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SOME CHARACTERISTICS OF BENTONITE IN ALBERTA

by

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SOME CHARACTERISTICS OF BENTONITE IN ALBERTA

Abstract

Bentonites are found throughout southern and central Alberta, mainly in Upper Cretaceous strata. Their wide variations in composition and properties are shown in tables which also include their locations and geologic settings. Some of these bentonites have been or are being mined, primarily for use in drilling muds.

INTRODUCTION

Increasing consumption of bentonite in Canada, particularly in the iron-ore pelletizing industry, currently is drawing attention to bentonite deposits in Alberta. Most iron-ore pellets contain about 0.6 per cent swelling bentonite. Alberta is the only producer of swelling bentonite in Canada. Supposing that bentonite continued to be required in this proportion as a pelletizing agent, Ross in 1964 predicted a consumption of 100,000 tons for this purpose during 1965, an increase of 90,000 tons from bentonite consumption during 1961. Although 1965 data on consumption are not yet available, this proportion of bentonite in pellets and the current capacity of Canadian pelletizing plants confirms the accuracy of Ross' prediction. Announced expansions and new plants indicate an annual Canadian consumption in excess of 150,000 tons by early 1969. At present all Canadian requirements for pelletizing are imported. Other important consumers of bentonite in Canada are the bleaching, steel foundry, and well drilling industries. Its use in civil engineering in constructing concrete walls below ground level and in barriers to groundwater is increasing.

Much of the data on bentonite in Alberta is available in three reports (Byrne, 1955; Ross, 1964; Banks and Watts, 1965). These data and additional data from other publications and the files of the Industrial Minerals section of the Research Council of Alberta are summarized in this report for the use of those interested in developing or beneficiating Alberta bentonite.

Bentonite is derived from the alteration of volcanic ash. The principal constituent is the clay mineral montmorillonite, mixed with varying amounts of impurities, such as quartz, cristobalite, feldspar, volcanic glass, and gypsum. Although montmorillonite is a common constituent in some of the Cretaceous and Tertiary formations of Alberta, most bentonites described in this report are present in relatively thick seams or beds containing a high percentage of montmorillonite. The characteristics of montmorillonite give bentonite the properties which make it useful in the drilling, bleaching, foundry, and pelletizing industries. An important property of montmorillonite is that of base exchange. Exchangeable cations, usually sodium or calcium, are located on the surfaces of the silicate layers. The exchange reaction generally takes place in a water solution, and the swelling properties of a bentonite differ depending primarily on the exchangeable cations present.

Good-quality swelling bentonite is used by the pelletizing industry as a binder of iron-ore concentrates. Prior to the development of pelletization of concentrates, a large percentage of finely divided iron ore was not recoverable, or was lost during handling and processing. Crushing and grinding of increasing numbers of low-grade iron ores to the fine mesh sizes required for their beneficiation to high-grade iron concentrates is economically feasible because the fine concentrates can be pelletized into feed suitable for charging to the blast furnace. Swelling bentonite is preferred to non-swelling bentonite as it disaggregates more readily into finer particles and provides a larger surface area to come into contact with the material being pelletized. The green and dried compressive strengths are important physical properties of pellets. Ross (1964) discusses specifications for pellets and indicates that a number of variables, such as processing methods and characteristics of the concentrate, affect the quality of such pellets. Requirements are determined by individual companies and are not standardized; consequently specifications are not given here.

Acknowledgment

The criticisms and helpful advice of Dr. L. B. Halferdahl are gratefully acknowledged.

USES AND PRODUCTION

Bentonite was used in the early days as a substitute for soap by the Indians and employees of the Hudson's Bay Company (Ries and Keele, 1913). Prior to 1930, small amounts of bentonite from the Saunders group (Paleocene or Upper Cretaceous) were mined in the Edson area near Bickerdike by Claynett Distributors Limited for use in cosmetics (Allan, 1931). Official records, however, indicate that commercial production began in Alberta in 1938 with shipments of bentonite by G. L. Kidd and Aetna Coals Limited from the Drumheller area to Calgary, where it was processed chiefly for use in drilling mud. The bentonite was recovered as a by-product of coal mining until 1957. In 1959, Magcobar Mining Company Limited began processing swelling bentonite from deposits about nine miles south of Rosalind. In 1960, Baroid of Canada Limited began processing swelling bentonite recovered from deposits near its plant at Onoway. Presently, the greater part of this production is used in the well drilling industry, with lesser amounts consumed in foundries, and in civil engineering.

