WYOMING BENTONITE

by

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SUMMARY AND OUTLOOK

Wyoming leads the nation in bentonite production. The mineral is found extensively in the Upper Cretaceous--Lower Tertiary formations of Wyoming which are exposed along the margins of most Wyoming basins. Although within the basins bentonite deposits underlie areas totalling many thousand square miles, the overburden for the most part is too thick to permit open pit mining and the quality of much of it is inferior. Major bentonite mining areas are located in Big Horn, Crook, Weston, Johnson and Natrona Counties, and are generally within 20 miles of a processing plant (Plate 1.).

The outlook for Wyoming's bentonite mining industry is that of continued growth and expansion. Based on the increase in production between 1956 and 1967, Wyoming can expect its bentonite production to nearly double by the year 2020. New applications for bentonite are constantly being found, and the availability of the mineral might attract new small industries to the state.

With increasing demand for bentonite in years to come, it may become practical to strip-mine bentonite from somewhat deeper pits and from steeply dipping beds. Continued research may eventually develop an inexpensive process for converting the incompletely altered, non-swelling "blue" bentonite to a marketable product (Bolmer and Biggs, 1965).

Data relating to bentonite reserves minable under present day conditions are far from complete, but enough is known to indicate that the deposits will last a century, even if it be assumed that the average annual production for the future will be double that of recent years (U. S. Geol. Survey, 1960).

DEFINITION OF MATERIAL AND FORMS

Bentonite is a sedimentary rock containing 75% of the montmorillonite group clay minerals. The two most common minerals of this group found in bentonite are montmorillonite ($(Ca, Mg)O.Al_2O_3.5SiO_2.nH_2O$) and beidellite ($Al_2O_3.3SiO_2.nH_2O$), both hydrous aluminum silicates (Ross and Shannon, 1926). The exact composition of these minerals is quite variable owing to substitution in the crystal structure. Aluminum commonly substitutes for silicon, and magnesium, iron, lithium and zinc for aluminum (Ross, 1964, p. 5). Sodium, calcium, magnesium and potassium are usually loosely attached to the crystal lattice, much as is water. Varying amounts of other clays, feldspar, micas, zircon, glass, cristobalite, quartz, and jarosite make up the remainder of the rock (Osterwald, et al, 1966 and Ross, 1964).

PROPERTIES

Bentonite has widely varying properties because of its many possible mineralogical and chemical combinations. The montmorillonite group minerals are responsible for most of the unusual properties of bentonite. Impurities generally subdue these properties (Ross, 1964).

The crystal structure of montmorillonite is composed of sheets of hydrous aluminum silicate. Each sheet is 9.6 angstrom units thick and is normally separated from another by polar molecules, usually water, and by exchangeable cations. Sodium and calcium are the most common exchangeable cations. When sodium is the exchangeable cation, one molecule layer of water is present.between sheets.

With calcium, there are two such layers between sheets. Sodium ions favor the orderly arrangement of water molecules between sheets and it is this arrangement that is necessary for a gel. Consequently, montmorillonite with sodium as the principal cation, forms gels much more readily than those of calcium. These gels become fluid upon disruption of the oriented water layers (Ross, 1964).

> Bentonites may be divided into two classes: (1) those that ~~absorb~~ adsorb large quantities of water "swelling" greatly in the process and that remain in suspension in thin water dispersions, with sodium as its predominant exchangeable ion, (2) those that ~~absorb~~ adsorb only slightly more water than ordinary plastic clays and do not swell noticeably and do settle rapidly in thin dispersions, with calcium as its principal exchangeable ion. (Chyba, 1961).

Bentonite adsorbs water!

Freshly quarried bentonite is commonly creamy or greenish grey, but may be cream, grey, off-white, pink, dark green, buff, brown, black or a mixture of these colors. Bentonite has a specific gravity of about 2.18 and generally contains about 40 percent moisture when mined, depending on type, climate and topography. When dried its color is lighter, usually cream or buff (Ross, 1964).

Bentonite outcrops are characterized by a partly dry crumbly crust, usually less than a foot thick in dry weather. The surface of the outcrop exhibits a highly granular, mud cracked surface which may resemble hoar frost or corn meal (Darton, 1906).

GEOLOGIC DISPOSITION AND ORIGIN

Bentonite occurs in sedimentary successions as lens-like beds which vary considerably in lateral extent. Bentonite beds vary in thickness from a fraction of an inch up to many feet. Only rarely are the beds more than 10 feet thick. Correlating bentonite beds is often difficult because the beds are frequently discontinuous. This discontinuity is directly related to the origin of bentonites.

Bentonite is formed by the alteration and de-vitrification of volcanic ash, and the crystallization of montmorillonite minerals. The volcanic-ash parent material of bentonites can usually be detected by the presence of clay pseudomorphs and a suite of non-clay minerals, such as biotite, and hornblende, characteristic of igneous material (Grim, 1953).

Volcanic ash is generally erupted violently and great quantities may be blown into the atmosphere. Ash resulting from such an explosion may cover several thousand square miles, but will only be preserved in areas where the environment is predominantly depositional, such as the seas.

Volcanic ash is usually a silica-rich, largely non-crystalline rock. It is very susceptible to chemical alteration because of its high permeability, generally fine-grained texture, the instability of glass, and the high solubility of amorphous silica in solution. A wide variety of authigenic minerals may form during the alteration of ash, the more common being clays, zeolites, quartz, and feldspar (Hay, 1966).

In order for bentonite to form, it is probably necessary that the ash fall in water. The kind of water, whether fresh or saline, is important in determining whether bentonite forms at all, and if it does, the nature of the resulting minerals. It appears certain that alteration can take place in sea water, since much bentonite is associated with marine formations. The composition of the ash is also important since ash lacking MgO does not seem to alter to montmorillonite minerals.

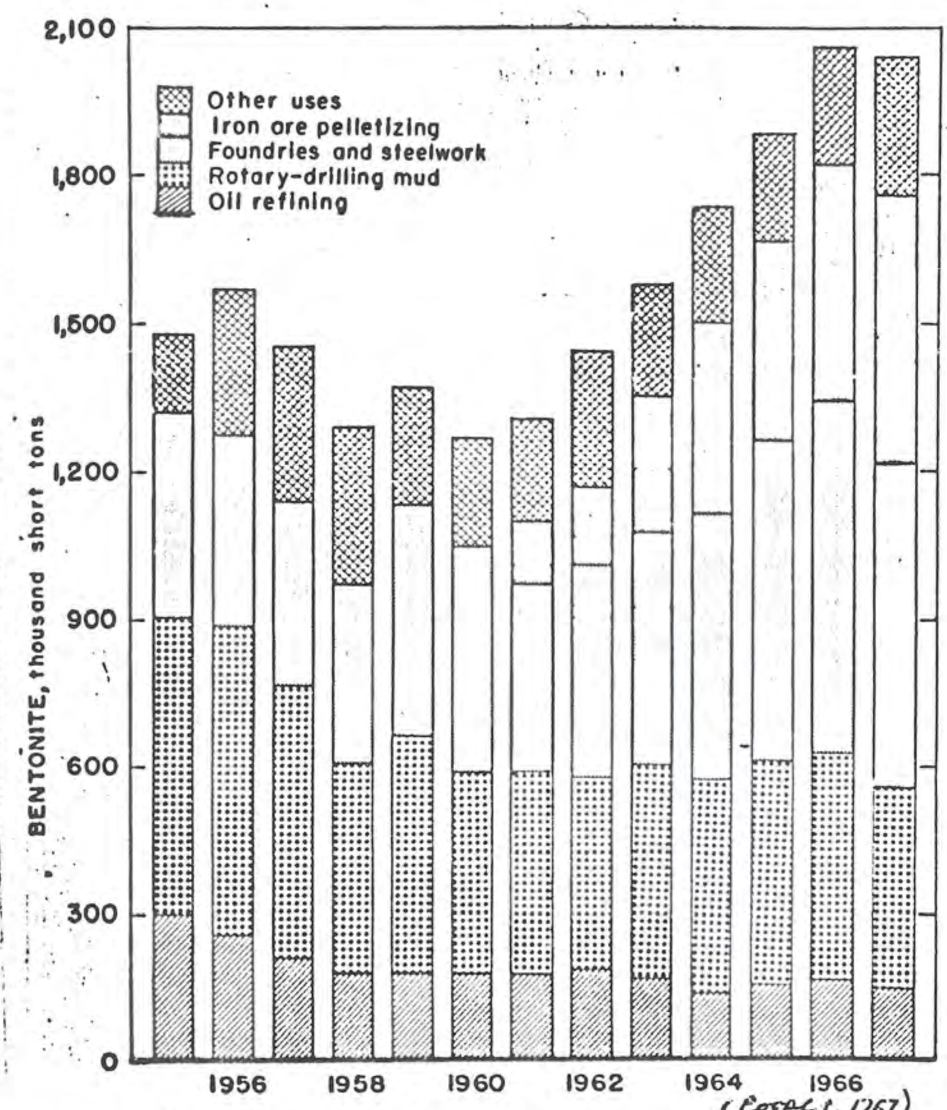
Evidence strongly indicates that the major alteration of ash to montmorillonite minerals takes place soon after or even contemporaneously with accumulation. Later reactions, which affect the amount of water and types of exchangeable cations of the montmorillonite minerals, probably take place when the bentonite is exposed to the atmosphere and weathering processes. This would account for the variation of bentonite properties with increasing depth of burial. The so-called "blue" bentonites, mined from deposits under thick overburden, have not been affected by atmospheric weathering processes and have no swelling properties.

PRODUCTION

Wyoming produces approximately 70 percent (1966) of the nation's bentonite (Osterwald, et al., 1966). Wyoming bentonite output increased from 1.3 million tons valued at $13.5 million in 1965 to 1.5 million tons valued at $15.8 million in 1966. Of the bentonite produced in 1966, 32 percent was used for pelletizing iron-ore concentrates; 30 percent for foundry use; 25 percent for rotary drilling, and 15 percent for miscellaneous uses (Meeves and Henkes, 1966). Figure 1. summarizes bentonite production and utilization in the United States from 1955 to 1967.

Wyoming bentonite is mined entirely by low cost surface mining methods. The mineral is usually quarried from deposits within a 20 mile radius of the various processing plants which are shown on Plate 1. Total production costs, including mining processing and bagging average about $4 to $5 a ton. The current price for high swelling bentonite (bagged 200 mesh material) is about $13 a ton in carlots f.o.b. mines. The price for brand-name bentonite, sold for drilling muds and similar purposes, often includes special consumer-engineering services provided by the producer and may be two or three times the quoted price (Bolmer and Biggs, 1965).

Bentonite deposits must satisfy the following conditions in order to be of commercial value: (1) the beds must have a fairly uniform horizontal or gentle dip to insure a continuity of readily available clay, (2) overburden must be thin to minimize mining costs, and (3) adequate transportation to market must be available (Osterwald, et al., 1966).



(Cooper, 1967)

Figure 1.—Bentonite sold or used by domestic producers for specified uses.

USES

Bentonite has many and varied uses because of its unusual physical properties. It was used long ago at the Hudson Bay post in Canada for washing garments and blankets. Wagoners noticed bentonite's resemblance to axle grease and used it to pack wagon hubs in emergencies. In 1888 several carloads of bentonite mined in the vicinity of Rock River, Wyoming, were shipped east and used in the manufacture of packing or dressing for the inflamed hoofs of horses (Darton, 1910).

Modern uses of bentonite are largely dependent on its swelling capacity. High-swelling bentonite is used chiefly by the petroleum industry as an ingredient of rotary well drilling mud and by the iron metals industry both as a binder in sand casting molds and as a binder in pelletizing taconite, an iron-rich ore mineral. It is also used in sealing irrigation canals, for filtering and decoloring oils and other liquids, in degreasing hides and wools, as a filler in paper products, in treating sewage, as an additive to cement, plaster and artificial stone, as a binder in pelletizing cattle feeds, and in briquetting chars and coke. U. S. Forest service tests have shown that sodium-rich bentonite, when used as a gel for retarding forest and brush fires, is more effective than sodium borate and only about a twelfth as expensive. Non-swelling calcium-rich bentonites are used primarily as fillers in insecticides, fungicides, pharmaceuticals, soaps, polishes and many other products (U. S. Geol. Survey, 1960, and Bolmer and Biggs, 1965).

