuses completely at 2400°F.

THE USES OF BENTONITE

Bentonite has been called the "clay with a thousand uses." Some of the more important uses are described below. Since these are definitely related to the unusual properties of bentonite, attention is called to the particular property or properties which make the use possible. A study of these will undoubtedly suggest many additional places where bentonite will fit into industry.

As a Drilling Mud

One of the principal uses of bentonite is found in oil well drilling where the rotary system is used. This system employs a cutting tool fastened to a drill pipe which extends from the surface to the bottom of the hole. The pipe is rotated by means of machinery at the surface, cuttings must be removed from the hole, and this can be accomplished only by floating them out by forcing a liquid into the hole through the drill pipe and allowing it to escape around the outside.

Various muds have been developed for this purpose, but type 1 bentonite of high quality such as that from the Belle Fourche district is superior to others, because only a relatively small quantity must be mixed with water in order to produce a gel capable of suspending and carrying cuttings from the hole, and because this type of bentonite will remain suspended in water indefinitely instead of settling as will ordinary muds.

A good drilling mud should also be free from abrasive grits and should have some lubricating qualities. Here again Belle Fourche type bentonite is superior to the ordinary muds used for this purpose.

Bentonite is also effective in sealing sands through which the drill has passed against loss of water.

It is suggested further that where drillers fill the space between the casing and wall of the well with mud, in order to prevent corrosion of the casing or to shut off water above the oil-bearing sand, bentonite might be used to advantage. Bentonite will maintain its gel-like consistency indefinitely. Thus, it seems that the use of bentonite in this way might prevent the casing from "freezing" in the hole and might permit its removal later with much greater ease.

It is suggested further that during times of over-production or when a well is shut down for any reason, it be plugged with a bentonite mud-fluid or gel. Bentonite will form an impervious plug and should protect the well until it is desired to operate it again.

As a Bonding Agent in Foundry Sands

Bentonite is being used extensively in foundries as a bonding agent in sand.

Foundry sands vary a great deal in quality, depending on the type of metal being poured and on the particular class of work. In general, however, foundry sands should possess several important properties.

They should possess plasticity so as to increase their workability. They should be as fine as possible so as to give a smooth surface to the casting. They should possess mechanical strength so that the mold or core can be handled and will be able to withstand the pressure and washing effect of molten metal. They should not fuse when the molten metal comes in contact with the sand of the core or mold. Lastly, sands should be permeable so as to permit the escape of gases generated when the hot metal is poured into the mold.

Obviously these properties depend primarily on the sand, but they are also dependent in part on the character of the bond in the sand. Bentonite of the Belle Fourche type is highly plastic and adds to the ease with which sands may be molded. It has greater bond strength than other clays, and so less may be used in obtaining the desired strength in sand. This, in turn, increases the permeability of sand, since clay tends to fill the openings between sand grains. Thus, a finer sand may be used and still maintain the same permeability. The use of a finer sand gives a smoother finish to the casting. Bentonite contains no organic matter, and in addition less water is required when bentonite is used, so that less steam or other gases are generated when the hot metal comes into contact with the sand. Finally, bentonite does not act as a flux, nor lower appreciably the fusion point of sand. A small percentage of the bentonite may, because of the high temperatures involved, lose some of its properties, but the necessary replacement is small.

Thus in foundries where scientific management or control is maintained, bentonite of the Belle Fourche type is used as the bonding agent. The principal use is as a binder for silica sand, but bentonite is used also for reclaiming sand and for making molds and cores and core washes.

As a Grouting Agent

Bentonite has another important use in stopping water flow and seepage.

It is very effective in waterproofing concrete and stucco, but its more important use is in sealing reservoirs against leakage and especially in preventing seepage underneath dams. For the latter purpose bentonite is mixed with water to the desired consistency and is injected into the sand or gravel under pressure. Irrigation ditches and reservoirs can be made leak-proof if bentonite is mixed with the upper several inches of sand and clay while the sand and clay are still dry.

Type 1 bentonite is an excellent grouting material because it is exceedingly fine grained when mixed with water. It has greater slipperiness than any other material used. Because of these two properties it can be forced into very small openings in the rocks. When so used it has been very effective in stopping the leakage of water.