DESCRIPTION OF DEPOSITS

Table 1 (Appendix) presents bentonite and overburden thicknesses, yields, silt and sand contents, and other information for bentonites from 80 locations in Alberta. The order of deposits in table 1 is by township from south to north, and then by range and meridian from east to west. Deposit locations are shown in figure 1. In addition to the deposits presently being mined, other reasonably thick and extensive deposits are numbered 7, 17, 21, 23, 34, 65, and 72 in table 1. The references numbered in table 1 are identified as follows: 1-Byrne, 1955; 2-Industrial Minerals files of the Research Council of Alberta; 3-Ross, 1964; 4-Spence, 1924; 5-Anderson and Plein, 1962; 6-Ross and Hendricks, 1945; 7-Maiklem and Campbell, 1965; 8-Allan, 1931.

CHEMICAL COMPOSITION

Table 2 (Appendix) consists of chemical data for 16 bentonites from Alberta, and 6 bentonites from the United States for comparison. Below each analysis are the atomic proportions of the sample, calculated from the chemical analyses according to the method described by Ross and Hendricks (1945). In the structure are four tetrahedral positions which must be filled, and three octahedral positions, of which approximately two are filled in these montmorillonites. All the silicon present is assigned to the tetrahedral sheet, with the remaining positions filled by aluminum. The remainder of the aluminum is assigned to the octahedral sheet, together with those cations which are not in exchange positions. Samples with a calculated silicon content exceeding the limits for tetrahedral coordination, or with less than two atoms calculated in octahedral coordination, undoubtedly contain excess silica as impurities such as quartz or cristobalite. The amount of exchangeable bases in most of the samples shown in table 2 is higher than the figures of Ross and Hendricks (1945) because of inaccurate chemical analyses or the presence of impurities such as mica or gypsum in the montmorillonite. Three ionic ratios have been calculated for some constituents, the determinations of which are not considered to be unduly affected by impurities in the samples or by incompleteness of the analyses. For the most part, the ratio of lime to soda is higher in the bentonites from

