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BENTONITE IN WYOMING

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BENTONITE IN WYOMING

By J. H. Heathman

INTRODUCTION

Wyoming bentonite has been discussed in many papers but, in most cases, only in a general way or in connection with a small area. The chemical and physical properties of bentonite have appeared in many publications. The purpose of this paper is to discuss the stratigraphic occurrence and areal distribution of bentonite throughout the larger part of the state. The principal outcrops are described in detail and several sections showing stratigraphic occurrence are given. A portion of the paper is devoted to the bentonite industry. This includes production history, figures, and methods, and a number of uses of bentonite. Factors controlling the value of deposits are also discussed. It is hoped that the facts included here will be of use in the development of the bentonite industry in the state.

Field work was carried on from August 1 to September 15, 1938, under the direction of Dr. S. H. Knight, State Geologist. Field expenses were furnished by the Geological Survey of Wyoming. Because of the large amount of territory to be covered in the short time available and the abundance of bentonite in or near the Mowry formation, most of the time was given to the study of the bentonite in this formation. The writer believes that he examined all of the major outcrops and a majority of the smaller ones in the area studied (Fig. 1).

The writer acknowledges the help of the staff of the Geology Department of the University of Wyoming and is especially indebted to Dr. R. H. Beckwith for help in the preparation of this paper. He extends thanks to James Vernon, field assistant, and to Mr. Paul Peterson of Upton and Mr. Ben Thoeming of Newcastle for valuable information provided during the field work.

DESCRIPTION

Bentonite is a clay material which contains 75% or more of the crystalline minerals montmorillonite, $(Mg, Ca)O.Al_2O_3.5SiO_2.nH_2O$, or beidellite, $Al_2O_3.3SiO_2.nH_2O$. A sample analysis (Table 1) shows the chemical composition of an average bentonite sample (5: 157).

The uses of bentonite at the present time depend on its physical properties rather than its chemical composition. Some bentonites have the physical property of swelling to ten or fifteen times their original volume when in contact with water, and it is this physical property that determines the value of such bentonites. The bentonites produced in the United States are divided into two classes (7: 1114), (1) those which swell to several times their original volume when in contact with water, and (2) those which swell no more than ordinary plastic clays.

TABLE 1

Analysis of Average Bentonite

SiO_2	61.94
Al_2O_3	15.97
P_2O_5	.07
Fe_2O_3	2.92
FeO	.71
MgO	2.45
CaO	1.72
Na_2O	1.61
K_2O	.29
H_2O-	7.17
H_2O+	3.95
TiO_2	.23
CO_2	.41
SO_3	.15
S	.01
C	.14

Most Wyoming bentonites are in the first class and are used as the standard for the United States.

Bentonite in the ground is usually damp. It is then a green, soft, wax-like material with a high luster. On drying, the luster becomes dull and the material becomes harder and lighter in color. The fracture is conchoidal. The surface of a weathered outcrop is white with a crinkly, coral-like appearance. Gypsum crystals up to three inches in length are often contained in the bentonite. These crystals weather out and are abundant near the outcrop.

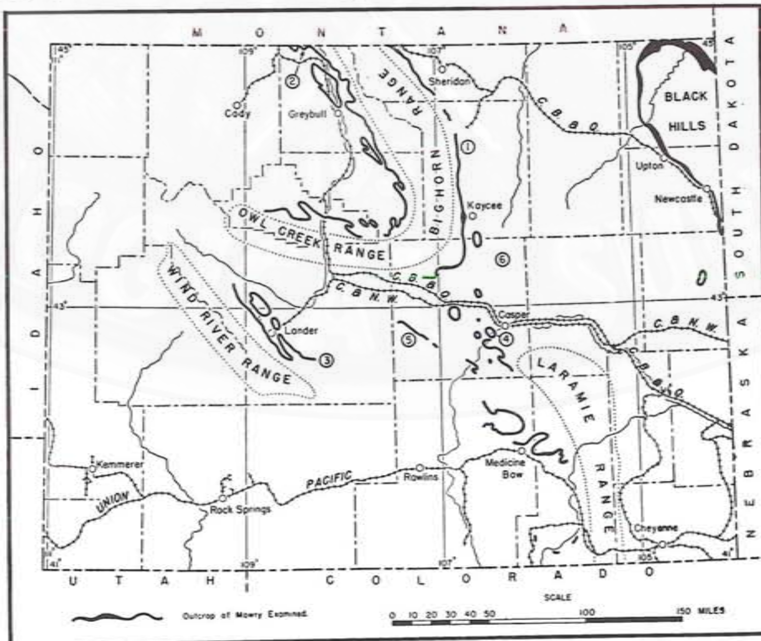

Fig. 1.—Map of Mowry outcrops examined.

ORIGIN

The origin of bentonite has been the subject of much discussion and many theories concerning its origin have been advanced. In 1926, however, Ross and Shannon (3: 79) restricted the rock name bentonite to a material derived from volcanic ash. This restriction was placed on the term because the physical properties of bentonite depend on inherited structure as much as on mineral composition. Conditions of deposition also must be taken into consideration. Rubey has shown (5: 159) that, around the Black Hills, the siliceous shales of the Mowry and the interstratified seams of bentonite are of approximately the same chemical composition. The shales were originally volcanic ash mixed with organic matter and other impurities. The bentonite seams were originally beds of pure volcanic ash.