As a Coagulent in the Purification of Water or as a Clarifying Agent

Bentonite is used in sanitary engineering as a coagulent in the purification of water. Olin and Gauler[1] say in discussing this use, "The alkali bentonites in water dispersion form in general highly colloidal systems of negatively charged particles which react with mono-,di-, and trivalent cations to form adsorptive flocs in accordance with well established physical laws." It is also pointed out by these authors that, "Lime softening of a water containing carbonate hardness presents a particularly favorable situation for use of bentonite for clarification." In other words, bentonite may perform a double function when used in treating a water supply. It will clarify the water by forming readily filterable flocs of impurities held in suspension and it will serve to reduce the hardness of water by exchanging its sodium and potassium for the calcium and magnesium in solution in the water.

Olin, Campbell and Gauler[2] in a later paper showed that bentonite can be used economically and effectively in treating sewage.

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1. Olin, H. L. and Gauler, J. V., "The use of bentonite clays in water treatment." Journal of the American Water Works Assoc., Vol. 30, No. 3, March, 1938, pp. 498-506.
2. Olin, H. L.; Campbell, Chas. L.;and Gauler,J. V. Experience with bentonite in the purification of sewage. Waterworks and Sewerage. July, 1937.

Still further uses based on this property of bentonite to attract positively charged particles of matter in suspension is in clarifying wines, honey, fruit juices, vinegar and other liquids.

In the Ceramic Industry

The use of bentonite in the ceramic industry is growing rapidly.

Bentonite of the Belle Fourche type is composed largely of colloidal particles and is remarkably plastic. Even when a small quantity is added to non-plastic and lean ceramic materials, the mobility and the ease with which the latter may be worked is greatly enhanced. At the same time, the strength of the ceramic body is greatly increased and its porosity reduced. There are no adverse effects such as an increase in drying and fire shrinkage or discoloration caused by firing as long as bentonite is used in small quantities. Only a small quantity need be added to clay to greatly increase its plasticity and workability.

In Concrete

Likewise bentonite when added to a concrete mix will increase workability of the latter. The concrete will be made waterproof. The strength of Portland cement used will be increased and its time of set reduced. Bentonite also serves to hold sand and gravel particles in suspension and will result in a better distribution of these ingredients in the concrete.

In Laundries

One of the oldest uses of bentonite is in washing blankets, overalls, shop rags, etc. This use was probably suggested because of the resemblance of bentonite mud to soft soap. Indians are reported to have washed their blankets in bentonite, and later the Hudson's Bay Company adopted the same practice. Now many commercial laundries use bentonite wholly or partly in place of soap.

The detergent value of bentonite is due to its dispersing, emulsifying, and suspending energies. It unites with oils or greases readily to form an emulsion which is easily removed. Its negatively charged particles attract positively charged particles of dirt, which are floated away.

Bentonite is also used as an ingredient of soaps, cleansers, and polishes, and as such, it is not merely a filler but possesses unique properties which function actively.

In Making Alsifilm

The most interesting new use for bentonite is in making Alsifilm, a transparent, flexible and fairly tough paper or film.[1] This film has the further beneficial properties of being fireproof, waterproof, and chemically inert. It is unaffected by mold and unattractive to insects. It has been suggested that this new product be used for wrapping electric wires and telephone cables, for permanent documents or to line food or beverage containers and to wrap butter, tobacco, cigarettes, and other perishable or oily products. Alsifilm was discovered by Dr. Earne A. Hauser, Massachusetts Institute of Technology in 1938.

Other Uses

Other uses of bentonite are:

1. As a suspending, spreading, and adhesive agent in making horticultural sprays, insecticides, fungicides.
2. In making emulsions and aqueous suspensions of bitumens, asphalts, latex, rubber, rosins, and other water-immersible substances.
3. As a thickening and suspending agent for valve-grinding and other pastes and in polishes and cleansers.
4. In adhesives and sizings in combination with starches and other substances.
5. As a lubricant in combination with geled oil.
6. In pharmaceuticals and cosmetics as a sorbent, penetrant and gelatinizing medium.

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1. Reported in Minerals Yearbook, 1938.