Cobban and Reeside, 1953

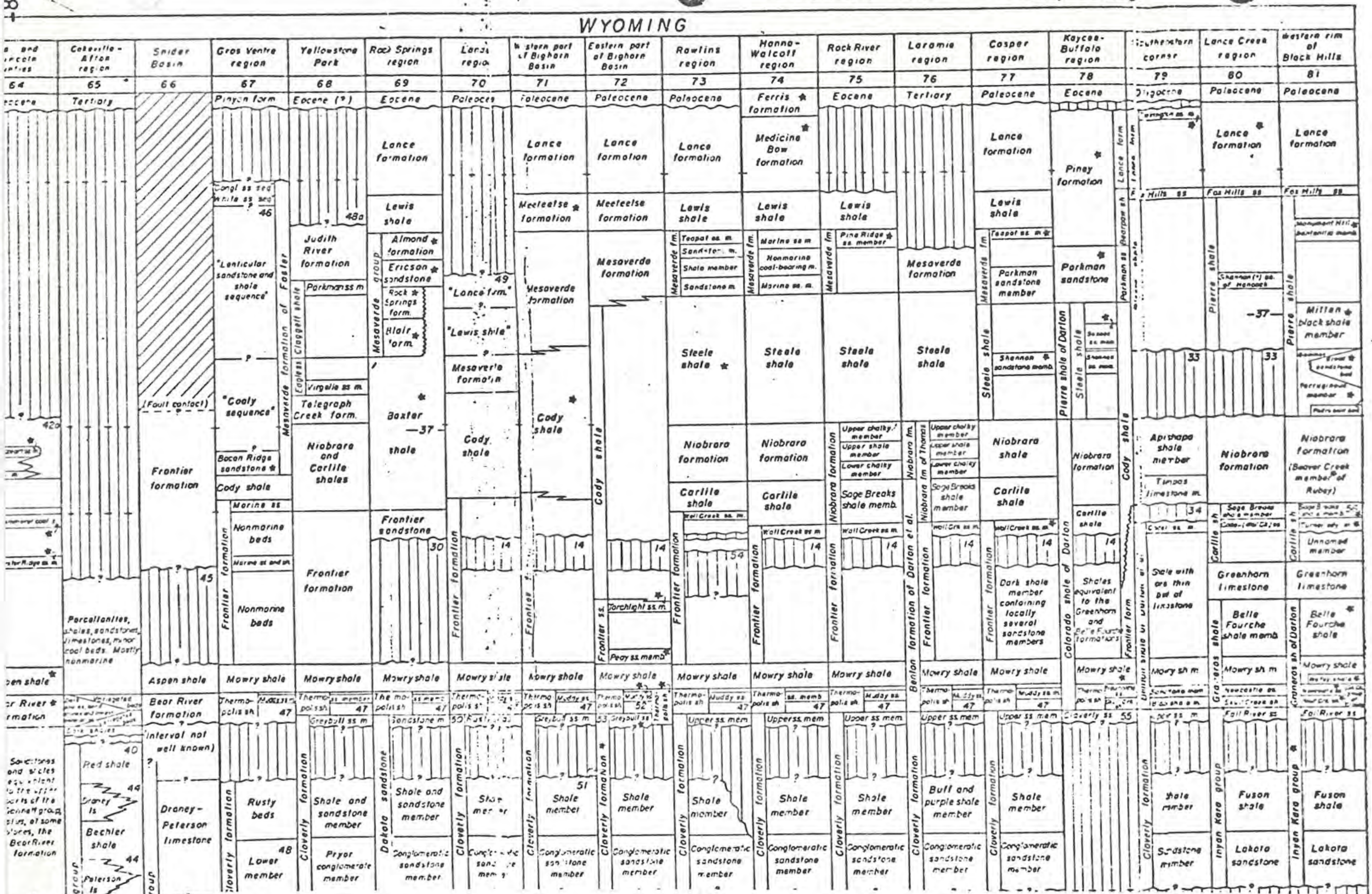


Fig. 2. Generalized Stratigraphic correlation and nomenclature of Cretaceous Formations in Wyoming. From Cobban and Reeside, 1953.

DISTRIBUTION AND STRATIGRAPHIC OCCURRENCE

Bentonite is found extensively in the Upper Cretaceous--Lower Tertiary formations of Wyoming. Most deposits are within the Cretaceous Mowry and Frontier Formations, and some bentonite is usually found wherever these beds crop out. Cretaceous bentonite is also found at some localities in the Thermopolis Shale, Graneros Shale, Newcastle Sandstone, Frontier Shale, Belle Fourche Shale, Greenhorn Limestone, Niobrara Shale, Steele Shale, Hillard Shale, Aspen Shale, and Mesaverde Formation. Figure 2. summarizes the stratigraphic correlation and nomenclature of Cretaceous formations in Wyoming. Bentonite of Tertiary age has been found in the Eocene Wasatch and Wind River Formations, and in unidentified beds ranging in age up to Oligocene. Plate 1. shows the distribution of bentonite-bearing formations in Wyoming.

PROSPECTS AND REPORTED OCCURRENCES

Many of Wyoming's bentonite deposits are of little economic value under existing conditions. The list below is of necessity incomplete since it is not feasible to discuss the many miles of outcrop of the various bentonite-bearing formations in Wyoming. The following list is organized by County (alphabetically) and, within the counties, by Township and Range. Plate 1. shows the outcrop trace of bentonite-bearing formations.

Albany County

N ½ sec. 2, T. 13 N., R. 75 W. A 4 ft. thick bentonite layer in the Mowry Formation crops out along the east bank of sand creek (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

NE ¼ sec. 14, T. 13 N., R. 76 W. to the SE ¼ sec. 6, T. 14 N., R. 75 W. A much weathered bentonite bed in the Mowry Formation crops out at this location on the Riverside Ranch. The bed is 2 ft. thick at the southernmost outcrop, but thickens northward to 4 ft. (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

Sec. 7, T. 14 N., R. 74 W. A 3 to 4 ft. thick bentonite layer in the Frontier Formation crops out on the northwest side of Creighton Lake. The outcrop is about 200 yds. long and the beds dip 5° SW (Siebenthal, 1905, and Darton and Siebenthal, 1909).

Sec. 6, T. 21 N., R. 74 W., and secs. 1, 10, 11, 12, 16, 17, T. 21 N., R. 75 W. Bentonite within the Mowry Formation crops out along the south limb of McGill Anticline. The beds dip about 10° S. and the outcrop is as much as 15 ft. wide in sec. 6, T. 21 N., R. 74 W. (Houlette, 1947, p. 28). The Linscott Claim, located in the NW ¼ sec. 17, T. 21 N., R. 75 W., is adjacent to the old Union Pacific Railroad line. The readily available supply was exhausted in 1905 after 20 carloads of bentonite had been mined. The clay composition is given in Table 1. (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 60).

NW¼ sec. 12, T. 21 N., R. 75 W. 4 to 5 ft. of high swelling bentonite is found in the Mowry Formation which dips gently south. A clay analysis is given in Table 1. (Siebenthal, 1905, p. 446-7, and Darton and Siebenthal, 1909, p. 61).

NW¼ sec. 30, T. 22 N., R. 75 W. A 4 to 5 ft. thick bentonite layer crops out ¼ mile north of abandoned Rock Creek Station on the south limb of Gillespie Anticline. The bed is within the Frontier Formation and dips 4° to 5° S. The Taylor mine, developed in 1888, produced 5,460 short tons of bentonite before closing in 1897 (Knight, 1897, p. 600-601). Two clay analyses are given in Table 1. (Siebenthal, 1905, p. 446, and Darton and Siebenthal, 1909, p. 59). A bentonite layer 2 to 5 ft. thick is generally found in the upper Mowry Formation along the north limbs of McGill and Gillespie Anticline.

SE¼ NE¼ sec. 14, T. 22 N., R. 76 W. 100 carloads of bentonite were mined starting in 1898 from a 4 to 5 ft. layer in the Mowry Formation north of Rock River. The bed dips 4° to 5° S. and lies beneath a thin shale overburden (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 60).

N½ sec. 10, T. 22 N., R. 76 W. A 4 to 5 ft. layer of bentonite in the Mowry Formation, which dips gently south, was claimed in 1909 by the Cassa Mining Co. A clay analysis is given in Table 1. (Siebenthal, 1905, p. 446-7, and Darton and Siebenthal, 1909, p. 60-61).

NW¼ sec. 20, T. 22 N., R. 77 W. Beds of bentonite in the Mowry Formation dip 8° to 20° S. off the south limb of Como Anticline. Some development work was done on a claim staked by Sam White (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

T. 23 N., R. 76 W. Bentonite has been reported in the upper Mowry Formation on the north limb of Como Anticline (Giddings, 1935, p. 32).

<table>
<tr><th></th><th>sec. 17, T. 21 N., R. 75 W.</th><th>sec. 12, T. 21 N., R. 75 W.</th><th>sec. 30, T. 22 N., R. 75 W.</th><th>sec. 30, T. 22 N., R. 75 W.</th><th>sec. 10, T. 22 N., R. 76 W.</th></tr>
<tr><td>SiO_2</td><td>66.5%</td><td>64.0%</td><td>59.78%</td><td>58.25%</td><td>60.2%</td></tr>
<tr><td>Al_2O_3</td><td>29.3</td><td>24.0</td><td>15.10</td><td>24.70</td><td rowspan="2">26.1</td></tr>
<tr><td>Fe_2O_3</td><td>3.1</td><td>3.2</td><td>2.40</td><td>2.61</td></tr>
<tr><td>MgO</td><td>1.0</td><td>1.5</td><td>4.14</td><td>1.30</td><td rowspan="2">2.5</td></tr>
<tr><td>CaO</td><td>0.5</td><td>0.6</td><td>0.73</td><td>1.61</td></tr>
<tr><td>H_2O</td><td>5.0</td><td>6.7</td><td>16.26</td><td>11.00</td><td>10.3</td></tr>
<tr><td>$Na_2O + K_2O$</td><td></td><td></td><td></td><td></td><td>0.8</td></tr>
<tr><td>Sp. Gr.</td><td></td><td></td><td>2.18</td><td></td><td></td></tr>
</table>

Table 1. Bentonite analyses; Albany County (After Siebenthal, 1905, and Darton and Siebenthal, 1909).

Big Horn County

T. 52 N., R. 93 W. Cretaceous bentonite-bearing formations crop out through a large area in the Greybull region and offer possibilities for commercial production (Osterwald, et al., 1966).

T. 54 N., R. 95 W. A 4 ft. layer of bentonite near the top of the Frontier Formation dips 31° W. and forms an outcrop 50 ft. wide and 1 mi. long (Heathman, 1939, p. 13-14).

Sec. 5, T. 57 N., R. 96 W. A 1.5 ft. thick bentonite bed near the top of the Thermopolis Formation crops out near the head of Dry Gulch, 5 mi. north of Cowley (Fisher, 1904, p. 562-3, and 1906, p. 57).

Sec. 30, T. 58 N., R. 95 W. Heathman (1939, p. 13) measured an Upper Cretaceous section at this location. Five bentonite seams from 0.7 to 2.0 ft. thick were found in 820 ft. of the Frontier Formation. Two bentonite beds, each 2.5 ft. thick were found in 95.4 ft. of Mowry Shale. 15 thin bentonite seams (0.5 to 2.5 ft. thick) are interbedded with 962.4 ft. of shale in the Thermopolis Formation.

Sec. 29, T. 58 N., R. 96 W. A 7½ ft. thick bentonite bed in the Thermopolis Shale consists of fine-grained, massive gray clay with green and yellow tints. It is apparently of good quality throughout. Two other beds, 2 and 1 ft. thick, are also found in the top 100 ft. of the Thermopolis Formation (Fisher, 1904, p. 562, and 1906, p. 57).

Sec. 29, T. 58 N., R. 100 W. Bentonite is found in beds above the Niobrara Formation near the Silver Tip Coal Mine (Fisher, 1906, p. 57).

Carbon County

Sec. 17, T. 18 N., R. 80 W., and secs. 20, 21, and 29, T. 18 N., R. 81 W. Bentonite seams up to 2 ft. thick are found in the Mowry Shale. The beds dip 10° to 74° and result in narrow bentonite outcrops and excessive overburden (Gries, 1964, p. 52).

Secs. 11, 12, and 13, T. 18 N., R. 87 W. Three gypsiferous bentonite beds in the lower Frontier Formation crop out along a low hogback. Eight ft. of shale overlies the low dipping clay beds. In secs. 17 and 18 a bentonite bed 3 ft. thick is found just above the base of the Frontier Formation. The dip of the formation is low and the bentonite is usually covered by thin overburden. Locally these bentonite beds form dip slopes (Buehner, 1936, p. 31-32).

T. 19 N., R. 82 W., T. 20 N., R. 82 W. and T. 20 N., R. 81 W. A few thin bentonite layers are found in the 150 ft. thick Mowry Formation west, north, and northeast of Elk Mountain, and south of Sheephead Mountain (Isberg, 1937, p. 31).

Secs. 6 and 7, T. 22 N., R. 78 W. An 8 ft. thick bentonite bed at the base of the Mesaverde Formation dips 35° W. This deposit, located just west of Medicine Bow, was once mined (Geol. Survey Wyo. files).

T. 23 N., R. 78 W. A 4 ft. thick bentonite layer, at the top of the Mowry Formation is found near Medicine Bow, but the dip is generally high and the outcrop narrow. Bentonite is exposed east and southeast of Medicine Bow, but where the dips are low and the overburden thin, the bentonite has been mined out (Heathman, 1939, p. 18).