The process involved in the alteration of ash to bentonite is not well known. Ross, Miser and Stephenson (4: 186) have produced evidence to show that the alteration took place after deposition. They also list several known factors involved in the alteration process. The factors listed are the absence of oxidizing conditions, the presence of water for hydration, the removal of excess chemical constituents, and the probable presence of bicarbonates, sodium chloride, and possibly of magnesium salts from the sea water. They say, "Alteration . . . . seems to have been the result of hydration and solution of an unstable glass that was perhaps more or less aided by the presence of chlorides and bicarbonates, the latter probably in very weak concentration."

USES

The prinicpal uses of bentonite are as a bonding agent in foundry molding sands; oil-well drilling mud; for bleaching petroleum products; in the manufacture of cement products, ceramic products, soaps, refractory materials, paper, cosmetics, water softeners, sealing agents, paints, medicinal emulsions, roofing; for de-inking newsprint, clarifying dry-cleaner fluids; as the core of earth-fill dams, and as lining for irrigation ditches. This list is not exhaustive, and new uses for bentonite are being found every year.

STRATIGRAPHIC OCCURRENCE

Bentonite occurs in Wyoming in seams interbedded in shales and sandstones. The seams range from a fraction of an inch up to twelve feet in thickness. Beds of siltstone and impure bentonite up to 150 feet thick (6: 3) have been reported. Some of the seams are constant enough in thickness so that they can be traced laterally for many miles. Others thicken and thin so markedly that they appear to be lenses. There are few seams of pure bentonite that maintain a thickness greater than five feet over many miles.

The bottom contact of a bentonite seam is, in most cases, sharp. The underlying few inches of shale is harder than the shale below and stands out in topographic relief (Fig. 2). The upper contact is, in most cases, gradational, especially in shale. The thickness of the zone

Fig. 2.
Hard altered shale bed beneath a bentonite seam.

of gradation is proportional to the thickness of the seam and may be two or three feet in the case of a ten-foot seam.

Most of the seams are in the lower part of the Upper Cretaceous series (Table 2). They are especially abundant in the Mowry shale, decreasing in number above and below it. The most persistent seam is at the top of the Mowry. This seam is fairly constant in thickness and can be located wherever the top of the Mowry crops out. Seams are present in the Thermopolis, Frontier, Steele, Mesaverde, and Meeteetse formations (Table 2) and their equivalents. A clay closely resembling bentonite has been reported from the Upper Eocene rocks in the Bighorn Basin (1: 196). This clay and the bentonite in the Meeteetse formation were not examined by the writer.

VARIATION IN CHARACTER

The writer's opinion, based only on field observation, is that the best bentonites in Wyoming are in the lower part of the Upper Cretaceous series and that these bentonites vary in character from the eastern and southeastern part of the state to the northwestern part. Bentonite in formations older than the Niobrara (Table 2) appears to be pure and of good grade, when in seams more than a few inches thick. With one or two exceptions, the bentonites in the formations younger than Niobrara contain sand or silt and do not appear to be of good grade. In the eastern, southeastern and central parts of the state the early Upper Cretaceous bentonites are dark green, soft, and moist when first removed from the ground. In the northwestern part of the state, bentonites of the same age are lighter in color, harder and drier when first re-

TABLE 2
Correlation of Upper Cretaceous formations in Wyoming

<table>
<tr><th colspan="2">Wind River Mountains and Bighorn Basin</th><th colspan="2">Southeastern, Central and North-central Wyoming</th><th colspan="3">Black Hills</th></tr>
<tr><td colspan="2">Meeteetse formation</td><td>Lewis shale</td><td>Fox Hills sandstone</td><td colspan="3">Fox Hills sandstone</td></tr>
<tr><td colspan="2" rowspan="2">Mesaverde formation</td><td colspan="2" rowspan="2">Mesaverde formation</td><td rowspan="4">Pierre shale</td><td colspan="2">Monument Hill shale</td></tr>
<tr><td colspan="2">Mitten shale</td></tr>
<tr><td colspan="2" rowspan="2">Cody shale</td><td rowspan="2">Steele shale</td><td rowspan="2">Shannon sandstone</td><td rowspan="2">Gammon</td><td>Groat sandstone</td></tr>
<tr><td>Pedro bentonite</td></tr>
<tr><td colspan="2" rowspan="2">Niobrara formation</td><td colspan="2" rowspan="2">Niobrara formation</td><td rowspan="2">Niobrara formation</td><td colspan="2">Beaver Creek chalk</td></tr>
<tr><td colspan="2">Sage Breaks shale</td></tr>
<tr><td rowspan="4">Frontier formation</td><td>Torchlight sandstone</td><td rowspan="4">Frontier formation</td><td>Wall Creek sandstone</td><td>Carlile shale</td><td colspan="2">Turner sand</td></tr>
<tr><td></td><td></td><td colspan="3">Greenhorn limestone</td></tr>
<tr><td>Peay sandstone</td><td>Peay sandstone</td><td rowspan="4">Graneros shale</td><td colspan="2">Belle Fourche shale</td></tr>
<tr><td></td><td></td><td colspan="2">Mowry shale</td></tr>
<tr><td colspan="2">Mowry shale</td><td colspan="2">Mowry shale</td><td colspan="2">Newcastle sandstone</td></tr>
<tr><td colspan="2">Thermopolis shale</td><td colspan="2">Thermopolis shale</td><td colspan="2">Skull Creek shale</td></tr>
</table>

moved from the ground. It does not seem probable that these differences are the result of differences in degree of folding of the beds, inasmuch as the bentonites from seams in the Mowry dipping at angles up to 90 degrees at the west end of Casper Mountain are identical in external characteristics with those from flat-lying beds in the same area. The variation from place to place in character of bentonites from approximately the same stratigraphic horizon is probably the result of differences in conditions of deposition, distance from source of supply of ash, or degree of alteration after deposition. The differences in character of the material as mined may have some correlation with differences in swelling properties, but whether or not this is true can be determined only by extensive laboratory work on a large number of samples.