BENTONITE SEAMS OF THE BELLE FOURCHE DISTRICT

The Upper Mowry Bed

Several beds of bentonite were found in the Belle Fourche region and are described in this report. One of these is the bed from which production comes in Middle Creek valley. Other beds are described because they appear to be commercially valuable or because they occur at horizons which may contain commercially valuable deposits of bentonite elsewhere.

Bentonite is produced in the Belle Fourche district from a bed approximately 3 feet thick which occurs in the top of the Mowry shale.

Conclusion as to the age of the bed is based upon the fact that approximately 3 feet of shale, resembling the Mowry, occurs above the bentonite. These shales are siliceous, light gray in color, and contain fish scales. Not only are they like the Mowry in these respects, but they are in direct contrast to the black shale which occurs directly above them. Thus the upper boundary of the Mowry is placed at the top of these shales or approximately 3 feet above the bentonite bed.

Outcrops of this bentonite occur along the southeastern side of Middle Creek valley and extend from Belle Fourche in a northwesterly direction to the state line. Wyoming reports show that this bed roughly encircles the Black Hills on the west and is the chief one from which bentonite is produced in that state. Pits of the American Colloid Company are located in Middle Creek valley between Belle Fourche and the state line, while those of Schundler & Co. occur across the state line in Wyoming.

This bed of bentonite is fairly uniform in thickness and averages approximately 3 feet near the state line. Near Belle Fourche, however, it is somewhat thinner and in some places is absent altogether. North of Belle Fourche the bed dips beneath the Belle Fourche River and where the Upper Mowry was observed east or south of this area, no commercial bentonite was observed at this horizon.

Bentonite Pits near Belle Fourche

Bentonite bed with cover removed showing thickness of seam.

Pit from which bentonite has been excavated. Car stands on shales below bentonite seam. Thickness of seam and cover in bank left of car.

Insley loader removing bentonite from seam which has been stripped of cover.

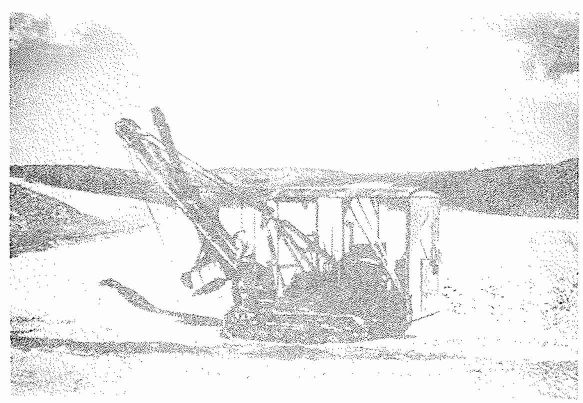


PLATE I

The mode of occurrence also changes from the state line toward the east. Near the state line the bed occurs beneath mounds and ridges which are capped by numerous moderately large, oval-shaped, dark colored concretions. In Sec. 16, T. 9 N., R. 1 E. and toward the east the bentonite occurs beneath the broad flat uplands and is exposed along the edges of small creeks which drain from the southeast into Middle Creek.

This bed of bentonite conforms to the general structure of the rocks in the area and dips away from the Black Hills or toward the northwest at the rate of between 2° and 4°. This is approximately equivalent to the slope into Middle Creek valley from the southeast and accounts for the narrow outcrops along the ravines leading into Middle Creek valley from this direction.

Outcrops are quite distinctive. Bentonite does not weather as rapidly as does shale, and consequently causes a slightly rounded shoulder along its outcrop. It is slightly lighter in color than the enclosing shale. It swells when wet and in that condition is as slippery and sticky as soft soap. When it dries it shrinks and the surface becomes covered with small curls. No vegetation grows on it because bentonite not only absorbs water very slowly but will also yield it too slowly to permit plant growth.

When freshly excavated from the bed, Middle Creek bentonite is light yellowish green in color and tends to have a conchoidal fracture. It resembles soap or wax in texture and when carved resembles wax or paraffin in that thin shavings are translucent. It contains approximately 40% water in its natural condition but dries quickly when exposed so that within a few minutes its surface is checked, and several shades lighter in color.