T. 24 N., R. 80 W. Thin bentonite layers are interbedded with shales in the 150 ft. thick Mowry Formation in the Difficulty--Little Shirley Basin area. These bentonite beds are probably not minable since the beds dip 25° under thick overburden (Brown, 1939, p. 6).

T. 26 N., R. 80 W. Bentonite beds 6 ft. thick have been found in the Mowry Formation near the Dolling Ranch on Muddy Creek (Peterson, 1935).

Sec. 31, T. 27 N., R. 88 W. Heisey (1949, p. 51-52) measured two 1 ft. bentonite beds in the Mowry Formation and 4 ft. of bentonite in the Frontier Formation.

Crook County

Most of the marine Cretaceous beds of the northern Black Hills area contain relatively pure beds of bentonite. Most commercial deposits are contained in beds near the base of the Belle Fourche Shale, at the top of the Mowry Formation (Clay Spur bentonite), and in the Newcastle Sandstone (Robinson, et.al., 1964). North of the broad northwest plunging Black Hills Anticline subordinate folds repeatedly bring bentonite beds to the surface resulting in large bentonite resources under thin overburden (Knechtel, M., and Patterson, S. H., 1962).

Fisher (1904, p. 446) gives an analysis of Crook County bentonite:

SiO_2	61.08%
Al_2O_3	17.12
Fe_2O_3	3.17
MgO	1.82
CaO	2.69
Na_2O	0.20
SO_3	0.88

Open pit mines in the Clay Spur district (Crook and Weston Counties) are of two types: (1) Shallow pits dug through relatively thin overburden to uncover bentonite beds preserved in small grabens or tilted fault blocks, and (2) successive cuts in bentonite beds cropping out along the margins of hills. The Clay Spur district produced 62% of all bentonite mined in Wyoming in 1950, but by 1960 production had declined to 23% (Davis, J. C., 1965).

Secs. 8, 17, 20, 29, T. 49 N., R. 65 W. A 2.5 ft. thick bentonite bed at the top of the Mowry Formation crops out extensively north of Thornton. The beds dip 3° SW. and have from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

Secs. 23, 36, T. 50 N., R. 66 W. Northeast of Moorcroft a bentonite layer in the upper Mowry Formation averages 2.5 ft. thick. The average dip of the bed is 3° SW. and the overburden ranges in thickness from 0 to 20 ft. (Heathman, 1939, p. 9-10). Extensive unmined deposits in the Mowry may be present west of Pine Ridge in the northern part of the township (Davis, 1965).

NW¼ sec. 25, T. 51 N., R. 67 W. Minable quantities of bentonite occur in the Mowry Shale and Newcastle Sandstone. Bentonite found at the top of the Mowry Shale has been mined from a shallow open cut which is nearly a quarter of a mile long (Bergendahl, 1961).

SW¼ sec. 2, T. 51 N., R. 67 W. At least one bentonite bed in the Newcastle Sandstone appears pure enough and is of sufficient thickness (3 ft.) to be minable (Bergendahl, 1961).

Sec. 34, T. 54 N., R. 67 W. (Northeast of Oshoto) A 4 ft. thick bentonite bed at the top of the Mowry Shale dips 3° W. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 4, T. 55 N., R. 60 W. A 4.5 ft. thick bentonite bed at the top of the Mowry Formation dips 5° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 10, T. 55 N., R. 61 W. A 3 ft. thick bentonite layer at the top of the Mowry Formation dips 2° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 26, T. 55 N., R. 61 W. A discontinuous bentonite layer about 2.5 ft. thick, is found at the top of the Mowry Shale. The bed crops out along the northern flank of the Black Hills Anticline, dips 5° NE., and has from 10 to 30 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 9, T. 56 N., R. 61 W. A 3.5 ft. thick bentonite layer at the top of the Mowry Formation dips 3° NE. and has from 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 12, T. 56 N., R. 61 W. A 2 ft. bentonite bed at the top of the Mowry Shale dips 3° NE. and has from 0 to 15 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 3, T. 56 N., R. 62 W. A bentonite layer 4.8 ft. thick is found in outcrops of the upper Mowry Shale at this locality. The bed dips 3° NE. and overburden is from 0 to 25 ft. thick (Heathman, 1939, p. 9-10).

Sec. 4, T. 56 N., R. 65 W. A 5 ft. thick bentonite bed occurs about 6 ft. above the base of the Newcastle Sandstone, which caps a small mesa at this locality. The swelling capacity of this bentonite was found to be great enough to make it suitable for industrial uses (Davis and Izett, 1962).

Sec. 4, T. 56 N., R. 66 W. A 2.5 ft. thick bentonite bed at the top of the Mowry Shale dips 2° NW. and is covered by 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 8, T. 57 N., R. 61 W. A bentonite at the top of the Mowry is 2 ft. thick, dips 4° NE., and has from 0 to 25 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 14, T. 57 N., R. 63 W. A 3 ft. thick bentonite seam at the top of the Mowry dips 2° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 25, T. 57 N., R. 66 W. A bentonite layer 5.5 ft. thick is found at the base of the Mowry Formation. The bed lies horizontal and overburden ranges from 0 to 15 ft. (Heathman, 1939, p. 9-10).

Sec. 35, T. 57 N., R. 66 W. A 2 ft. thick bentonite layer at the top of the Mowry Formation dips 3° NW. and has from 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 32, T. 58 N., R. 63 W. A bentonite layer at the base of the Mowry Formation is 5 ft. thick. The bed dips 2° NE. and has from 0 to 35 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 34, T. 58 N., R. 65 W. A 4.2 ft. thick bentonite seam at the top of the Mowry Formation dips 5° N. and has from 0 to 25 ft. of shale overburden (Heathman, 1939, p. 9-10).

Fremont County

Two bentonite layers, 2.5 and 3 ft. thick are found at the top of the Mowry Shale and crop out along the northeast flank of the Wind River Mountains. The Mowry bentonites are the high swelling type, but their outcrops are narrow because of the generally high dips. Bentonite has also been found in the upper part of the Frontier and Thermopolis Formations (Heathman, 1939, p. 13-14).

Sec. 11, 14, T. 6 N., R. 2 E. Nine bentonite layers, varying in thickness from 1 to 6 ft., form a total of 24 ft. of bentonite in 560 ft. of the Mowry Formation. These deposits are on the Wind River Indian Reservation (Love, 1947).

T. 6 N., R. 2 W. Two 5 ft. thick beds of bentonite near the top of the Mowry Formation crop out around Maverick Springs Anticline on the Wind River Indian Reservation. In general the beds dip fairly steeply and the overburden is thick (Collier, 1920, and Bolmer and Biggs, 1965).

T. 8 N., R. 6 W. The Wyoming Geological Survey reports a bentonite deposit 5 to 10 ft. thick one mile northeast of the Duncan post office on the Wind River Indian Reservation.

Sec. 36, T. 30 N., R. 97 W. Gooldy (1947, p. 36).measured a section of Cretaceous Rocks and found many thin bentonites in the 450 Ft. thick Mowry Formation.

Sec. 34, T. 31 N., R. 96 W. 55 thin bentonite seams (0.1 to 2.5 ft. thick) are found in the 190.6 ft. thick Mowry Formation. No large outcrops were seen (Heathman, 1939, p. 14-15).

Sec. 1, T. 42 N., R. 107 W. Love (1947) reported numerous bentonite layers in the Frontier and Mowry Formations. Many of the beds over 2 ft. thick contain impurities of various kinds. Exposures are rather poor in this area of complex folding. A total of 28 ft. of bentonite was measured.

Secs. 30, 31, T. 43 N., R. 107 W. An 11 ft. thick layer of white bentonite forms the upper bed of the Wind River Formation which crops out for a distance of 3 mi. near White Pass. The layer contains montmorillonite, zeolite, and moderate amounts of quartz and feldspar (Keefer, 1955).

Bentonite is found in the Frontier and Mowry Formations north of Dubois in the Du Noir Area. A few pure beds ranging in thickness up to 14 ft. were observed, with the thickest beds occurring in the Frontier Formation (Keefer, 1955).

Hot Springs County

NW$\frac{1}{4}$ sec. 33, T. 47 N., R. 99 W. Hewett (1926) measured a 3 ft. thick bentonite seam in the Meeteetse Formation.

SW$\frac{1}{4}$ sec. 16, T. 44 N., R. 99 W. 16 ft. of bentonites of unknown quality were observed in Post-Wasatch tuffs.

Bentonite is found in the Frontier and Mowry Formations where they outcrop along the north flank of the Owl Creek Range.

Johnson County

Sec. 36, T. 49 N., R. 83 W. Four bentonite seams from 0.5 to 1.5 ft. thick are found in 47.3 ft. of upper Frontier Shales. Eleven bentonite beds (0.5 to 3.5 ft. thick) are found in 259.5 ft. of Mowry Shale and seven thin layers are found within the 502.1 ft. thick Thermopolis Shale. These beds dip 15° E. (Heathman, 1939, p. 11).

Bentonite seams are found in the Thermopolis, Mowry and Frontier Fromations along the east flank of the Big Horn Mountains (Clabaugh, et al., 1946).

Laramie County

T. 19 N., R. 71 W. Thin bentonite seams are found in the Mowry Formation near Iron Mountain (Hammond, 1949).

T. 19 N., R. 70 W. Haun (1949) reports thin bentonite beds in the Mowry Formation along the east flank of the Laramie Range at this location (Haun, 1949).

Natrona County

Fisher (1905) made the following analysis of Natrona County bentonite:

SiO_2	65.24%
Al_2O_3	15.88
Fe_2O_3	3.12
MgO + CaO	5.34
H_2O	9.17

SW$\frac{1}{4}$ sec. 3, SE$\frac{1}{4}$ sec. 4, W$\frac{1}{2}$ sec. 10, NE$\frac{1}{4}$ sec. 15, T. 30 N., R. 81 W. A 5 ft. thick bentonite layer in the Mowry Formation crops out around the flanks of an asymmetric anticline in the Bates Park area. Only the northwest flank of the anticline has low dips and thin overburden above the bentonite. The best exposures are in sec. 10 where the bentonite contains 90% montmorillonite. Estimated reserves are "several million" short tons (Dengo, 1946, p. 9-10, 17). Peterson (1935) reports 6 ft. thick bentonite beds in the Mowry Formation north of Bolton Creek oil field.

NE¼ sec. 31, T. 30 N., R. 82 W. A 5 ft. thick bentonite layer in the Mowry Formation crops out in a SE. plunging syncline just east of Alcova Reservoir. The bentonite layer dips 5° to 7° N. with very little overburden on the southwest limb of the syncline. Estimated reserves for the Alcova area are 300,000 short tons (Dengo, 1946, p. 8, 17).

Sec. 25, 36, T. 30 N., R. 83 W. Bentonite in the Mowry Formation dips 6° NE. Wider outcrops and thinner overburden are found away from Alcova Reservoir. A bentonite specimen from sec. 36 contained 85% to 90% montmorillonite (Dengo, 1946, p. 8-9).

Sec. 10, T. 31 N., R. 80 W. A 4.8 ft. thick bentonite bed in the Mowry Formation crops out on the slopes of several hills in the area. Although the bed dips gently to the southwest, the overburden is generally greater than 15 ft. The bentonite is 90% montmorillonite and estimated reserves are 224,800 short tons (Dengo, 1946, p. 10, 17).

SW¼ sec. 31, T. 32 N., R. 80 W. and N½ sec. 36, SE¼ sec. 35, T. 32 N., R. 81 W. A 4.8 ft. thick bentonite bed is found in the Mowry Formation which dips southwest. Frontier Shale overburden is thick. Reserves are estimated at 264,000 short tons (Dengo, 1946, p. 10, 17).

Secs. 18, 19, T. 32 N., R. 81 W. and secs. 13, 24, T. 32 N., R. 82 W. Five ft. of Mowry bentonite and two thin bentonite layers in the Frontier Formation are found in the vicinity of Lee Lake. The beds are complexly folded and faulted and overburden greater than 15 ft. Estimated reserves are 101,300 short tons (Dengo, 1946, p. 12, 13, 17).

T. 32 N., R. 86, 87 W., T. 33 N., R. 87, 88 W., and T. 34 N., R. 88 W. A 3.5 ft. thick bentonite bed at the top of the Mowry Shale crops out for 25 mi. along the northeast flank of the Rattlesnake Hills. The beds dip 30° NE. and are probably discontinuous since it appears that the upper part of the Mowry Formation has slid down dip (Heathman, 1939, p. 15).

SE¼ sec. 31, T. 33 N., R. 80 W. A Mowry bentonite bed containing 85% to 90% clay minerals crops out around small Frontier Shale outliers in the Blue Hill vicinity. A 4.8 ft. thick bentonite layer in the Mowry (?) Formation dips 9° E. and crops out around a 400 ft. wide, 500 ft. long Frontier remnant in the NE¼ of the same section (Dengo, 1946, p. 11).