AREAL DISTRIBUTION

BLACK HILLS

Most of the bentonite seams in the Black Hills (Fig. 1) are in the Mowry shale and Belle Fourche shale, the upper two members of the Graneros formation. The Mowry is a succession of black siliceous shales, which weather silver-gray and contain many fish scales. The thickness averages 150 feet. The Mowry is more resistant to erosion than the beds above and below and forms a low ridge covered by scrub pine and oak. Above the Mowry is the Belle Fourche shale, a succession of black thin-bedded soft shales containing black to rust-colored hard siderite concretions up to six feet in diameter. The concretions, locally known as "turtle backs," are especially abundant in the basal 20 or 30 feet of the member. The total thickness of the Belle Fourche is approximately 300 feet. The area of outcrop of the member takes the topographic expression of a broad valley adjacent to the ridge formed by the Mowry.

The beds involved in the Black Hills uplift dip, in general, away from the center of the dome. In the southern and western parts of the area (Fig. 3) they dip to the southwest, in the northern part to the north, and in the northeastern part to the northeast. On the flanks of the dome there are, however, gentle, minor anticlines and synclines, which cause repetition of the Mowry and Belle Fourche in a few places.

There are many bentonite seams in the Mowry and lower part of the Belle Fourche. The thickest two are in the bottom and top parts of the Mowry. The lower seam crops out along one side of the Mowry ridge and extends beneath it. The outcrop is covered in most places by weathered material, which has crept down the side of the ridge, and consequently the area of outcrop under cover is not known. The upper seam, called the Clay Spur bentonite bed (6: 4) crops out along the opposite side of the Mowry ridge and, in many places, extends to the crest of the ridge. Over large areas the bentonite seam has been exposed by the erosion of the overlying basal beds of the Belle Fourche and has a width of outcrop up to a mile. The outcrop of the bentonite is not a continuous band. In some places the bentonite is overlain by outliers of the lower portion of the Belle Fourche up to five acres in extent and, in other places, gullies have cut through the bentonite into the underly-

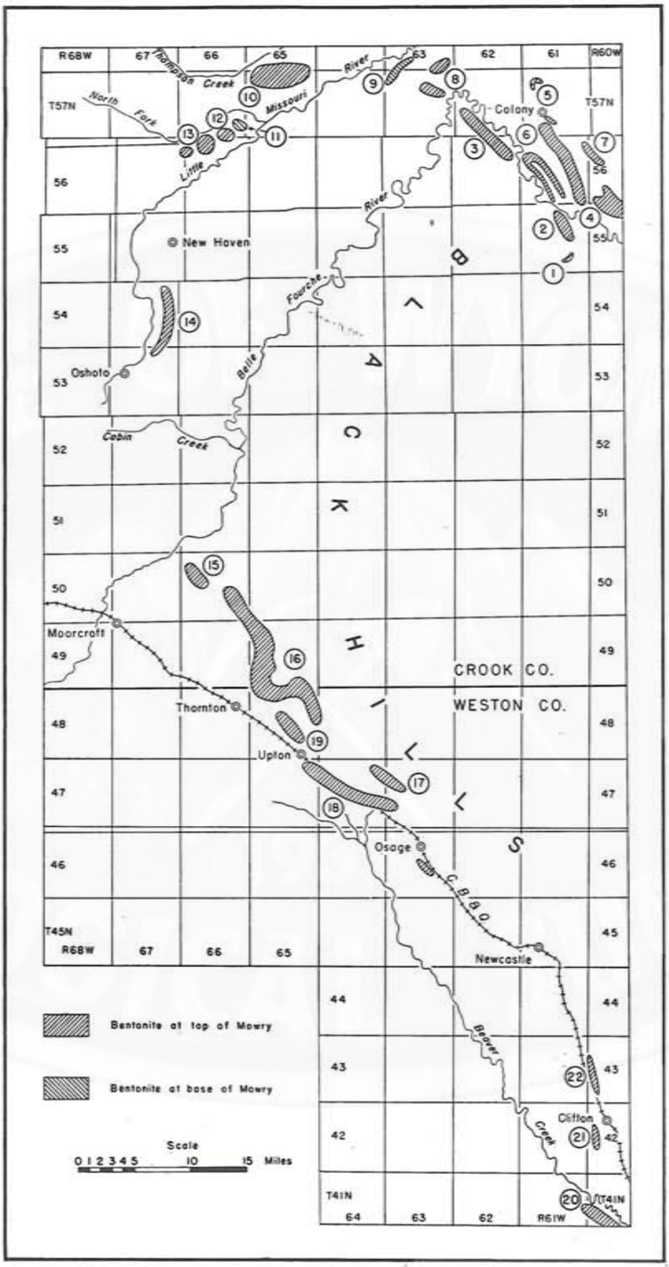

Fig. 3.—Map of major bentonite outcrops around the Black Hills in Wyoming.

ing shale. The Clay Spur seam can be traced completely around the Black Hills in Wyoming. Near Osage and near Clifton a 3-foot seam lies 20 feet above the base of the Belle Fourche. The width of outcrop of this seam is only a few feet. The Pedro bentonite bed at the base of the Pierre shale (6:4) was examined by the writer, but the bentonite is impure and contains much sand and silt.

The most extensive areas of outcrop of the thicker bentonite seams are shown on the map (Fig. 3). At each numbered outcrop the thickness was measured and a sample of about two pounds was collected and preserved for further study. The thickness given below (Table 3) is that between the overlying and underlying shale. Over large parts of the mapped areas the thickness of the bentonite is less than the figure given because the upper part of the seam has been eroded.