Belle Fourche bentonite belongs to type 1. It consists largely of material so fine as to be colloidal in character and is the high swelling type. It has many uses not possible for type 2 or the low swelling type of bentonite.

Methods of Production: Bentonite in the Belle Fourche district is produced from open pits. Overburden, ranging up to 15 feet thick and consisting of black shale and brown sandstone concretions, is removed by power shovels. Then the surface is scraped so that no foreign material from the overburden gets into the bentonite. The bentonite is then loaded by power shovels into trucks and is hauled to the plants. Loading in this way is possible because the bentonite rests in a hard floor of siliceous shale and there is little danger that foreign material from the under beds will become mixed with the bentonite even when a power shovel is used.

Both the American Colloid and Schundler companies maintain large stock piles for winter use. This is desirable because bentonite in the bed contains a large percentage of water and will freeze in the winter, making production much more difficult.

In the plant, bentonite is sent through a large rotary drier where its moisture content is reduced to 8 per cent. In the drier the temperature is carefully controlled since temperatures greater than 400° F. will destroy some of the valuable properties of the product.

As the material comes from the drier it is several shades lighter in color, and is quite porous from the loss of moisture. The product is then ground or granulated and after screening is packed in 100 lb. bags for shipment. The usual commercial grade is in the form of a powder 90 to 95 per cent of which will pass through the 200 mesh screen by dry sieve test.

As shown by the following table, production of bentonite in the Belle Fourche district has grown rapidly.

TABLE I
Production of Bentonite in the Belle Fourche District

Year	Cars of 40 short tons each
1934	117
1935	235
1936	550
1937	699
1938	699
1939(1st 6 mos.)	470

South Dakota ranked third among the states producing bentonite in 1938 and was exceeded only by Wyoming and Texas.

During 1938 high grade Belle Fourche bentonite was shipped to England, France, Germany, Italy, Spain, Norway, Sweden, and India, and to most of the states in the United States.

Reserves in the district are so large as to be considered almost inexhaustible. It is probable that a greater depth of overburden may be removed in the future to greatly increase the reserve. It should be remembered also that Belle Fourche is the processing and shipping center for valuable and extensive deposits in Wyoming.

Available bentonite: The following estimates of cubic yards of bentonite available is based upon careful measurements of the thickness of the bed and the length of outcrops. Where the bentonite lies beneath hills or narrow ridges it is believed that the entire deposit is recoverable. On the other hand, where the deposit lies beneath broad, flat uplands and outcrops along ravines as in sections 15 and 23, only a relatively narrow strip can be recovered. The width of this strip depends on the thickness of the overburden. At present not more than 16 feet of overburden is removed at any one place and the average is much less than this. The following estimates include only those deposits which lie under narrow ridges and other deposits where the overburden is not more than 16 feet thick.

TABLE II
Estimate of the quantity of bentonite available in Middle Creek valley

Location					Cubic Yards
SW ¼,	Sec.	31,	T.10 N.,	R.1 E.	29,000
NW "	"	6,	T. 9 N.,	"	106,000
SW "	"	"	"	"	10,000
SE "	"	"	"	"	10,000
NE "	"	7	"	"	29,000
NW "	"	8	"	"	58,000
SE "	"	"	"	"	39,000
NE "	"	17	"	"	48,000
SW "	"	9	"	"	29,000
NW "	"	16	"	"	34,000
SW "	"	"	"	"	73,000

NE $\frac{1}{4}$,	Sec. 16,	T. 9 N.,	R. 1 E.		48,000
SE "	"	"	"		145,000
NW "	" 15	"	"		58,000
SW "	" "	"	"		290,000
SE "	" "	"	"		339,000
NE "	" 22	"	"		126,000
SW "	" 14	"	"		87,000
NW "	" 23	"	"		216,000
NE "	" "	"	"		58,000
SW "	" "	"	"		29,000
SE "	" "	"	"		96,000
NE "	" 26	"	"		48,000
SW "	" 24	"	"		216,000
NW "	" 25	"	"		216,000
NE "	" "	"	"		126,000
SE "	" "	"	"		5,000
NW "	" 30	"	2		1,000
SW "	" "	"	"		15,000
SE "	" "	"	"		19,000
NE "	" 31	"	"		14,000
SW "	" 32	"	"		5,000
NE "	" 5	8	"		5,000
NW "	" 2	"	"		5,000
					2,632,000