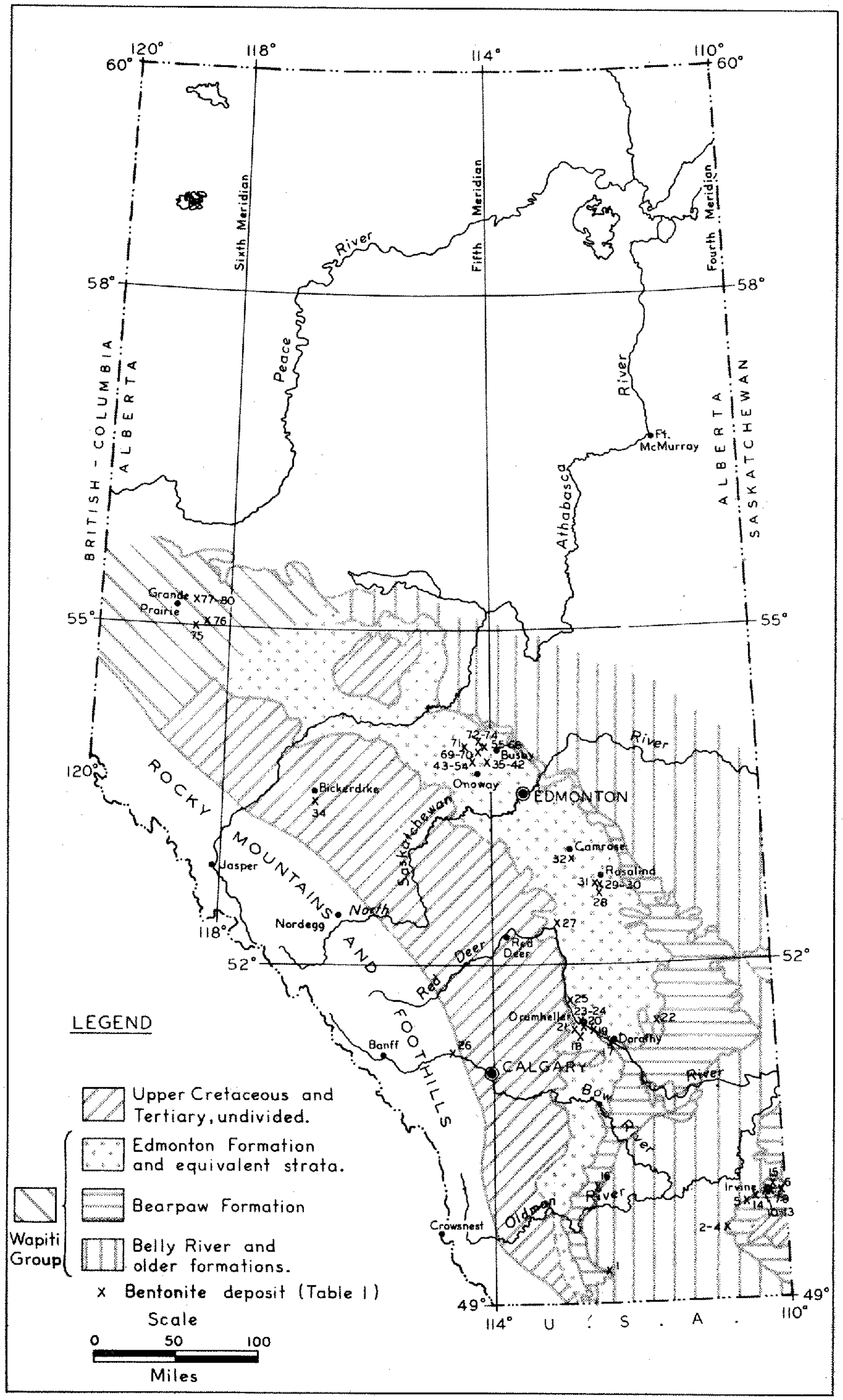

Figure 1. Locations of some bentonite deposits in Alberta

Alberta than in some swelling bentonites from Wyoming and South Dakota.

Table 3 (Appendix) consists of data on exchangeable ions and cation-exchange capacities for ten Alberta bentonites. The difference between the total of exchanged ions in the leachate and the cation-exchange capacity is due to the presence of soluble salts in the clays tested (Anderson and Plein, 1963). The presence of ions from soluble salts together with the exchangeable ions from montmorillonite in the leachate casts uncertainty on attempts to correlate physical properties with particular exchangeable ions.

PHYSICAL PROPERTIES

Table 4 (Appendix) is a compilation of some physical properties of Alberta bentonites from two recent reports by the Mines Branch of the Canadian Department of Mines and Technical Surveys. Some of the samples in the two reports appear to be the same, but have different numbers. These samples are correlated primarily on the basis of an identical swelling index and colloidal content.

SUMMARY

Table 5 (Appendix) indicates various similarities and differences in bentonites from Alberta with swelling bentonites from Wyoming and South Dakota. The data on the physical properties of the bentonite from the United States are mainly after Knechtel and Patterson (1962). Only analyses of beds of the Clay Spur Member of the Mowry Shale which are at least two feet thick are included.

The bentonite from the Clay Spur Member of the Mowry Shale generally has better swelling properties than most of the bentonites found thus far in Alberta. There are, however, other bentonite beds within the Mowry Shale having swelling properties similar to some of the bentonites in Alberta. The differing physical properties suggest that the bentonites were derived from volcanic ash of different compositions. Physical properties of bentonite are also modified by environment and degree of alteration of the ash, conditions which are partly controlled by the depth of overburden, nearness to the face of the outcrop, climate, and possibly the flow and composition of groundwater. The presence of thin beds of bentonite having excellent swelling properties in Alberta implies that the composition of some volcanic ash was appropriate, and environmental conditions suitable for their formation. Therefore, other deposits of bentonite which comply with swelling specifications can be expected in Alberta.

Fundamental research on the nature of the montmorillonite

itself, as distinct from the total bentonite, can be expected to provide leads to methods of beneficiating some Alberta bentonites to meet additional industrial specifications, and to show new uses for the abundant deposits throughout Alberta.