TABLE 3

Bentonite outcrops of the Black Hills

Outcrop No.	Thickness of Seam, Feet	Average Dip, Degrees	Place of Measurement Section	T. N.	R. W.	Over-burden, Feet	Sample No.
1	2.5	5	26	55	61	10—30	....
2	3.0	2	10	55	61	0—15	1
3	4.8	3	3	56	62	0—25	2
4	4.5	5	4	55	60	0—25	3
5	2.0	4	8	57	61	0—25	4 & 5
6	3.5	3	9	56	61	0—20	6
7	2.0	3	12	56	61	0—15	7
8	3.0	2	14	57	63	0—15	8
* 9	5.0	2	32	58	63	0—35	9
10	4.2	5	34	58	65	0—25	10
*11	5.5	0	25	57	66	0—15	14
12	2.0	3	35	57	66	0—20	15 & 16
13	2.5	2	4	56	66	0—20	17
14	4.0	3	34	54	67	0—25	18
†15	2.5	3	23	50	66	0—20	20
16	2.5	3	36	50	66	0—20	21
16	2.5	3	8	49	65	0—20	22
16	2.5	3	17	49	65	0—20	23
16	2.5	3	17	49	65	0—20	24
16	2.5	3	20	49	65	0—20	25
16	2.5	3	29	49	65	0—20	26
16	2.5	3	2	48	65	0—20	31
17	2.5	3	11	47	64	0—20	27
18	2.5	3	27	47	64	0—20	28 & 29
18	2.5	3	17	47	64	0—20	33
19	2.5	3	16	48	65	0—20	32
20	3.0	4	13	41	61	0—25	34 & 35
21	2.5	4	7	42	60	0—20	38
22	1.3	7	19	43	60	0—25	39

*Seam at base of Mowry.
†Thickness, dip, and overburden are average for 15—19.

For northern Crook County, the nearest railway shipping point is Belle Fourche, South Dakota, which is 25 miles southeast of Colony, Wyoming. Alzeda, Montana, is two miles north of the state line, north of T. 58 N., R. 63 W., and an oiled highway extends from Alzeda, through Colony to Belle Fourche. The highway is easily accessible from all the bentonite outcrops in the northern part of Crook County. A county road extends from Alzeda, through New Haven and Oshoto, to Moorcroft. An oiled highway parallels the Burlington railroad tracks from Moorcroft to Clifton and then turns south into Niobrara County. This highway is easily accessible from all the outcrops between Moorcroft and Clifton, and is within five miles of all of them. A network of trail roads covers the Mowry outcrops all around the Black Hills.

EAST FLANK OF BIGHORN MOUNTAINS

Most of the bentonite seams on the east and south sides of the Bighorn Mountains (Fig. 1) are in the Thermopolis, Mowry and Frontier formations. The Thermopolis is a succession of black thin-bedded soft shales containing black to rust-colored hard siderite concretions. There are several hard slabby tan sandstone beds about two feet thick and a buff friable sandstone bed about 20 feet thick near the middle of the formation. The total thickness of the formation is approximately 500 feet. The Thermopolis is the probable time equivalent of the Skull Creek and Newcastle members (Table 2) of the Graneros formation of the Black Hills. Above the Thermopolis is the Mowry formation, lithologically and topographically the same as the Mowry in the Black Hills. The total thickness of the Mowry here is approximately 300 feet. It is thought that the Mowry is of the same age throughout the state. Above the Mowry is the Frontier formation, a succession of black thin-bedded soft shales containing black to rust-colored hard siderite concretions and, in the southern part of the range, tan massive compact sandstones. The total thickness of the formation is approximately 700 feet. The Wall Creek sandstone member at the top of the formation is about 100 feet thick. The sandstones below the Wall Creek are lenses up to 80 feet thick, which range from one to five in number. The total thickness of the sandstone lenses is greatest at the south end of the range. They are thinner and fewer in number north of Kaycee (Fig. 1). South and west of Kaycee the thick sandstones form cuestas with high cliffs that rise abruptly from the dip slope of the Mowry hogback or succeeding cuestas. The Frontier is the time equivalent of the Carlile and Greenhorn formations and the Belle Fourche member of the Graneros formation of the Black Hills.

The stratigraphic positions of a number of bentonite seams are given in the following section (Table 4), which was measured at location 1 (Fig. 1).

TABLE 4

Section of the Thermopolis, Mowry, and lower Frontier measured in sec. 36, T. 49 N., R. 83 W.

	Thickness (feet)
Lower Frontier:	
Bentonite	1.5
Shale	14.4
Bentonite	0.5
Shale	2.0
Bentonite	0.5
Shale	15.4
Bentonite	1.0
Shale	12.0
	47.3
Top of Mowry:	
Bentonite	2.5
Shale	40.1
Bentonite	3.5
Shale	51.8
Bentonite	3.5
Shale (poorly exposed)	27.7
Shale	11.5
Bentonite	1.0
Shale (poorly exposed)	45.3
Bentonite	0.3
Shale	10.5
Bentonite	0.5
Shale	5.0
Bentonite	0.4
Shale	3.5
Bentonite	1.0
Shale	7.8
Bentonite	0.3
Shale	26.3
Mowry: (continued)	
Bentonite	0.5
Shale	11.0
Bentonite	1.5
Shale	4.0
	259.5
Top of Thermopolis:	
Shale (poorly exposed)	21.0
Bentonite	0.3
Shale	5.7
Bentonite	0.3
Shale	5.2
Bentonite	2.5
Shale	3.8
Bentonite	0.5
Shale	4.3
Bentonite	0.5
Shale	15.4
Bentonite	0.5
Shale	8.6
Bentonite	1.5
Shale	51.5
Covered interval	25.9
Shale	45.4
Sandstone	20.0
Shale and sandstone	118.2
Shale	171.0
	502.1

Fig. 4.—Bentonite seam (white) at the top of the Mowry dipping beneath the Frontier T. 38 N., R. 85 W.