Bentonite beneath Middle Creek Limestone

Another promising bed of bentonite occurs approximately 9 feet below the Middle Creek limestone. Like other beds of bentonite this one is not continuous but is found only in that belt between the west side of Sec. 18, T.9 N., R.2 E., and the state line. Exposures are prominent near the top of Middle Creek Buttes and just under the escarpment north of Highway 30. Other exposures occur in Crow Creek valley.

Thickness of the bed varies from nearly 4 feet in Middle Creek Buttes and near the state line to 2 feet in Sec. 18, T.9 N., R.2 E. East of this point the bed is absent. It could not be determined from Wyoming reports whether or not the bed has been observed across the line in that state.

This bed is generally light olive-gray in color but in some places is white. In general the upper surface and those surfaces along joints are stained yellow with iron. Since the formation was almost pure white in test pits dug back several feet from the face of the outcrop, it appears probable that the greenish and rust colors are weathering phenomena and that the bed may yield largely white bentonite. In places this bentonite shows well developed Liesegang rings.

Outcrops of this bed are characterized by their whitish appearance and not by curls as in the type 1 bentonite in Middle Creek valley.

Tests show that this is not the high swelling type of bentonite. It has a pH value of 6.9. When the dried material is placed in water, it slakes rapidly. When dry, pulverized product is placed in suspension in water, it settles quickly.

There has been no production to date from this bed. Uses have not been established. It is probable that this bentonite will not be suitable for all of the uses now found for the high swelling, type 1 bentonite. It is felt, however, that research will disclose other equally important uses.

The bed is so situated that it may be worked from open pits. Since the bed lies 9 feet below the Middle Creek limestone, the overburden along the outcrop averages between 10 and 12 feet in thickness. It is suggested that if the uses justify the expense and a particularly white product is desired, it be mined by underground methods. Such mines would have to be located on the northeastern side of Crow Creek and within two or three miles of the state line.

Estimates of the quantity available are as follows:

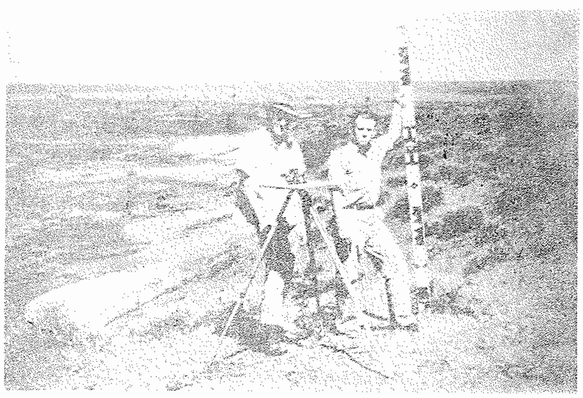
TABLE III

Estimate of the quantity of bentonite available under the Middle Creek limestone

Location	Volume
Middle Creek buttes, Sec.32, T.10 N., and Sec. 5, T.9 N., R.1 E.	44,000 cu.yds.
Deposit on section line between Secs.19 and 20, T.10 N., R.1 E.	19,000 " "
Deposit near NW corner of Sec. 29, T.10 N., R.1 E.	19,000 " "
Deposit SE of center of Sec. 29, T.10 N., R.1 E.	73,000 " "
Deposit in NW$\frac{1}{4}$ of Sec. 23, T.10 N., R.1 E.	68,000 " "
Deposit in SW$\frac{1}{4}$ of Sec. 34, T.10 N., R.1 E.	29,000 " "
Deposit NW of center of Sec. 2, T.9 N., R.1 E.	77,000 " "
Deposit in NE corner of Sec. 11 and NW corner of Sec. 12, T.9 N., R.1 E.	73,000 " "
Sec. 12, T.9 N., R.1 E.	73,000 " "
" 13, " "	82,000 " "
" 18, " 2	77,000 " "
" 19, " "	73,000 " "
" 20, " "	73,000 " "
	780,000 cu.yds.