Sec. 32, T. 33 N., R. 80 W. Heathman (1939, p. 16-17) found a 4 ft. bentonite seam at the top of the Mowry Shale and noted many thin bentonite seams interbedded with shale in the Thermopolis and Mowry Formations which crop out west and southwest of Casper.

Sec. 9, T. 33 N., R. 81 W. A 4.5 ft. thick bentonite bed in the Mowry crops out around the flanks of the Emigrant Gap Anticline. In sec. 9 the exposures extend 4000 ft. and dip of the beds varies from 10° to 40° NE. Overburden is thickest in gullies. The bentonite is the high-swelling type and contains 90% to 95% montmorillonite. Estimated reserves for the entire Emigrant Gap area are 277,375 short tons (Dengo, 1946, p. 7,8).

NE¼ sec. 24, T. 33 N., R. 81 W. A thin bentonite bed in the Mowry Formation north of the Platte River dips 10° E. Mining conditions are favorable, but the deposits are small (Dengo, 1946, p. 7).

Secs. 24, 25, T. 33 N., R. 81 W. A 4.8 ft. thick bed of bentonite at the top of the Mowry Formation dips 6° to 9° E. and has more than 15 ft. of overburden. The Mowry Shale is exposed in several gullies in this area (Dengo, 1946, p. 8).

Sec. 4, N½ sec. 3, T. 36 N., R. 83 W. Two bentonite layers, 4 ft. and 5 ft. thick, are contained in the Steele Formation north of Natrona. The beds dip 9° S. and overburden is relatively thick over most of the area. Selenite crystals are scattered through the clay which contains 95% montmorillonite and some kaolin (Dengo, 1946, p. 16-17).

T. 39, 40, 41 N., R. 79 W. A 9 to 12 ft. thick bentonite bed in the Steele Formation crops for a considerable distance in the syncline west of Salt Creek Anticline. South of Columbine a 2 ft. thick bentonite bed is found below the 9 ft. thick bed in the Steele Shale. Neither of the beds are uniform and the amounts of selenite and shale interbedded with the bentonite vary. Bentonite from sec. 20, T. 40 N., R. 79 W. contains 95% montmorillonite (Dengo, 1946, p. 16).

Niobrara County

The thick bentonite layers present in the Pierre Shale in Weston and Crook Counties thin to the south. Any bentonite in Niobrara County is probably of little if any economic value (Hancock, 1920).

W½ sec. 2, T. 35 N., R. 65 W. A bentonite bed in the Pierre Shale forms a dip slope on the south limb of Lance Creek Anticline. The bed dips about 4° S. (Hancock, 1920).

SE¼ sec. 26, T. 36 N., R. 65 W. A bentonite bed in the Pierre Shale dips 16° N. on the north limb of Lance Creek Anticline (Hancock, 1920).

Park County

Bentonite is common in the Thermopolis, Mowry and Frontier Formations on the west side of the Big Horn Basin. There are two zones in the Frontier Formation: 1) from 85 ft. to 140 ft. below the top of the Formation and 2) 90 ft. to 140 ft. above the base. A great many thin seams are found in the Mowry and Thermopolis Formations.

Hewett (1914, p. 97) found 35 thin bentonite beds in 392 ft. of Cretaceous shales along the Shoshone River. Hewett (1926, p. 56) made the following analysis of bentonite from the uppermost Frontier Formation:

SiO_2	65.63%
Al_2O_3	13.40
Fe_2O_3 + FeO	2.55
MgO	2.17
CaO	0.85
Na_2O	0.69
K_2O	0.27
H_2O	14.33

Platte County

T. 20 N., R. 69 W. Several bentonite seams interbedded with gray and black Mowry Shale are found in the Chugwater Creek-Deadhead Creek area of Platte and Laramie Counties (Haun, 1949, p. 13).

Sheridan County

T. 58 N., R. 88 W. Two beds of bentonite, one in the Mowry Formation and the other in the Frontier Formation, are sources of commercial bentonite. A bentonite layer in the Mowry is 5 ft. thick in sec. 20. In sec. 17, 18 and 21, the bentonite layer in the Frontier Formation is as much as 20.5 ft. thick and has been mined by the Wyotana Bentonite Mining Co. (Knechtel, M. M., and Patterson, S. H., 1956).

Sublette and Lincoln Counties

T. 20 N., R. 117 W. Bentonite has been reported at Skull Point Gap by Mr. Chris Vrang of Evanston, Wyo. (Osterwald, 1947).

Sec. 15, 21, T. 29 N., R. 115 W. Bentonite beds up to 2 ft. thick have been found in the Aspen Shale in Sec. 15. In sec. 21 bentonite beds 2 to 8 inches thick occur in the Hillard Formation (Fruchy, 1962, and Furer, 1962).

T. 28, 29 N., R. 116 W. The Hillard Formation probably contains bentonite at this location (Hauf, 1963, and Suydam, 1963).

Teton County

T. 44 N., R. 110 W. "A large amount" of bentonite was found in lower Eocene rocks in Black Rock Meadows, 3 mi. southwest of Togwotee Pass at Teton Canyon (Osterwald, et al., 1966).

T. 43 N., R. 110 W. Bentonite was found in Oligocene rocks 10 miles south of Togwotee Pass at Teton Canyon (Osterwald, et al., 1966).

Uinta County

Sec. 30, T. 14 N., R. 119W. Bentonite from a deposit in the Knight Formation has been used as a reservoir lining, but only thin seams are now visible. This deposit on the Jamison Claim (Osterwald, 1947).

E$\frac{1}{2}$ sec. 2, T. 17 N., R. 117 W. A 5 ft. thick bentonite bed at the base of the Frontier Formation is exposed along the dip slope of a small hogback. There is no overburden and outcrops are visible for $\frac{1}{2}$ mi. along the strike of the beds (Osterwald, 1947).

Bentonite has been reported at Spring Valley by Mr. Chris Vrang of Evanston, Wyo. (Osterwald, 1947).

Washakie County

Bentonite mined in the northeastern part of Washakie County from the Frontier and Mowry Formations has been used for dam and ditch linings. The bentonite is suitable for both foundry and drilling mud use (Trotter, 1954).

T. 45 N., R. 88 W. A 5 ft. thick bentonite layer at the base of the Frontier Formation is exposed in cliffs west of No Wood Creek (Morgan, 1951, p. 38).

Sec. 30, T. 46 N., R. 88 W. A 6 ft. thick clay deposit possessing properties similar to bentonite, is found in the Wasatch Formation (Eocene?) at the head of Bud Kimball Draw, 12 miles southeast of Tensleep.

Weston County

Most of the Cretaceous beds which crop out along the southwestern flanks of the Black Hills Uplift contain relatively pure beds of bentonite. Most commercial deposits are contained in beds near the base of the Bell Fourche Formation, at the top of the Mowry Formation (Clay Spur bentonite), and in the Newcastle Sandstone (Robinson, et al., 1964). Some analyses of Weston County bentonites are given in Table 2.

Sec. 13, T. 41 N., R. 61 W. A 3 ft. thick bentonite bed at the top of the Mowry Formation dips 4° SSW. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 7, T. 42 N., R. 60 W. A 2.5 ft. thick bentonite layer in the upper Mowry Formation crops out near Clifton. The bed dips 4° SW. and has from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

	1	2	3	4	5	6	7	8	9
SiO_2	56.93%	63.25%	60.80%	53.50%	54.31%	70.36%	61.00%	61.78%	63.25%
Sol. SiO_2	-----	-----	-----	-----	-----	0.62	-----	-----	-----
$Al_2O_3 + P_2O_5$	14.75	-----	-----	21.57	-----	11.47	-----	-----	-----
Al_2O_3	-----	12.63	22.40	-----	20.22	-----	20.98	21.56	17.62
Fe_2O_3	2.08	3.70	0.97	3.28	1.88	2.48	3.04	3.10	3.70
FeO	-----	-----	0.41	-----	0.19	-----	0.34	0.28	-----
MgO	1.86	3.97	2.34	1.89	0.98	1.38	2.68	2.62	3.70
CaO	6.35	4.12	0.76	1.25	0.94	0.26	0.44	0.68	4.12
Na_2O	2.28	-----	2.69	1.94	2.35	1.69	2.36	2.22	-----
MnO	-----	-----	0.12	-----	-----	-----	0.10	0.08	-----
K_2O	0.93	3.55	0.32	1.04	0.21	0.75	0.35	0.31	-----
H_2O	10.61	6.71	8.90	15.20	18.64	11.32	8.19	7.71	-----
TiO_2	0.11	-----	-----	-----	-----	0.10	-----	-----	-----
H_2SO_4	-----	1.58	-----	-----	-----	-----	-----	-----	-----
SO_3	-----	-----	0.18	-----	-----	-----	0.36	trace	1.53
CO_2	4.61	-----	-----	-----	-----	-----	-----	-----	-----

Table 2. Bentonite analyses; Weston County.

1) T. 45 N., R. 62 W. Pedro bentonite bed at base of Mowry Formation (Mapel and Pillmore, 1963).
2) T. 46 N., R. 63 W. Graneros Shale bentonite at Osage (Darton, 1904, p. 9).
3) T. 46 N., R. 63 W. Graneros Shale bentonite at Osage (O'Harra, 1929, p. 47-48).
4) T. 46 N., R. 63 W. Belle Fourche bentonite at Osage (Mapel and Pillmore, 1963).
5) Sec. 30, T. 47 N., R. 63 W. Graneros Shale bentonite (Hewett, 1914, p. 56).
6) Sec. 30, T. 47 N., R. 63 W. Clay Spur bentonite at top of Mowry Formation (Rubey, 1928, p. 157).
7) T. 47 N., R. 64 W. Clay Spur bentonite bed at top of Mowry Formation west of Jerome (O'Harra, 1929, p. 47-48).
8) T. 48 N., R. 65 W. Clay Spur bentonite 2 mi. northwest of Upton (O'Harra, 1929, p. 47-48).
9) Weston County bentonite (Fisher, 1904, p. 560).

Sec. 19, T. 43 N., R. 60 W. A 1.3 ft. thick bentonite seam at the top of the Mowry Formation is exposed north of Clifton. The layer dips 7° SW. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

T. 45 N., R. 61 W. A 1 to 4 ft. thick bentonite bed at the top of the Newcastle sandstone and a 3 ft. thick layer near the top of the Belle Fourche Shale are exposed in the Newcastle area and may be extensive enough to mine. The Clay Spur bentonite bed at the top of the Mowry Formation is thin and does not appear to contain large reserves. Bentonite is also found in the Pierre Shale (Mapel and Pillmore, 1963).

T. 45 N., R. 62 W. (?) Bentonite is found in the Upper Cretaceous Pierre Formation (O'Harra, 1929).

T. 45 N., R. 62, 63 W. A steeply dipping 12 ft. thick bentonite bed is found near the top of the Niobrara Formation 3/4 mi. east of Pedro and 1 mi. west of Pedro (Darton, 1904).

Secs. 8, 9, T. 45 N., R. 62 W. and sec. 1, T. 45 N., R. 63 W. The Pedro bentonite bed at the base of the Pierre Shale, is 30 ft. thick at this locality. The bentonite has been strip mined but only small amounts were removed because of steep dips (Mapel and Pillmore, 1963).

Sec. 31, T. 46 N., R. 62 W. Bentonite has been strip mined from a bed in the lower part of the Belle Fourche Shale (Mapel and Pillmore, 1963).

Sec. 9, T. 46 N., R. 63 W. A 4 ft. bentonite bed in the Graneros Shale dips gently SW. at Osage (Darton, 1904). An analysis is given in Table 2.

Secs. 11, 17, 27, T. 47 N., R. 64 W. A 2.5 ft. thick bentonite layer at the top of the Mowry Shale is exposed northwest of Osage. The bed dips 3° SW. and has from 0 to 20 ft. overburden (Heathman, 1939, p. 9-10). In the NE$\frac{1}{4}$ sec. 27, near Jerome, two bentonite beds dip 40° S. Estimated reserves (with 15 ft. or less overburden) are 73,000 tons in the lower bed and 45,575 tons in the upper bed (Love, 1935).

T. 47 N., R. 64 W. A 3.5 ft. thick bentonite bed in the Mowry Formation has been mined 1.5 miles west of Jerome. Jerome was once the site of a bentonite processing plant. (O'Harra, 1929, p. 47-48). A bentonite analysis is given in Table 2.

T. 48 N., R. 65 W. A 3.5 ft. thick bentonite layer lies above the Mowry Shale 2 mi. northwest of Upton at Colloid Siding. The bed has very little overburden and has been mined (O'Harra, 1929, p. 47-48). An analysis of the bentonite is given in Table 2.