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APPENDIX: TABLES 1 - 5

Table 1. Summary of Bentonite Deposits in Alberta

Loc. No.	Location Lsd.* Sec. Tp. R. Mer.	Formation	Thickness Bentonite (Feet)	Thickness Overburden (Feet)	Yield (Bbl/Ton)	Sand and Silt Per Cent >74µ >48µ 2-48µ	Other Information	Reference
1	— 9 4 19 W.4 (N side of Milk River ridge)	Lower Bearpaw	1.5-2	Thick	Low	Fairly silty	Unknown tonnage available.	2
2	NW 1/4 2 8 7 W.4 (SW side of Bullshead Butte)	Bearpaw (100 feet from base)	2	8	~50	-	Small known tonnage available.	2
3	NE 1/4 2 8 7 W.4 (SW side of Bullshead Butte)	Bearpaw	2	10-15	58	6.70 0.72 15.50	Buffish-grey color. 72 ml gel vol. (B.P.)**; pH 8.8.	1,5
4	NW 1/4 14 8 7 W.4 (1 1/2 mi. N of preceding location)	Bearpaw	2	>15	32	-		1
5	— 25 10 5 W.4 (Gros Ventre area, near Medicine Hat)	Bearpaw	8.7 4.5	- 25.3	-	-	Measured section from top: bentonite 8.7 ft., shale 25.3 ft., bentonite 4.5 ft., shale concealed.	2
6	SW 1/4 28 11 1 W.4 (Near Walsh, just S of Trans-Canada Highway)	Upper Oldman (or Lower Bearpaw?)	4-5	<10 (~2)	28	8.80 3.63 46.29	Quite pure; buffish-grey color; 6-inch silty parting near top; large tonnage probably available. 10 ml gel vol. (B.P.); 11 ml apparent swelling vol. (B.P.)***; pH 8.05.	1,5
7	— 20 11 2 W.4 (SE of Irvine)	Bearpaw	11.0	-	-	-	Measured section from top: shale, bentonite and ash 11.0 ft., shale 26.0 ft., bentonite 0.4 ft., shale 10.5 ft., bentonite 1.0 ft.	2
8	— 30 11 2 W.4 (SE of Irvine)	Bearpaw	9.8	-	-	- 3.79	Measured section from top: shale, bentonite 9.8 ft., shale 27.8 ft., bentonite 1.4 ft.,	2,5

						20.82	shale 21.3 ft., bentonite and ash 0.8 ft. 22 ml gel vol. (B.P.); pH 8.54.	
9	NW 1/4 30 11 2 W.4 (1 mi. S of Irvine)	Bearpaw	1-5	5-10	38	4.9 - -	Mixed bentonite and volcanic ash; ash content increases in an easterly direction.	1
10	— 17 11 3 W.4 (Gros Ventre area)	Bearpaw	10.1	-	-	-	Measured section from top: glacial drift, shale 2.6 ft., ash and bentonite 10.1 ft., shale 21.0 ft., bentonite 0.9 ft., shale 4.4 ft., bentonite 0.5 ft.	2
11	— 23 11 3 W.4 (Irvine area)	Bearpaw	0.4-1.2	Thick	-	-	Overburden of volcanic ash and shale.	2
12	NE 1/4 25 11 3 W.4 (1 mi. S of Irvine)	Bearpaw (100 feet from base)	1-8	0-10	~30-40	-	Probably small tonnages available; present in patches mixed with volcanic ash.	2
13	— 25 11 3 W.4 (Irvine area)	Bearpaw (?)	9.0 1.2 1.0	- 29.2 5.2	-	-	Measured section from top: glacial drift, ash and bentonitic shale 9.0 ft., shale 29.2 ft., bentonite and ash 1.2 ft., shale 5.2 ft., bentonite 1.0 ft.	2
		Bearpaw	6.5 1.1	- 28.7			Measured section from top: glacial drift, bentonite and ash 6.5 ft., shale 28.7 ft., bentonite 1.1 ft., shale 4.7 ft., bentonite 0.8 ft.	2
14	— 12 11 4 W.4 (Gros Ventre area)	Bearpaw	0.4-1.9	Thick	-	-	Overburden of limestone, bentonite and ash, or shale.	2
15	— 4, 15 12 2 W.4 (N of Irvine)	Bearpaw	10-11	-	-	-	Thickness includes some ash.	2
16	NW 1/4 14 12 20 W.4 (Along Little Bow River near Turin)	Bearpaw (?)	15	-	-	Silty		2

* Quarter section is shown in some cases where legal subdivision is unknown.
** B.P.= British Pharmacopoeia.
*** Swelling volumes in Table 1 determined after purification by water sedimentation.

Summary of Bentonite Deposits in Alberta (Cont'd.)