This section does not show a 2-foot seam approximately 100 feet above the base of the Frontier, and another 2-foot seam approximately 200 feet above the base.

From the state line on the north to Kaycee on the south the Upper Cretaceous rocks are concealed by thick alluvium, which extends eastward several miles from the mountain front. Erosion has cut through the alluvium in only a few places. At a point three miles south of the state line the dip of the Mowry is 18 degrees and this increases to 45 degrees at a point ten miles south of the line. At the location of the section (Table 4) the dip is 15 degrees and the width of outcrop of a bentonite seam is only slightly greater than its thickness. Five miles west of Kaycee the bentonite seam at the top of the Mowry crops out in the center of a small syncline, but the area of outcrop is only a few acres and erosion has removed about fifty percent of the bentonite. From Kaycee on south and west to the end of the Bighorn Range the Upper Cretaceous rocks are well exposed. All the bentonite seams, however, dip under the cuesta formed by the sandstones in the Frontier (Fig. 4). The seam at the top of the Mowry appears as a white band at the base of the cliff formed by the lowest Frontier sandstone. The dips around the south end of the Bighorn Range change rapidly from place to place, but 12 degrees probably would be an average for the whole southern area.

SOUTH AND EAST SIDES OF BIGHORN BASIN

The majority of the bentonite seams in the Bighorn Basin, located west of the Bighorn Range (Fig. 1), are at approximately the same horizons as those on the east side of the Bighorn Range. The descriptions of the Thermopolis, Mowry, and Frontier formations given for the Black Hills and the east flank of the Bighorn Mountains will serve, with a few exceptions, for the Bighorn Basin and the central and southeastern parts of the state. In the Bighorn Basin the Thermopolis is slightly thicker, the Mowry thins to less than a hundred feet at the north end of the basin, and both the Mowry and Frontier contain more sandy material at the north end of the basin. A massive sandstone, the correlative of the Wall Creek, at the top of the Frontier is called the Torchlight sandstone member, and a persistent sandstone in the lower part of the Frontier is the Peay sandstone member.

The stratigraphic positions of a number of bentonite seams are given in the following section (Table 5), which was measured at location 2 (Fig. 1).

TABLE 5

Section of the Thermopolis, Mowry, and Frontier measured in sections 30 and 31, T. 58 N., R. 95 W.

	Thickness (feet)
Top of Frontier:	
Massive sandstone (Torchlight)	73.7
Shale	272.4
Bentonite	1.0
Pebble conglomerate	1.0
Shale	152.0
Bentonite	2.0
Shale	65.1
Concretionary sandstone (Peay)	87.6
Bentonite	0.7
Sandstone	8.5
Bentonite	0.7
Sandstone and shale	20.2
Bentonite	0.3
Sandstone and shale	134.8
	820.0
Top of Mowry:	
Bentonite	2.5
Shale	0.7
Bentonite	2.5
Hard sandy shale	36.8
Shale (poorly exposed)	52.9
	95.4
Top of Thermopolis:	
Shale (poorly exposed)	54.5
Bentonite	1.0
Shale	7.7
Bentonite	1.5
Thermopolis: (continued)	
Shale	34.3
Bentonite	0.5
Shale	1.7
Bentonite	2.5
Shale	54.2
Bentonite	2.5
Shale	34.8
Bentonite	0.5
Shale	91.7
Bentonite	0.5
Shale	80.0
Bentonite	1.3
Shale	58.8
Bentonite	1.0
Shale	42.1
Bentonite	1.3
Shale	2.3
Bentonite	0.7
Shale	28.7
Bentonite	1.0
Shale	51.6
Bentonite	0.5
Shale	7.2
Bentonite	0.5
Shale	4.5
Bentonite	1.0
Shale	392.0
	962.4

The stratigraphic positions of a number of bentonite seams in the Frontier on the west side of the Bighorn Basin are given by Hewett (2:14).

The beds on the southern and eastern margins of the Bighorn Basin are involved in a number of sharp anticlines and synclines. The lower formations of the Upper Cretaceous series crop out in the steep flanks of the folds, and the outcrops of bentonite seams are, in most cases, narrow. In the few areas of low dips the bentonite beds dip under the cliffs formed by the Frontier sandstones.

The largest bentonite outcrop seen by the writer in the Bighorn Basin is located 18 miles northwest of Greybull and one-half mile east of the oiled road between Greybull and Lovell. Here there is a strip approximately a mile long and fifty feet wide. The seam is approximately thirty feet above the top of the Peay sandstone and dips 31 degrees to the west. The hard altered shale bed forming the floor under the bentonite seam stands out in a number of smaller flatiron-shaped hogbacks on the dip slope of the Peay hogback. The minor hogbacks are up to 50 feet high and 40 feet wide along strike. The sediments above the bentonite, and part of the bentonite have been removed by erosion, so that the thickness of the seam ranges from zero at the top of the hogback to a full thickness of four feet at the base.

NORTHEAST FLANK OF WIND RIVER MOUNTAINS

Bentonite seams on the northeast flank of the Wind River Mountains (Fig. 1) are at approximately the same horizons as in the Bighorn Basin, and the Thermopolis, Mowry, and Frontier formations are closely similar. The Frontier contains more sandy material.