Secs. 2, 16, T. 48 N., R. 65 W. A bentonite seam at the top of the Mowry Formation averages 2.5 ft. thick northeast of Thornton. The bed dips 3° SW. and has from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

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Geological Survey of Wyoming
Mineral Report MR 69-2.

WYOMING BENTONITE

by

Robert Stevenson

March 22, 1969

note by JKK
this is very similar
to the caaerson Eng report
by RV Bailey

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SUMMARY AND OUTLOOK

Wyoming leads the nation in bentonite production. The mineral is found extensively in the Upper Cretaceous--Lower Tertiary formations of Wyoming which are exposed along the margins of most Wyoming basins. Although within the basins bentonite deposits underlie areas totalling many thousand square miles, the overburden for the most part is too thick to permit open pit mining and the quality of much of it is inferior. Major bentonite mining areas are located in Big Horn, Crook, Weston, Johnson and Natrona Counties, and are generally within 20 miles of a processing plant (Plate 1.).

The outlook for Wyoming's bentonite mining industry is that of continued growth and expansion. Based on the increase in production between 1956 and 1967, Wyoming can expect its bentonite production to nearly double by the year 2020. New applications for bentonite are constantly being found, and the availability of the mineral might attract new small industries to the state.

With increasing demand for bentonite in years to come, it may become practical to strip-mine bentonite from somewhat deeper pits and from steeply dipping beds. Continued research may eventually develop an inexpensive process for converting the incompletely altered, non-swelling "blue" bentonite to a marketable product (Bolmer and Biggs, 1965).

Data relating to bentonite reserves minable under present day conditions are far from complete, but enough is known to indicate that the deposits will last a century, even if it be assumed that the average annual production for the future will be double that of recent years (U. S. Geol. Survey, 1960).

DEFINITION OF MATERIAL AND FORMS

Bentonite is a sedimentary rock containing 75% of the montmorillonite group clay minerals. The two most common minerals of this group found in bentonite are montmorillonite ($(Ca, Mg)O.Al_2O_3.5SiO_2.nH_2O$) and beidellite ($Al_2O_3.3SiO_2.nH_2O$), both hydrous aluminum silicates (Ross and Shannon, 1926). The exact composition of these minerals is quite variable owing to substitution in the crystal structure. Aluminum commonly substitutes for silicon, and magnesium, iron, lithium and zinc for aluminum (Ross, 1964, p. 5). Sodium, calcium, magnesium and potassium are usually loosely attached to the crystal lattice, much as is water. Varying amounts of other clays, feldspar, micas, zircon, glass, cristobalite, quartz, and jarosite make up the remainder of the rock (Osterwald, et al, 1966 and Ross, 1964).

PROPERTIES

Bentonite has widely varying properties because of its many possible mineralogical and chemical combinations. The montmorillonite group minerals are responsible for most of the unusual properties of bentonite. Impurities generally subdue these properties (Ross, 1964).

The crystal structure of montmorillonite is composed of sheets of hydrous aluminum silicate. Each sheet is 9.6 angstrom units thick and is normally separated from another by polar molecules, usually water, and by exchangeable cations. Sodium and calcium are the most common exchangeable cations. When sodium is the exchangeable cation, one molecule layer of water is present between sheets.

With calcium, there are two such layers between sheets. Sodium ions favor the orderly arrangement of water molecules between sheets and it is this arrangement that is necessary for a gel. Consequently, montmorillonite with sodium as the principal cation, forms gels much more readily than those of calcium. These gels become fluid upon disruption of the oriented water layers (Ross, 1964).

> Bentonites may be divided into two classes: (1) those that absorb large quantities of water "swelling" greatly in the process and that remain in suspension in thin water dispersions, with sodium as its predominant exchangeable ion, (2) those that absorb only slightly more water than ordinary plastic clays and do not swell noticeably and do settle rapidly in thin dispersions, with calcium as its principal exchangeable ion. (Chyba, 1961).

Freshly quarried bentonite is commonly creamy or greenish grey, but may be cream, grey, off-white, pink, dark green, buff, brown, black or a mixture of these colors. Bentonite has a specific gravity of about 2.18 and generally contains about 40 percent moisture when mined, depending on type, climate and topography. When dried its color is lighter, usually cream or buff (Ross, 1964).

Bentonite outcrops are characterized by a partly dry crumbly crust, usually less than a foot thick in dry weather. The surface of the outcrop exhibits a highly granular, mud cracked surface which may resemble hoar frost or corn meal (Darton, 1906).

GEOLOGIC DISPOSITION AND ORIGIN

Bentonite occurs in sedimentary successions as lens-like beds which vary considerably in lateral extent. Bentonite beds vary in thickness from a fraction of an inch up to many feet. Only rarely are the beds more than 10 feet thick. Correlating bentonite beds is often difficult because the beds are frequently discontinuous. This discontinuity is directly related to the origin of bentonites.

Bentonite is formed by the alteration and de-vitrification of volcanic ash, and the crystallization of montmorillonite minerals. The volcanic-ash parent material of bentonites can usually be detected by the presence of clay pseudomorphs and a suite of non-clay minerals, such as biotite, and hornblende, characteristic of igneous material (Grim, 1953).

Volcanic ash is generally erupted violently and great quantities may be blown into the atmosphere. Ash resulting from such an explosion may cover several thousand square miles, but will only be preserved in areas where the environment is predominantly depositional, such as the seas.

Volcanic ash is usually a silica-rich, largely non-crystalline rock. It is very susceptible to chemical alteration because of its high permeability, generally fine-grained texture, the instability of glass, and the high solubility of amorphous silica in solution. A wide variety of authigenic minerals may form during the alteration of ash, the more common being clays, zeolites, quartz, and feldspar (Hay, 1966).

In order for bentonite to form, it is probably necessary that the ash fall in water. The kind of water, whether fresh or saline, is important in determining whether bentonite forms at all, and if it does, the nature of the resulting minerals. It appears certain that alteration can take place in sea water, since much bentonite is associated with marine formations. The composition of the ash is also important since ash lacking MgO does not seem to alter to montmorillonite minerals.

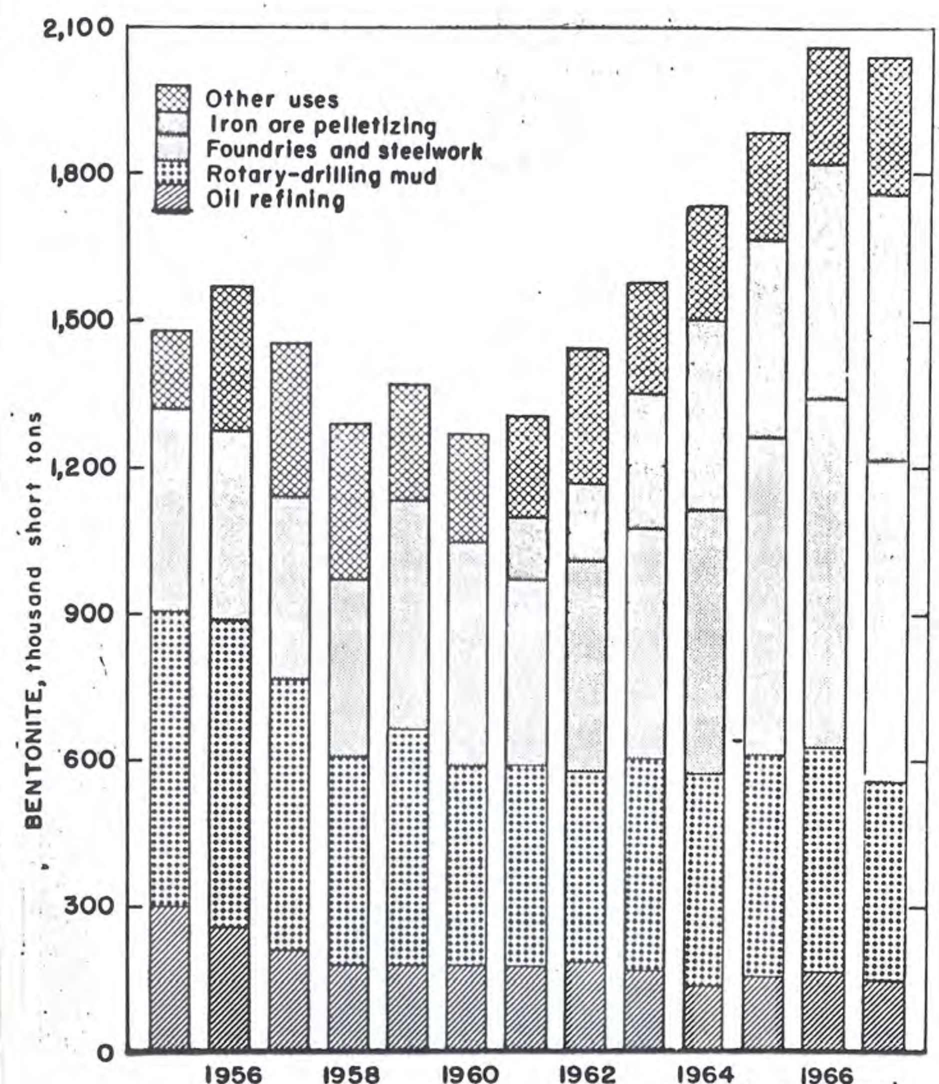
Evidence strongly indicates that the major alteration of ash to montmorillonite minerals takes place soon after or even contemporaneously with accumulation. Later reactions, which affect the amount of water and types of exchangeable cations of the montmorillonite minerals, probably take place when the bentonite is exposed to the atmosphere and weathering processes. This would account for the variation of bentonite properties with increasing depth of burial. The so-called "blue" bentonites, mined from deposits under thick overburden, have not been affected by atmospheric weathering processes and have no swelling properties.

PRODUCTION

Wyoming produces approximately 70 percent (1966) of the nation's bentonite (Osterwald, et al., 1966). Wyoming bentonite output increased from 1.3 million tons valued at $13.5 million in 1965 to 1.5 million tons valued at $15.8 million in 1966. Of the bentonite produced in 1966, 32 percent was used for pelletizing iron-ore concentrates; 30 percent for foundry use; 25 percent for rotary drilling, and 15 percent for miscellaneous uses (Meeves and Henkes, 1966). Figure 1. summarizes bentonite production and utilization in the United States from 1955 to 1967.

Wyoming bentonite is mined entirely by low cost surface mining methods. The mineral is usually quarried from deposits within a 20 mile radius of the various processing plants which are shown on Plate 1. Total production costs, including mining processing and bagging average about $4 to $5 a ton. The current price for high swelling bentonite (bagged 200 mesh material) is about $13 a ton in carlots f.o.b. mines. The price for brand-name bentonite, sold for drilling muds and similar purposes, often includes special consumer-engineering services provided by the producer and may be two or three times the quoted price (Bolmer and Biggs, 1965).

Bentonite deposits must satisfy the following conditions in order to be of commercial value: (1) the beds must have a fairly uniform horizontal or gentle dip to insure a continuity of readily available clay, (2) overburden must be thin to minimize mining costs, and (3) adequate transportation to market must be available (Osterwald, et al., 1966).



(Cooper, 1967)

Figure 1.—Bentonite sold or used by domestic producers for specified uses.

USES

Bentonite has many and varied uses because of its unusual physical properties. It was used long ago at the Hudson Bay post in Canada for washing garments and blankets. Wagoners noticed bentonite's resemblance to axle grease and used it to pack wagon hubs in emergencies. In 1888 several carloads of bentonite mined in the vicinity of Rock River, Wyoming, were shipped east and used in the manufacture of packing or dressing for the inflamed hoofs of horses (Darton, 1910).

Modern uses of bentonite are largely dependent on its swelling capacity. High-swelling bentonite is used chiefly by the petroleum industry as an ingredient of rotary well drilling mud and by the iron metals industry both as a binder in sand casting molds and as a binder in pelletizing taconite, an iron-rich ore mineral. It is also used in sealing irrigation canals, for filtering and de-coloring oils and other liquids, in degreasing hides and wools, as a filler in paper products, in treating sewage, as an additive to cement, plaster and artificial stone, as a binder in pelletizing cattle feeds, and in briquetting chars and coke. U. S. Forest service tests have shown that sodium-rich bentonite, when used as a gel for retarding forest and brush fires, is more effective than sodium borate and only about a twelfth as expensive. Non-swelling calcium-rich bentonites are used primarily as fillers in insecticides, fungicides, pharmaceuticals, soaps, polishes and many other products (U. S. Geol. Survey, 1960, and Bolmer and Biggs, 1965).