Outcrops of Upper Mowry Bentonite Bed

Capping Bluff along Belle Fourche River near Belle Fourche.



Typical exposure along sides of small valley Sec. 23 T.9 N., R.1 E.

Bentonite seam typically exposed on terrace Sec. 6, T.9 N., R.1 E.

PLATE II

In the Middle Creek buttes and in the small outliers in sections 19, 20 and 29, the entire deposit could be removed. In the other deposits north of highway 30, however, only a narrow strip along the southern margin of the deposit could be recovered. This is due to the fact that the overburden thickens toward the northwest. This fact was taken into consideration in determining the above estimates.

Lower Graneros Bentonite near Minnelusa

A deposit of bentonite of limited extent was found in the northeastern corner of Sec. 30, T.8 N., R.3 E. This is approximately 1 mile southeast of Minnelusa. This deposit is easily accessible and could be reached from an all-weather road leading through Minnelusa.

The bed is approximately 18 inches thick and is light olive-green color. As near as could be determined, the bed occurs in the lower Graneros shale.

Pierre Shale Bentonite Northwest of Belle Fourche

A deposit of bentonite was observed in Sec.26, T.12 S., R.1 E. about 36 miles northwest of Belle Fourche. The best exposure occurs about one-half mile west of the Hantz house under a wooden bridge. Elsewhere the bed is so completely covered that its extent could not be determined.

The exposure showed an 18 inch bed of bentonite at the base and a foot bed of bentonite at the top, separated by a 1 foot layer of black bentonitic clay. Both beds were yellowish olive-green in color and appeared to be of good quality. No attempt was made, however, to test them since they occur too far from a shipping center to be of commercial importance.

This deposit apparently occurs near the base of the Pierre shale, and is possibly equivalent to the Pedro bentonite of Wyoming and the Ardmore bentonite produced at Ardmore, South Dakota.

Pierre Shale Bentonite east of Sturgis

Another Pierre shale bentonite is exposed along Elm Creek, where highway 24 crosses the creek 36½ miles east of Sturgis. This is the deposit which is being exploited by the Cody Bentonite Corporation of Sturgis, although no bentonite had been processed by the end of the field season in 1939. The company had reached the stage where a mill was being erected in Sturgis, and only a few tons of bentonite had been hauled from the field.

The bentonite averages about two feet in thickness. The upper part is light yellow green in color and appears to be of good quality. The lower foot is slightly brownish in color and may not be quite so pure. The bed grades downward into black bentonitic shale. In some places the bentonite contains large shells of calcite which could not be avoided altogether in producing the bentonite. It is possible, however, to remove calcite in the milling operation and it is further suggested that calcite might not affect the bentonite for certain uses. As near as could be ascertained this bed occurs in the Virgin Creek member or its equivalent in the Pierre shale.

CONCLUSION

Although there are a number of beds of bentonite in the area north and east of the Black Hills ranging in age from the lower Graneros to the Virgin Creek division of the Pierre, only two are of undoubted commercial value. One of these is the high grade, type 1 bentonite occurring in the top of the Mowry shale from which the Belle Fourche bentonite is produced at the present time. The reserves in this field are exceedingly large and may be greatly extended by including deposits in Wyoming which must be shipped from Belle Fourche.

The other promising bed is the one occurring beneath the Middle Creek limestone and is classed as bentonite here because of its origin. It differs, however, in its properties from type 1 bentonite now produced at Belle Fourche. Because of its unusual properties and the large tonnage available it is desirable that further research be undertaken with material from this bed so as to establish its suitability for certain uses.

References

In addition to articles concerned with bentonite listed in the Annotated Bibliography of Economic Geology,[1] attention is directed to others not listed. The latter are publications of producers and are concerned chiefly with the properties and uses of bentonite. These articles will prove helpful and should be studied carefully by prospective users of bentonite.

Producers who have issued noteworthy publications are:

1. The American Colloid Co., 363 West Superior Street, Chicago, Illinois.
2. F. E. Schundler and Co., Inc., 600 Railroad Street, Joliet, Illinois.

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1. Economic Geology Publishing Co., Urbana, Ill.