The stratigraphic positions of the bentonite seams in the Mowry are given in the following section (Table 6), which was measured at location 3 (Fig. 1).

TABLE 6

Section of the Mowry formation measured in sec. 34, T. 31 N., R. 96 W.

Top of Mowry:	Thickness (feet)
Covered interval	20.0
Shale	10.9
Bentonite	0.4
Shale	1.2
Bentonite	0.5
Shale	1.0
Sandstone	1.0
Shale	1.0
Bentonite	0.5
Shale	1.5
Bentonite	3.0
Shale	1.5
Bentonite	2.5
Shale	7.4
Bentonite	0.3
Shale	3.2
Bentonite	0.1
Shale	13.0
Bentonite	0.5
Shale	7.0
Bentonite	0.1
Shale	16.9
Shale	3.8
Bentonite	0.8
Shale	1.0
Sandstone	0.7
Shale	6.8
Bentonite	1.5
Shale	3.1
Bentonite	0.1
Shale	5.5
Bentonite	0.1
Shale	0.8
Bentonite	0.1
Shale	4.5
Bentonite	0.1
Shale	1.5
Bentonite	0.2
Shale	5.0
Bentonite	0.1
Shale	2.0
Bentonite	0.2
Shale	3.0
Bentonite	0.4
Shale	2.5
Bentonite	0.1
Shale	0.4
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.5
Bentonite	0.1
Shale	1.0
Bentonite	0.1
Shale	0.6
Bentonite	0.4
Shale	0.3

Mowry: (continued)	Thickness (feet)
Bentonite	0.3
Shale	0.1
Bentonite	0.1
Shale	0.5
Bentonite	0.2
Shale	1.6
Bentonite	0.4
Shale	3.3
Bentonite	0.3
Shale	5.1
Bentonite	0.2
Shale	2.5
Bentonite	0.1
Shale	0.2
Bentonite	0.1
Shale	0.4
Bentonite	0.2
Shale	0.6
Bentonite	0.8
Shale	1.0
Bentonite	0.1
Shale	0.4
Bentonite	0.1
Shale	0.3
Bentonite	0.1
Shale	0.6
Bentonite	0.2
Shale	1.3
Bentonite	0.1
Shale	2.0
Bentonite	0.1
Shale	0.2
Bentonite	0.3
Shale	0.8
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.3
Bentonite	0.1
Shale	0.8
Bentonite	0.2
Shale	6.0
Bentonite	0.2
Shale	0.2
Bentonite	0.3
Shale	1.2
Bentonite	0.1
Shale	0.3
Bentonite	0.1
Shale	2.0
Bentonite	0.7
Shale	3.5
Bentonite	0.4
Shale	1.0
Bentonite	1.0
Shale	1.0
Bentonite	5.0
	190.6

This section was measured in a road cut, and shows many thin bentonite seams which cannot be located on the surface. The thinnest seams appear to be bentonite, but in some cases the identification is doubtful.

The beds of the north flank of the Wind River Range proper dip to the northeast. The main range is paralleled on the northeast side by a syncline and an adjacent anticline, along the crest of which are several domes. The beds on the southwest flank of the anticline dip up to 90 degrees and, in some cases, are overturned. The best exposures of Thermopolis, Mowry, and Frontier are on the flanks of the anticline, but the bentonite outcrops are narrow. No sizable outcrops of bentonite were seen by the writer in this area.

CENTRAL AND SOUTHEASTERN PARTS OF WYOMING

General Statement.—Most of the bentonite seams in the central and southeastern parts of the state are in the Thermopolis, Mowry, and Frontier formations. The sandstones in the Frontier become fewer in number and less prominent topographically in the southeastern part of the state. A concretionary band is present at the base of the Frontier, much like the one at the base of the Belle Fourche member of the Graneros formation in the Black Hills. In addition to the seams in these formations, there is a thick bentonite seam in the upper part of the Steele and another at the base of the Mesaverde.

Rattlesnake Hills.—The thickest bentonite seam on the north flank of the Rattlesnake Hills (location 5, Fig. 1) is the one at the top of the Mowry; its thickness is approximately three and one-half feet. The beds on the north flank of the Rattlesnake Hills dip to the northeast at an average angle of 30 degrees. The upper 15 or 20 feet of the Mowry shale has slid down in the direction of dip and forms an irregular ridge that parallels the hogback of the lower Mowry for the full length of its outcrop, a distance of some 25 miles. The large bentonite seam is included in the land-slip material and, although easily located, changes strike and dip every few feet. Because of the high dip, the outcrop of any bentonite seam is narrow.

Salt Creek Area.—Bentonite seams in the Salt Creek area (location 6, Fig. 1) are in the Steele shale (Table 2), a succession of soft thin-bedded gray shales with the Shannon sandstone member near the middle. The total thickness of the formation is 2300 feet. The Shannon sandstone is 170 feet thick and is located 1000 feet above the base of the Steele.

A thick bentonite seam approximately 300 feet above the Shannon sandstone crops out in a syncline adjacent to the southwest flank of the Salt Creek dome. The area of outcrop comprises about seven square miles located from one to four miles west of the abandoned town of Salt Creek, in the western part of T. 39 N., R. 79 W. The oiled highway between Casper and Midwest is three miles east of the area. The bentonite seam is approximately 12 feet thick and the dip is three degrees. The lower four feet of bentonite appears to be pure and of good grade. The overlying five feet is slightly shaly and sandy, and the upper three

Fig. 5.—Thin seams of bentonite (white) exposed in a road cut in the Mowry shale. Location 4 (Fig. 1).

feet is part of a zone of gradation into the overlying shale. The overburden of soft shale probably averages less than 20 feet for the whole area of outcrop.