Cobban and Reeside, 1953

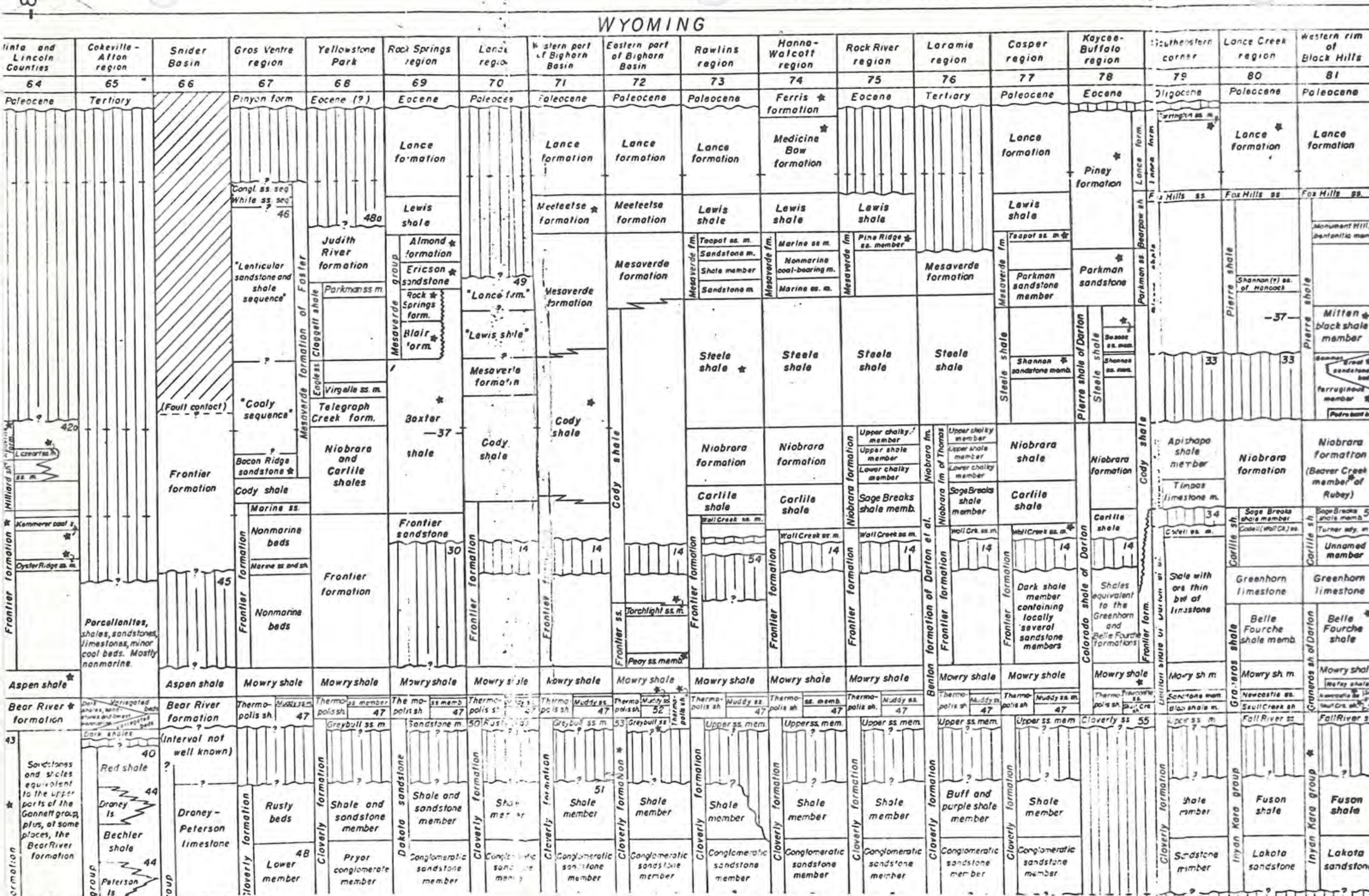


Fig. 2. Generalized Stratigraphic correlation and nomenclature of Cretaceous Formations in Wyoming. From Cobban and Reeside, 1953.

15B

DISTRIBUTION AND STRATIGRAPHIC OCCURRENCE

Bentonite is found extensively in the Upper Cretaceous--Lower Tertiary formations of Wyoming. Most deposits are within the Cretaceous Mowry and Frontier Formations, and some bentonite is usually found wherever these beds crop out. Cretaceous bentonite is also found at some localities in the Thermopolis Shale, Graneros Shale, Newcastle Sandstone, Frontier Shale, Belle Fourche Shale, Greenhorn Limestone, Niobrara Shale, Steele Shale, Hillard Shale, Aspen Shale, and Mesaverde Formation. Figure 2. summarizes the stratigraphic correlation and nomenclature of Cretaceous formations in Wyoming. Bentonite of Tertiary age has been found in the Eocene Wasatch and Wind River Formations, and in unidentified beds ranging in age up to Oligocene. Plate 1. shows the distribution of bentonite-bearing formations in Wyoming.

PROSPECTS AND REPORTED OCCURRENCES

Many of Wyoming's bentonite deposits are of little economic value under existing conditions. The list below is of necessity incomplete since it is not feasible to discuss the many miles of outcrop of the various bentonite-bearing formations in Wyoming. The following list is organized by County (alphabetically) and, within the counties, by Township and Range. Plate 1. shows the outcrop trace of bentonite-bearing formations.

Albany County

N ½ sec. 2, T. 13 N., R. 75 W. A 4 ft. thick bentonite layer in the Mowry Formation crops out along the east bank of sand creek (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

NE ¼ sec. 14, T. 13 N., R. 76 W. to the SE ¼ sec. 6, T. 14 N., R. 75 W. A much weathered bentonite bed in the Mowry Formation crops out at this location on the Riverside Ranch. The bed is 2 ft. thick at the southernmost outcrop, but thickens northward to 4 ft. (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

Sec. 7, T. 14 N., R. 74 W. A 3 to 4 ft. thick bentonite layer in the Frontier Formation crops out on the northwest side of Creighton Lake. The outcrop is about 200 yds. long and the beds dip 5° SW (Siebenthal, 1905, and Darton and Siebenthal, 1909).

Sec. 6, T. 21 N., R. 74 W., and secs. 1, 10, 11, 12, 16, 17, T. 21 N., R. 75 W. Bentonite within the Mowry Formation crops out along the south limb of McGill Anticline. The beds dip about 10° S. and the outcrop is as much as 15 ft. wide in sec. 6, T. 21 N., R. 74 W. (Houlette, 1947, p. 28). The Linscott Claim, located in the NW ¼ sec. 17, T. 21 N., R. 75 W., is adjacent to the old Union Pacific Railroad line. The readily available supply was exhausted in 1905 after 20 carloads of bentonite had been mined. The clay composition is given in Table 1. (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 60).

NW¼ sec. 12, T. 21 N., R. 75 W. 4 to 5 ft. of high swelling bentonite is found in the Mowry Formation which dips gently south. A clay analysis is given in Table 1. (Siebenthal, 1905, p. 446-7, and Darton and Siebenthal, 1909, p. 61).

NW¼ sec. 30, T. 22 N., R. 75 W. A 4 to 5 ft. thick bentonite layer crops out ¼ mile north of abandoned Rock Creek Station on the south limb of Gillespie Anticline. The bed is within the Frontier Formation and dips 4° to 5° S. The Taylor mine, developed in 1888, produced 5,460 short tons of bentonite before closing in 1897 (Knight, 1897, p. 600-601). Two clay analyses are given in Table 1. (Siebenthal, 1905, p. 446, and Darton and Siebenthal, 1909, p. 59). A bentonite layer 2 to 5 ft. thick is generally found in the upper Mowry Formation along the north limbs of McGill and Gillespie Anticline.

SE¼ NE¼ sec. 14, T. 22 N., R. 76 W. 100 carloads of bentonite were mined starting in 1898 from a 4 to 5 ft. layer in the Mowry Formation north of Rock River. The bed dips 4° to 5° S. and lies beneath a thin shale overburden (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 60).

N½ sec. 10, T. 22 N., R. 76 W. A 4 to 5 ft. layer of bentonite in the Mowry Formation, which dips gently south, was claimed in 1909 by the Cassa Mining Co. A clay analysis is given in Table 1. (Siebenthal, 1905, p. 446-7, and Darton and Siebenthal, 1909, p. 60-61).

NW¼ sec. 20, T. 22 N., R. 77 W. Beds of bentonite in the Mowry Formation dip 8° to 20° S. off the south limb of Como Anticline. Some development work was done on a claim staked by Sam White (Siebenthal, 1905, p. 447, and Darton and Siebenthal, 1909, p. 61).

T. 23 N., R. 76 W. Bentonite has been reported in the upper Mowry Formation on the north limb of Como Anticline (Giddings, 1935, p. 32).

	sec. 17, T. 21 N., R. 75 W.	sec. 12, T. 21 N., R. 75 W.	sec. 30, T. 22 N., R. 75 W.	sec. 30, T. 22 N., R. 75 W.	sec. 10, T. 22 N., R. 76 W.
SiO_2	66.5%	64.0%	59.78%	58.25%	60.2%
Al_2O_3	29.3	24.0	15.10	24.70	26.1
Fe_2O_3	3.1	3.2	2.40	2.61	
MgO	1.0	1.5	4.14	1.30	2.5
CaO	0.5	0.6	0.73	1.61	
H_2O	5.0	6.7	16.26	11.00	10.3
$Na_2O + K_2O$					0.8
Sp. Gr.			2.18		

Table 1. Bentonite analyses; Albany County (After Siebenthal, 1905, and Darton and Siebenthal, 1909).

Big Horn County

T. 52 N., R. 93 W. Cretaceous bentonite-bearing formations crop out through a large area in the Greybull region and offer possibilities for commercial production (Osterwald, et al., 1966).

T. 54 N., R. 95 W. A 4 ft. layer of bentonite near the top of the Frontier Formation dips 31° W. and forms an outcrop 50 ft. wide and 1 mi. long (Heathman, 1939, p. 13-14).

Sec. 5, T. 57 N., R. 96 W. A 1.5 ft. thick bentonite bed near the top of the Thermopolis Formation crops out near the head of Dry Gulch, 5 mi. north of Cowley (Fisher, 1904, p. 562-3, and 1906, p. 57).

Sec. 30, T. 58 N., R. 95 W. Heathman (1939, p. 13) measured an Upper Cretaceous section at this location. Five bentonite seams from 0.7 to 2.0 ft. thick were found in 820 ft. of the Frontier Formation. Two bentonite beds, each 2.5 ft. thick were found in 95.4 ft. of Mowry Shale. 15 thin bentonite seams (0.5 to 2.5 ft. thick) are interbedded with 962.4 ft. of shale in the Thermopolis Formation.

Sec. 29, T. 58 N., R. 96 W. A 7½ ft. thick bentonite bed in the Thermopolis Shale consists of fine-grained, massive gray clay with green and yellow tints. It is apparently of good quality throughout. Two other beds, 2 and 1 ft. thick, are also found in the top 100 ft. of the Thermopolis Formation (Fisher, 1904, p. 562, and 1906, p. 57).

Sec. 29, T. 58 N., R. 100 W. Bentonite is found in beds above the Niobrara Formation near the Silver Tip Coal Mine (Fisher, 1906, p. 57).

Carbon County

Sec. 17, T. 18 N., R. 80 W., and secs. 20, 21, and 29, T. 18 N., R. 81 W. Bentonite seams up to 2 ft. thick are found in the Mowry Shale. The beds dip 10° to 74° and result in narrow bentonite outcrops and excessive overburden (Gries, 1964, p. 52).

Secs. 11, 12, and 13, T. 18 N., R. 87 W. Three gypsiferous bentonite beds in the lower Frontier Formation crop out along a low hogback. Eight ft. of shale overlies the low dipping clay beds. In secs. 17 and 18 a bentonite bed 3 ft. thick is found just above the base of the Frontier Formation. The dip of the formation is low and the bentonite is usually covered by thin overburden. Locally these bentonite beds form dip slopes (Buehner, 1936, p. 31-32).

T. 19 N., R. 82 W., T. 20 N., R. 82 W. and T. 20 N., R. 81 W. A few thin bentonite layers are found in the 150 ft. thick Mowry Formation west, north, and northeast of Elk Mountain, and south of Sheephead Mountain (Isberg, 1937, p. 31).

WRONG LOCATION!

Secs. 6 and 7, T. 22 N., R. 78 W. An 8 ft. thick bentonite bed at the base of the Mesaverde Formation dips 35° W. This deposit, located just west of Medicine Bow, was once mined (Geol. Survey Wyo. files).

T. 23 N., R. 78 W. A 4 ft. thick bentonite layer, at the top of the Mowry Formation is found near Medicine Bow, but the dip is generally high and the outcrop narrow. Bentonite is exposed east and southeast of Medicine Bow, but where the dips are low and the overburden thin, the bentonite has been mined out (Heathman, 1939, p. 18).

T. 24 N., R. 80 W. Thin bentonite layers are interbedded with shales in the 150 ft. thick Mowry Formation in the Difficulty--Little Shirley Basin area. These bentonite beds are probably not minable since the beds dip 25° under thick overburden (Brown, 1939, p. 6).

T. 26 N., R. 80 W. Bentonite beds 6 ft. thick have been found in the Mowry Formation near the Dolling Ranch on Muddy Creek (Peterson, 1935).

Sec. 31, T. 27 N., R. 88 W. Heisey (1949, p. 51-52) measured two 1 ft. bentonite beds in the Mowry Formation and 4 ft. of bentonite in the Frontier Formation.

Crook County

Most of the marine Cretaceous beds of the northern Black Hills area contain relatively pure beds of bentonite. Most commercial deposits are contained in beds near the base of the Belle Fourche Shale, at the top of the Mowry Formation (Clay Spur bentonite), and in the Newcastle Sandstone (Robinson, et al., 1964). North of the broad northwest plunging Black Hills Anticline subordinate folds repeatedly bring bentonite beds to the surface resulting in large bentonite resources under thin overburden (Knechtel, M., and Patterson, S. H., 1962).

Fisher (1904, p. 446) gives an analysis of Crook County bentonite:

SiO_2	61.08%
Al_2O_3	17.12
Fe_2O_3	3.17
MgO	1.82
CaO	2.69
Na_2O	0.20
SO_3	0.88

Open pit mines in the Clay Spur district (Crook and Weston Counties) are of two types: (1) Shallow pits dug through relatively thin overburden to uncover bentonite beds preserved in small grabens or tilted fault blocks, and (2) successive cuts in bentonite beds cropping out along the margins of hills. The Clay Spur district produced 62% of all bentonite mined in Wyoming in 1950, but by 1960 production had declined to 23% (Davis, J. C., 1965).

Secs. 8, 17, 20, 29, T. 49 N., R. 65 W. A 2.5 ft. thick bentonite bed at the top of the Mowry Formation crops out extensively north of Thornton. The beds dip 3° SW. and have from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

Secs. 23, 36, T. 50 N., R. 66 W. Northeast of Moorcroft a bentonite layer in the upper Mowry Formation averages 2.5 ft. thick. The average dip of the bed is 3° SW. and the overburden ranges in thickness from 0 to 20 ft. (Heathman, 1939, p. 9-10). Extensive unmined deposits in the Mowry may be present west of Pine Ridge in the northern part of the township (Davis, 1965).

NW¼ sec. 25, T. 51 N., R. 67 W. Minable quantities of bentonite occur in the Mowry Shale and Newcastle Sandstone. Bentonite found at the top of the Mowry Shale has been mined from a shallow open cut which is nearly a quarter of a mile long (Bergendahl, 1961).

SW¼ sec. 2, T. 51 N., R. 67 W. At least one bentonite bed in the Newcastle Sandstone appears pure enough and is of sufficient thickness (3 ft.) to be minable (Bergendahl, 1961).

Sec. 34, T. 54 N., R. 67 W. (Northeast of Oshoto) A 4 ft. thick bentonite bed at the top of the Mowry Shale dips 3° W. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 4, T. 55 N., R. 60 W. A 4.5 ft. thick bentonite bed at the top of the Mowry Formation dips 5° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 10, T. 55 N., R. 61 W. A 3 ft. thick bentonite layer at the top of the Mowry Formation dips 2° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 26, T. 55 N., R. 61 W. A discontinuous bentonite layer about 2.5 ft. thick, is found at the top of the Mowry Shale. The bed crops out along the northern flank of the Black Hills Anticline, dips 5° NE., and has from 10 to 30 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 9, T. 56 N., R. 61 W. A 3.5 ft. thick bentonite layer at the top of the Mowry Formation dips 3° NE. and has from 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 12, T. 56 N., R. 61 W. A 2 ft. bentonite bed at the top of the Mowry Shale dips 3° NE. and has from 0 to 15 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 3, T. 56 N., R. 62 W. A bentonite layer 4.8 ft. thick is found in outcrops of the upper Mowry Shale at this locality. The bed dips 3° NE. and overburden is from 0 to 25 ft. thick (Heathman, 1939, p. 9-10).

Sec. 4, T. 56 N., R. 65 W. A 5 ft. thick bentonite bed occurs about 6 ft. above the base of the Newcastle Sandstone, which caps a small mesa at this locality. The swelling capacity of this bentonite was found to be great enough to make it suitable for industrial uses (Davis and Izett, 1962).

Sec. 4, T. 56 N., R. 66 W. A 2.5 ft. thick bentonite bed at the top of the Mowry Shale dips 2° NW. and is covered by 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 8, T. 57 N., R. 61 W. A bentonite at the top of the Mowry is 2 ft. thick, dips 4° NE., and has from 0 to 25 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 14, T. 57 N., R. 63 W. A 3 ft. thick bentonite seam at the top of the Mowry dips 2° NE. and has from 0 to 15 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 25, T. 57 N., R. 66 W. A bentonite layer 5.5 ft. thick is found at the base of the Mowry Formation. The bed lies horizontal and overburden ranges from 0 to 15 ft. (Heathman, 1939, p. 9-10).

Sec. 35, T. 57 N., R. 66 W. A 2 ft. thick bentonite layer at the top of the Mowry Formation dips 3° NW. and has from 0 to 20 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 32, T. 58 N., R. 63 W. A bentonite layer at the base of the Mowry Formation is 5 ft. thick. The bed dips 2° NE. and has from 0 to 35 ft. of shale overburden (Heathman, 1939, p. 9-10).

Sec. 34, T. 58 N., R. 65 W. A 4.2 ft. thick bentonite seam at the top of the Mowry Formation dips 5° N. and has from 0 to 25 ft. of shale overburden (Heathman, 1939, p. 9-10).

Fremont County

Two bentonite layers, 2.5 and 3 ft. thick are found at the top of the Mowry Shale and crop out along the northeast flank of the Wind River Mountains. The Mowry bentonites are the high swelling type, but their outcrops are narrow because of the generally high dips. Bentonite has also been found in the upper part of the Frontier and Thermopolis Formations (Heathman, 1939, p. 13-14).

Sec. 11, 14, T. 6 N., R. 2 E. Nine bentonite layers, varying in thickness from 1 to 6 ft., form a total of 24 ft. of bentonite in 560 ft. of the Mowry Formation. These deposits are on the Wind River Indian Reservation (Love, 1947).

T. 6 N., R. 2 W. Two 5 ft. thick beds of bentonite near the top of the Mowry Formation crop out around Maverick Springs Anticline on the Wind River Indian Reservation. In general the beds dip fairly steeply and the overburden is thick (Collier, 1920, and Bolmer and Biggs, 1965).

T. 8 N., R. 6 W. The Wyoming Geological Survey reports a bentonite deposit 5 to 10 ft. thick one mile northeast of the Duncan post office on the Wind River Indian Reservation.

Sec. 36, T. 30 N., R. 97 W. Gooldy (1947, p. 36).measured a section of Cretaceous Rocks and found many thin bentonites in the 450 Ft. thick Mowry Formation.

Sec. 34, T. 31 N., R. 96 W. 55 thin bentonite seams (0.1 to 2.5 ft. thick) are found in the 190.6 ft. thick Mowry Formation. No large outcrops were seen (Heathman, 1939, p. 14-15).

Sec. 1, T. 42 N., R. 107 W. Love (1947) reported numerous bentonite layers in the Frontier and Mowry Formations. Many of the beds over 2 ft. thick contain impurities of various kinds. Exposures are rather poor in this area of complex folding. A total of 28 ft. of bentonite was measured.

Secs. 30, 31, T. 43 N., R. 107 W. An 11 ft. thick layer of white bentonite forms the upper bed of the Wind River Formation which crops out for a distance of 3 mi. near White Pass. The layer contains montmorillonite, zeolite, and moderate amounts of quartz and feldspar (Keefer, 1955).

Bentonite is found in the Frontier and Mowry Formations north of Dubois in the Du Noir Area. A few pure beds ranging in thickness up to 14 ft. were observed, with the thickest beds occurring in the Frontier Formation (Keefer, 1955).

Hot Springs County

NW¼ sec. 33, T. 47 N., R. 99 W. Hewett (1926) measured a 3 ft. thick bentonite seam in the Meeteetse Formation.

SW$\frac{1}{4}$ sec. 16, T. 44 N., R. 99 W. 16 ft. of bentonites of unknown quality were observed in Post-Wasatch tuffs.

Bentonite is found in the Frontier and Mowry Formations where they outcrop along the north flank of the Owl Creek Range.

Johnson County

Sec. 36, T. 49 N., R. 83 W. Four bentonite seams from 0.5 to 1.5 ft. thick are found in 47.3 ft. of upper Frontier Shales. Eleven bentonite beds (0.5 to 3.5 ft. thick) are found in 259.5 ft. of Mowry Shale and seven thin layers are found within the 502.1 ft. thick Thermopolis Shale. These beds dip 15° E. (Heathman, 1939, p. 11).

Bentonite seams are found in the Thermopolis, Mowry and Frontier Fromations along the east flank of the Big Horn Mountains (Clabaugh, et al., 1946).

Laramie County

T. 19 N., R. 71 W. Thin bentonite seams are found in the Mowry Formation near Iron Mountain (Hammond, 1949).

T. 19 N., R. 70 W. Haun (1949) reports thin bentonite beds in the Mowry Formation along the east flank of the Laramie Range at this location (Haun, 1949).

Natrona County

Fisher (1905) made the following analysis of Natrona County bentonite:

SiO_2	65.24%
Al_2O_3	15.88
Fe_2O_3	3.12
MgO + CaO	5.34
H_2O	9.17

SW$\frac{1}{4}$ sec. 3, SE$\frac{1}{4}$ sec. 4, W$\frac{1}{2}$ sec. 10, NE$\frac{1}{4}$ sec. 15, T. 30 N., R. 81 W. A 5 ft. thick bentonite layer in the Mowry Formation crops out around the flanks of an asymmetric anticline in the Bates Park area. Only the northwest flank of the anticline has low dips and thin overburden above the bentonite. The best exposures are in sec. 10 where the bentonite contains 90% montmorillonite. Estimated reserves are "several million" short tons (Dengo, 1946, p. 9-10, 17). Peterson (1935) reports 6 ft. thick bentonite beds in the Mowry Formation north of Bolton Creek oil field.

NE$\frac{1}{4}$ sec. 31, T. 30 N., R. 82 W. A 5 ft. thick bentonite layer in the Mowry Formation crops out in a SE. plunging syncline just east of Alcova Reservoir. The bentonite layer dips 5° to 7° N. with very little overburden on the southwest limb of the syncline. Estimated reserves for the Alcova area are 300,000 short tons (Dengo, 1946, p. 8, 17).

Sec. 25, 36, T. 30 N., R. 83 W. Bentonite in the Mowry Formation dips 6° NE. Wider outcrops and thinner overburden are found away from Alcova Reservoir. A bentonite specimen from sec. 36 contained 85% to 90% montmorillonite (Dengo, 1946, p. 8-9).

Sec. 10, T. 31 N., R. 80 W. A 4.8 ft. thick bentonite bed in the Mowry Formation crops out on the slopes of several hills in the area. Although the bed dips gently to the southwest, the overburden is generally greater than 15 ft. The bentonite is 90% montmorillonite and estimated reserves are 224,800 short tons (Dengo, 1946, p. 10, 17).

SW$\frac{1}{4}$ sec. 31, T. 32 N., R. 80 W. and N$\frac{1}{2}$ sec. 36, SE$\frac{1}{4}$ sec. 35, T. 32 N., R. 81 W. A 4.8 ft. thick bentonite bed is found in the Mowry Formation which dips southwest. Frontier Shale overburden is thick. Reserves are estimated at 264,000 short tons (Dengo, 1946, p. 10, 17).

Secs. 18, 19, T. 32 N., R. 81 W. and secs. 13, 24, T. 32 N., R. 82 W. Five ft. of Mowry bentonite and two thin bentonite layers in the Frontier Formation are found in the vicinity of Lee Lake. The beds are complexly folded and faulted and overburden greater than 15 ft. Estimated reserves are 101,300 short tons (Dengo, 1946, p. 12, 13, 17).

T. 32 N., R. 86, 87 W., T. 33 N., R. 87, 88 W., and T. 34 N., R. 88 W. A 3.5 ft. thick bentonite bed at the top of the Mowry Shale crops out for 25 mi. along the northeast flank of the Rattlesnake Hills. The beds dip 30° NE. and are probably discontinuous since it appears that the upper part of the Mowry Formation has slid down dip (Heathman, 1939, p. 15).

SE$\frac{1}{4}$ sec. 31, T. 33 N., R. 80 W. A Mowry bentonite bed containing 85% to 90% clay minerals crops out around small Frontier Shale outliers in the Blue Hill vicinity. A 4.8 ft. thick bentonite layer in the Mowry (?) Formation dips 9° E. and crops out around a 400 ft. wide, 500 ft. long Frontier remnant in the NE$\frac{1}{4}$ of the same section (Dengo, 1946, p. 11).

Sec. 32, T. 33 N., R. 80 W. Heathman (1939, p. 16-17) found a 4 ft. bentonite seam at the top of the Mowry Shale and noted many thin bentonite seams interbedded with shale in the Thermopolis and Mowry Formations which crop out west and southwest of Casper.