Casper Area.—The Thermopolis, Mowry, and Frontier formations are exposed on the flanks of several folds west and southwest of Casper, (Fig. 1) and on the westward-plunging nose of the Laramie Range south of Casper. The stratigraphic positions of the bentonite seams in the upper Thermopolis and Mowry formations are given in the following section (Table 7), which was measured in a road cut (Fig. 5) at location 4 (Fig. 1).

TABLE 7

Section of upper Thermopolis and Mowry measured in sec. 32, T. 33 N., R. 80 W.

Top of Mowry:	Thickness (feet)	Mowry (Continued)	Thickness (feet)
Bentonite	4.0	Bentonite	0.9
Shale (poorly exposed)	55.1	Shale	2.3
Bentonite	2.2	Bentonite	0.5
Shale	0.3	Shale	2.4
Bentonite	2.0	Bentonite	2.5
Shale	1.4	Shale	3.5
Bentonite	0.1	Bentonite	0.3
Shale	1.2	Shale	3.6
Bentonite	0.1	Bentonite	0.2
Shale	1.1	Shale	1.4
Bentonite	0.1	Bentonite	0.1
Shale	0.4	Shale	1.8
Bentonite	0.3	Bentonite	0.1
Shale	0.2	Shale	0.3
Bentonite	0.1	Bentonite	0.1
Shale	2.5	Shale	2.0
Bentonite	0.2	Bentonite	0.1
Shale	15.6	Shale	1.5
Bentonite	0.2	Bentonite	0.1
Shale	1.1	Shale	0.7

Mowry (Continued)	Thickness (feet)
Bentonite	0.1
Shale	1.5
Bentonite	0.1
Shale	2.1
Bentonite	0.1
Shale	2.0
Bentonite	0.1
Shale	1.8
Bentonite	0.1
Shale	1.7
Bentonite	0.3
Shale	1.9
Bentonite	0.1
Shale	0.5
Bentonite	0.1
Shale	1.0
Bentonite	0.1
Shale	0.9
Bentonite	0.1
Shale	0.9
Bentonite	0.2
Shale	0.9
Bentonite	0.1
Shale	0.3
Bentonite	0.1
Shale	1.0
Bentonite	0.1
Shale	2.2
Bentonite	0.4
Shale	4.6
Bentonite	0.3
Shale	0.2
Bentonite	0.2
Shale	0.1
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.3
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.6
Bentonite	0.4
Shale	0.6
Bentonite	0.1
Shale	0.4
Bentonite	0.1
Shale	2.2
Bentonite	0.3
Shale	2.6
Bentonite	0.1
Shale	0.4
Bentonite	0.3
Shale	8.3
Bentonite	0.2
Shale	0.2
Bentonite	0.3
Shale	1.6
Bentonite	0.4
Shale	0.2
Bentonite	0.1
Shale	0.4
Bentonite	0.2
Shale	1.2
Bentonite	0.1
Shale	0.4
Bentonite	0.2
Shale	0.2
Bentonite	1.7
Shale	1.5
Bentonite	0.1
Shale	1.1
Bentonite	0.1
Shale	1.3
Bentonite	0.5
Shale	1.1

Mowry (Continued)	Thickness (feet)
Bentonite	0.1
Shale	6.6
Bentonite	0.1
Shale	3.1
Bentonite	0.6
Shale	1.7
Bentonite	1.5
Shale	1.3
Bentonite	0.1
Shale	4.3
Bentonite	0.2
Shale	11.5
Bentonite	0.1
Shale	1.0
Bentonite	0.3
Shale	0.7
Bentonite	0.2
Shale	0.3
Bentonite	0.1
Shale	0.8
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	0.4
Bentonite	2.2
	206.7

Top of Thermopolis:	Thickness (feet)
Shale	1.9
Bentonite	0.1
Shale	0.8
Bentonite	0.2
Shale	2.9
Bentonite	0.2
Shale	1.5
Bentonite	0.3
Shale	2.8
Bentonite	0.1
Shale	0.1
Bentonite	0.1
Shale	2.5
Bentonite	0.1
Shale	0.9
Bentonite	0.1
Shale	3.0
Bentonite	0.1
Shale	0.2
Bentonite	0.1
Shale	0.6
Bentonite	1.0
Shale	1.1
Bentonite	0.4
Shale	0.6
Bentonite	0.1
Shale	2.5
Bentonite	0.1
Shale	0.2
Bentonite	0.6
Shale	3.1
Bentonite	0.2
Shale	1.0
Bentonite	0.5
Shale	1.8
Bentonite	0.9
Shale	0.7
Bentonite	0.5
Shale	22.8
Bentonite	0.7
Shale	7.1
Bentonite	0.5
Shale (poorly exposed)	35.4
	100.4

The dips on the flanks of the folds and on the nose of the Laramie Range are, in most cases, high. In one or two small areas with dips as low as 12 degrees the bentonite seam at the top of the Mowry is well exposed near the top of the hogback, but dips under a ridge formed by the concretionary band at the base of the Frontier.

Medicine Bow Area.—The two main bentonite seams in the area around Medicine Bow (Fig. 1) are at the top of the Mowry and at the base of the Mesaverde (Table 2).

To the northeast, north, and northwest of Medicine Bow, in places where dips of the Mowry are high, the outcrop of the bentonite seam is narrow; in areas of low dip the bentonite seam is covered by alluvium. The seam at the base of the Mesaverde formation is approximately eight feet thick and crops out along the west flank of an anticline located one to three miles west of Medicine Bow. The dip of the seam is approximately 35 degrees to the west, and its width of outcrop is only slightly greater than its thickness.

To the east and southeast of Medicine Bow the seam at the top of the Mowry is exposed in a number of small areas with low dips. The thickness of the seam in these small areas is approximately four and one-half feet. Because of recent mining activity, the bentonite which was originally under the least overburden is exhausted.

PRODUCTION

HISTORY

Bentonite was first produced in Wyoming in 1888, when William Taylor shipped a small amount from Rock Creek. The price was $25.00 per ton at Rock Creek until 1896, when the consumers refused to pay more than $5.00. In 1897 a pit was opened near Newcastle by Messrs. Edgar and Thole, and in that year the total output of the state was 150 tons. Shipments averaged about 60 tons per year until 1902, when production rose to 1,200 tons. From that time until 1919 production figures are not available. In 1919 the price rose to $7.00 per ton, and approximately 25 cars were shipped.

About 1920 the Owyhee Chemical Products Company installed at Cheyenne the first plant for drying, grinding, and sacking bentonite. The crude material came from near Medicine Bow. Since that time there has been a nearly continuous increase in production.

Figures given on page 19 (Table 8) for the production of bentonite were taken from Government publications (8). In these figures bentonite is listed under the heading, "Miscellaneous Clays," until 1930, when it was differentiated from other clays. Since bentonite was probably the only clay being marketed from Wyoming, it is probable that these figures represent bentonite. It will be noticed that the industry made a distinct gain in 1928. This was due to the fact that in 1926 several new mills were established at Newcastle, Osage, and Upton. The companies operating these mills found many new uses and new markets for bentonite, with the result that production continued to increase until 1930. In 1929 there were six companies operating mills in Wyoming. In 1931 and 1932 there was a decline in production. Since 1933 production has increased steadily until the present time. The base price of processed bentonite at the present time is $10.50 per ton.

TABLE 8

Production of Bentonite in Wyoming

Year	Short tons	Value
1921	433	$ 2,155
1922	466	7,313
1923	614	10,448
1924	23,716	41,172
1925	2,584	63,657
1926	4,409	96,853
1927	7,498	121,146
1928	22,918	383,970
1929	22,053	190,156
1930	25,006	249,765
1931	16,080	143,969
1932	12,632	107,567
1933	21,306	166,630
1934	27,161	246,548
1935	34,415	350,846
1936	55,090	520,852
1937	67,958	659,111

PRODUCING AREAS AND METHODS

Bentonite production at the present time is confined to two areas, one in the Newcastle region, and one northwest of Greybull. The Newcastle area includes outcrops number 15-22 in Figure 2. Here the overburden is cleared away by bulldozers and the bentonite is loaded into trucks by power shovels. The overburden stripped varies up to 15 feet, but does not average over 7 feet. The bentonite in some cases is hauled 25 miles to mills. As the bentonite freezes in the winter, all mining is done in the summer and large stock piles are accumulated for winter milling. The Greybull area is described on page 13. There is no overburden and the material is shoveled into trucks or sacks by hand. The bentonite is hauled approximately eighteen miles.

FACTORS CONTROLLING VALUE OF DEPOSITS

The commercial value of a bentonite deposit depends upon (1) the type or class of bentonite, (2) the thickness of the seam, (3) dip of the seam, (4) amount of overburden, and (5) transportation costs. An example of an area presenting favorable conditions is the one around Newcastle, where the bentonite is of the best grade, the seam averages 30 inches in thickness, the dips are less than 5 degrees, there are large amounts of bentonite with less than 15 feet of overburden, and transportation costs are low because of good roads and the short distance between the bentonite deposits and the mills on the railroad.

CONCLUSIONS

Although bentonite seams occur in all the Upper Cretaceous rocks in Wyoming, the best grade and the largest amount of bentonite are in the lower formations of the series. The bentonite in these formations differs in character in different parts of the state, but whether or not this influences the swelling property of the bentonite is not known by the writer.

Bentonite seams, as a rule, thicken and thin from place to place, so that a seam may be prominent in one area and cannot be located in another. An exception to this rule, however, is a thick seam at the top of the Mowry, for this seam is present throughout more than half of the area of the state.

At present the Black Hills and Bighorn Basin areas are, and will probably be for many years, the principal producing areas in Wyoming because of low mining costs and proximity to railroads.

WORKS TO WHICH REFERENCE IS MADE

Hewett, D. F.

1. The origin of bentonite and the geologic range of related materials in Bighorn Basin, Wyoming: Washington Acad. Sci., Jour., vol. 7, pp. 196-198, 1917.
2. Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin Quadrangles, Wyoming: U. S. Geol. Survey, Prof. Paper 145, 111 pages, 1926.

Ross, C. S., and Shannon, E. V.

3. The minerals of bentonite and related clays and their physical properties: Am. Ceramic Soc. Jour., vol. 9, pp. 77-96, 1926.

Ross, C. S., Miser, H. D., and Stephenson, L. W.

4. Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey, Prof. Paper 154, pp. 175-203, 1928.

Rubey, W. W.

5. Origin of the siliceous Mowry shale of the Black Hills region: U. S. Geol. Survey, Prof. Paper 154, pp. 153-171, 1928.
6. Lithologic studies of fine-grained Upper Cretaceous sedimentary rocks of the Black Hills region: U. S. Geol. Survey, Prof. Paper 165, pp. 1-54, 1930.

Tyler, P. M., and Metcalf, R. W.

7. Clays: kaolin (china clay and paper clay), ball clay, fire clay, bentonite, fuller's earth (bleaching clays), and miscellaneous clay: Minerals Yearbook, pp. 1111-1124, 1938.

....

8. Mineral Resources U. S., 1922-1931, and Minerals Yearbook, 1932-1938.