Sec. 9, T. 33 N., R. 81 W. A 4.5 ft. thick bentonite bed in the Mowry crops out around the flanks of the Emigrant Gap Anticline. In sec. 9 the exposures extend 4000 ft. and dip of the beds varies from 10° to 40° NE. Overburden is thickest in gullies. The bentonite is the high-swelling type and contains 90% to 95% montmorillonite. Estimated reserves for the entire Emigrant Gap area are 277,375 short tons (Dengo, 1946, p. 7,8).

NE$\frac{1}{4}$ sec. 24, T. 33 N., R. 81 W. A thin bentonite bed in the Mowry Formation north of the Platte River dips 10° E. Mining conditions are favorable, but the deposits are small (Dengo, 1946, p. 7).

Secs. 24, 25, T. 33 N., R. 81 W. A 4.8 ft. thick bed of bentonite at the top of the Mowry Formation dips 6° to 9° E. and has more than 15 ft. of overburden. The Mowry Shale is exposed in several gullies in this area (Dengo, 1946, p. 8).

Sec. 4, N$\frac{1}{2}$ sec. 3, T. 36 N., R. 83 W. Two bentonite layers, 4 ft. and 5 ft. thick, are contained in the Steele Formation north of Natrona. The beds dip 9° S. and overburden is relatively thick over most of the area. Selenite crystals are scattered through the clay which contains 95% montmorillonite and some kaolin (Dengo, 1946, p. 16-17).

T. 39, 40, 41 N., R. 79 W. A 9 to 12 ft. thick bentonite bed in the Steele Formation crops for a considerable distance in the syncline west of Salt Creek Anticline. South of Columbine a 2 ft. thick bentonite bed is found below the 9 ft. thick bed in the Steele Shale. Neither of the beds are uniform and the amounts of selenite and shale interbedded with the bentonite vary. Bentonite from sec. 20, T. 40 N., R. 79 W. contains 95% montmorillonite (Dengo, 1946, p. 16).

Niobrara County

The thick bentonite layers present in the Pierre Shale in Weston and Crook Counties thin to the south. Any bentonite in Niobrara County is probably of little if any economic value (Hancock, 1920).

W$\frac{1}{2}$ sec. 2, T. 35 N., R. 65 W. A bentonite bed in the Pierre Shale forms a dip slope on the south limb of Lance Creek Anticline. The bed dips about 4° S. (Hancock, 1920).

SE$\frac{1}{4}$ sec. 26, T. 36 N., R. 65 W. A bentonite bed in the Pierre Shale dips 16° N. on the north limb of Lance Creek Anticline (Hancock, 1920).

Park County

Bentonite is common in the Thermopolis, Mowry and Frontier Formations on the west side of the Big Horn Basin. There are two zones in the Frontier Formation: 1) from 85 ft. to 140 ft. below the top of the Formation and 2) 90 ft. to 140 ft. above the base. A great many thin seams are found in the Mowry and Thermopolis Formations.

Hewett (1914, p. 97) found 35 thin bentonite beds in 392 ft. of Cretaceous shales along the Shoshone River. Hewett (1926, p. 56) made the following analysis of bentonite from the uppermost Frontier Formation:

SiO_2	65.63%
Al_2O_3	13.40
Fe_2O_3 + FeO	2.55
MgO	2.17
CaO	0.85
Na_2O	0.69
K_2O	0.27
H_2O	14.33

Platte County

T. 20 N., R. 69 W. Several bentonite seams interbedded with gray and black Mowry Shale are found in the Chugwater Creek-Deadhead Creek area of Platte and Laramie Counties (Haun, 1949, p. 13).

Sheridan County

T. 58 N., R. 88 W. Two beds of bentonite, one in the Mowry Formation and the other in the Frontier Formation, are sources of commercial bentonite. A bentonite layer in the Mowry is 5 ft. thick in sec. 20. In sec. 17, 18 and 21, the bentonite layer in the Frontier Formation is as much as 20.5 ft. thick and has been mined by the Wyotana Bentonite Mining Co. (Knechtel, M. M., and Patterson, S. H., 1956).

Sublette and Lincoln Counties

T. 20 N., R. 117 W. Bentonite has been reported at Skull Point Gap by Mr. Chris Vrang of Evanston, Wyo. (Osterwald, 1947).

Sec. 15, 21, T. 29 N., R. 115 W. Bentonite beds up to 2 ft. thick have been found in the Aspen Shale in Sec. 15. In sec. 21 bentonite beds 2 to 8 inches thick occur in the Hillard Formation (Fruchy, 1962, and Furer, 1962).

T. 28, 29 N., R. 116 W. The Hillard Formation probably contains bentonite at this location (Hauf, 1963, and Suydam, 1963).

Teton County

T. 44 N., R. 110 W. "A large amount" of bentonite was found in lower Eocene rocks in Black Rock Meadows, 3 mi. southwest of Togwotee Pass at Teton Canyon (Osterwald, et al., 1966).

T. 43 N., R. 110 W. Bentonite was found in Oligocene rocks 10 miles south of Togwotee Pass at Teton Canyon (Osterwald, et al., 1966).

Uinta County

Sec. 30, T. 14 N., R. 119W. Bentonite from a deposit in the Knight Formation has been used as a reservoir lining, but only thin seams are now visible. This deposit on the Jamison Claim (Osterwald, 1947).

E½ sec. 2, T. 17 N., R. 117 W. A 5 ft. thick bentonite bed at the base of the Frontier Formation is exposed along the dip slope of a small hogback. There is no overburden and outcrops are visible for ½ mi. along the strike of the beds (Osterwald, 1947).

Bentonite has been reported at Spring Valley by Mr. Chris Vrang of Evanston, Wyo. (Osterwald, 1947).

Washakie County

Bentonite mined in the northeastern part of Washakie County from the Frontier and Mowry Formations has been used for dam and ditch linings. The bentonite is suitable for both foundry and drilling mud use (Trotter, 1954).

T. 45 N., R. 88 W. A 5 ft. thick bentonite layer at the base of the Frontier Formation is exposed in cliffs west of No Wood Creek (Morgan, 1951, p. 38).

Sec. 30, T. 46 N., R. 88 W. A 6 ft. thick clay deposit possessing properties similar to bentonite, is found in the Wasatch Formation (Eocene?) at the head of Bud Kimball Draw, 12 miles southeast of Tensleep.

Weston County

Most of the Cretaceous beds which crop out along the southwestern flanks of the Black Hills Uplift contain relatively pure beds of bentonite. Most commercial deposits are contained in beds near the base of the Bell Fourche Formation, at the top of the Mowry Formation (Clay Spur bentonite), and in the Newcastle Sandstone (Robinson, et al., 1964). Some analyses of Weston County bentonites are given in Table 2.

Sec. 13, T. 41 N., R. 61 W. A 3 ft. thick bentonite bed at the top of the Mowry Formation dips 4° SSW. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

Sec. 7, T. 42 N., R. 60 W. A 2.5 ft. thick bentonite layer in the upper Mowry Formation crops out near Clifton. The bed dips 4° SW. and has from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

	1	2	3	4	5	6	7	8	9
SiO_2	56.93%	63.25%	60.80%	53.50%	54.31%	70.36%	61.00%	61.78%	63.25%
Sol. SiO_2	-----	-----	-----	-----	-----	0.62	-----	-----	-----
Al_2O_3 + P_2O_5	14.75	-----	-----	21.57	-----	11.47	-----	-----	-----
Al_2O_3	-----	12.63	22.40	-----	20.22	-----	20.98	21.56	17.62
Fe_2O_3	2.08	3.70	0.97	3.28	1.88	2.48	3.04	3.10	3.70
FeO	-----	-----	0.41	-----	0.19	-----	0.34	0.28	-----
MgO	1.86	3.97	2.34	1.89	0.98	1.38	2.68	2.62	3.70
CaO	6.35	4.12	0.76	1.25	0.94	0.26	0.44	0.68	4.12
Na_2O	2.28	------	2.69	1.94	2.35	1.69	2.36	2.22	-----
MnO	-----	-----	0.12	-----	-----	-----	0.10	0.08	-----
K_2O	0.93	3.55	0.32	1.04	0.21	0.75	0.35	0.31	-----
H_2O	10.61	6.71	8.90	15.20	18.64	11.32	8.19	7.71	-----
TiO_2	0.11	-----	-----	-----	-----	0.10	-----	-----	-----
H_2SO_4	-----	1.58	-----	-----	-----	-----	-----	-----	-----
SO_3	-----	-----	0.18	-----	-----	-----	0.36	trace	1.53
CO_2	4.61	-----	-----	-----	-----	-----	-----	-----	-----

Table 2. Bentonite analyses; Weston County.

1) T. 45 N., R. 62 W. Pedro bentonite bed at base of Mowry Formation (Mapel and Pillmore, 1963).
2) T. 46 N., R. 63 W. Graneros Shale bentonite at Osage (Darton, 1904, p. 9).
3) T. 46 N., R. 63 W. Graneros Shale bentonite at Osage (O'Harra, 1929, p. 47-48).
4) T. 46 N., R. 63 W. Belle Fourche bentonite at Osage (Mapel and Pillmore, 1963).
5) Sec. 30, T. 47 N., R. 63 W. Graneros Shale bentonite (Hewett, 1914, p. 56).
6) Sec. 30, T. 47 N., R. 63 W. Clay Spur bentonite at top of Mowry Formation (Rubey, 1928, p. 157).
7) T. 47 N., R. 64 W. Clay Spur bentonite bed at top of Mowry Formation west of Jerome (O'Harra, 1929, p. 47-48).
8) T. 48 N., R. 65 W. Clay Spur bentonite 2 mi. northwest of Upton (O'Harra, 1929, p. 47-48).
9) Weston County bentonite (Fisher, 1904, p. 560).

Sec. 19, T. 43 N., R. 60 W. A 1.3 ft. thick bentonite seam at the top of the Mowry Formation is exposed north of Clifton. The layer dips 7° SW. and has from 0 to 25 ft. of overburden (Heathman, 1939, p. 9-10).

T. 45 N., R. 61 W. A 1 to 4 ft. thick bentonite bed at the top of the Newcastle sandstone and a 3 ft. thick layer near the top of the Belle Fourche Shale are exposed in the Newcastle area and may be extensive enough to mine. The Clay Spur bentonite bed at the top of the Mowry Formation is thin and does not appear to contain large reserves. Bentonite is also found in the Pierre Shale (Mapel and Pillmore, 1963).

T. 45 N., R. 62 W. (?) Bentonite is found in the Upper Cretaceous Pierre Formation (O'Harra, 1929).

T. 45 N., R. 62, 63 W. A steeply dipping 12 ft. thick bentonite bed is found near the top of the Niobrara Formation 3/4 mi. east of Pedro and 1 mi. west of Pedro (Darton, 1904).

Secs. 8, 9, T. 45 N., R. 62 W. and sec. 1, T. 45 N., R. 63 W. The Pedro bentonite bed at the base of the Pierre Shale, is 30 ft. thick at this locality. The bentonite has been strip mined but only small amounts were removed because of steep dips (Mapel and Pillmore, 1963).

Sec. 31, T. 46 N., R. 62 W. Bentonite has been strip mined from a bed in the lower part of the Belle Fourche Shale (Mapel and Pillmore, 1963).

Sec. 9, T. 46 N., R. 63 W. A 4 ft. bentonite bed in the Graneros Shale dips gently SW. at Osage (Darton, 1904). An analysis is given in Table 2.

Secs. 11, 17, 27, T. 47 N., R. 64 W. A 2.5 ft. thick bentonite layer at the top of the Mowry Shale is exposed northwest of Osage. The bed dips 3° SW. and has from 0 to 20 ft. overburden (Heathman, 1939, p. 9-10). In the NE$\frac{1}{4}$ sec. 27, near Jerome, two bentonite beds dip 40° S. Estimated reserves (with 15 ft. or less overburden) are 73,000 tons in the lower bed and 45,575 tons in the upper bed (Love, 1935).

T. 47 N., R. 64 W. A 3.5 ft. thick bentonite bed in the Mowry Formation has been mined 1.5 miles west of Jerome. Jerome was once the site of a bentonite processing plant. (O'Harra, 1929, p. 47-48). A bentonite analysis is given in Table 2.

T. 48 N., R. 65 W. A 3.5 ft. thick bentonite layer lies above the Mowry Shale 2 mi. northwest of Upton at Colloid Siding. The bed has very little overburden and has been mined (O'Harra, 1929, p. 47-48). An analysis of the bentonite is given in Table 2.

Secs. 2, 16, T. 48 N., R. 65 W. A bentonite seam at the top of the Mowry Formation averages 2.5 ft. thick northeast of Thornton. The bed dips 3° SW. and has from 0 to 20 ft. of overburden (Heathman, 1939, p. 9-10).

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