Loc. No.	Location Lsd. Sec. Tp. R. Mer.	Formation	Thickness Bentonite (Feet)	 Overburden (Feet)	Yield (Bbl/Ton)	Sand and Silt Per Cent >74μ >48μ 2-48μ	Other Information	Reference
17	NE 1/4 3 27 17 W.4 SW 1/4 10 27 17 W.4 (Along Red Deer River in vicinity of Dorothy)	Upper Bearpaw	20-29	Low or variable	30-37	0.02-0.2 Trace 32.01	Relatively uniform, can be traced over long distances; green to greenish-grey color; contains some sandstone and volcanic ash; main deposit extends into valley sides under deep overburden; large tonnages available. Swelling sodium type; chemical analysis no. 11; 97 ml gel vol. (B.P.); 30 ml apparent swelling vol. (B.P.); pH 7.3-9.75. Concentration (%): 10 12 14 16 Viscosity (cp) : 4 6.5 14.5 34 Initial gel strength (gm) : 2 2.5 2.5 3.5 10 min. gel strength (gm) : 3.5 3.5 4.5 6.5 Filtrate (cc) : 13.5 12 11.5 10.5 Filter cake (inch) : 3/64 3/64 4/64 5/64	1,2,3,5
18	SE 1/4 32 27 20 W.4 (Near Beynon, along Rosebud River)	Edmonton	3.5	Low	51	0.2 11.23 37.35	Lens shaped deposit; underlies coal seam 2 1/2 ft. thick; unknown tonnage available. Chemical analysis no. 10; 98 ml gel vol. (B.P.); 57 ml apparent swelling vol. (B.P.); pH 9.27.	1,5
19	SE 1/4 22 28 19 W.4 (Aetna Coal Mine, at Rosedale)	Edmonton	0.5-0.7	-	90	0.4 - -	Pale olive grey color; present as a parting in No. 1 coal seam; could be mined with coal. Sodium-type swelling to nearly eight times the original volume; chemical analyses nos. 7, 8, 14; analysis no. 6 from outcrop; low thixotropy.	1,4,6
20	NE 1/4 34 28 20 W.4 (About 1 1/2 mi. SW of Drumheller)	Edmonton	1	-	-	-	Apparently pure, becoming siltier up and down stream.	1

21	— 26 28 21 W.4 (W rim Horseshoe Canyon; adjacent to Highway No. 9)	Edmonton (top of middle member)	20	10	-	Slightly silty	Calcium type; large available tonnage.	2
22	W 1/2 13 29 13 W.4 (Above coal strip mined at Sheerness by Western Dominion Coal Mines)	Edmonton	1-5	Overlain by brown bentonite of lower quality	58	0.5 - -	Olive green color; lateral extent not fully known. Concentration : 9 % 10 % 12 % Initial gel strength : 3 gm 3 gm 6 gm 10 min. gel strength: 10 gm 16 gm 30 gm	1,2
		Edmonton	-	-	43	1.7 - -	Brown grading below into olive green. Concentration : 9 % 10 % 12 % Initial gel strength : 5 gm 7 gm 9 gm 10 min. gel strength: 7 gm 15 gm 25 gm	
23	SE 1/4 9 29 20 W.4 (Newcastle)	Edmonton	5-10	Light	42-66	3.9-11.6 - -	Contains local lenses of fine-grained sandstone.	1
24	NW 1/4 14 29 20 W.4 (Ridge 1 1/2 mi. N of Drumheller)	Edmonton (lower member)	3	Nil	56	2.30 0.72 14.48	Situated between No. 5 and No. 6 coals; overburden thickens downstream; mined intermittently for a number of years. Decolorizing ability fair; chemical analysis no. 12 is for a 3-foot bed between the two coals, though not from location listed; 73 ml gel vol. (B.P.); 32 ml apparent swelling vol. (B.P.); pH 9.35.	1,2,5
25	NE 1/4 32 31 21 W.4 (Morrin ferry, along Red Deer River, 19 mi. NW of Drumheller)	Edmonton (middle member)	5	Thick	42	1.1 - -	Underlain by 4 inches blue-grey tuff; grades laterally into silty bentonite.	1
26	Bow River Section (W of Calgary)	Belly River	-	Thick	-	-	Chemical analyses nos. 2-5.	7
27	SW 1/4 22 39 22 W.4 (Nevis)	Edmonton	-	-	-	-	99 ml gel vol. (B.P.); 33 ml apparent swelling vol. (B.P.); pH 9.6.	5

Summary of Bentonite Deposits in Alberta (Cont'd.)

Loc. No.	Location Lsd. Sec. Tp. R. Mer.	Formation	Thickness Bentonite (Feet)	 Overburden (Feet)	Yield (Bbl/Ton)	Sand and Silt Per Cent >74μ >48μ 2-48μ	Other Information	Reference
28	N 1/2 31 42 17 W.4 (About 9 mi. S of Rosalind)	Edmonton	8-10	5-33	50-110	1.20-1.52 0.75-1.96 4.52-16.31	Production by Magcobar started in 1959; estimated reserves more than one million tons; main zone 500 ft. wide and 3600 ft. long; individual seams up to 1 ft. thick. 40-57 ml gel vol. (B.P.); 94-100 ml apparent swelling vol. (B.P.); viscosity 11-22 cp (6-8% bentonite); pH 7.1-9.2 (8.2 avg.).	2,3,5
29	3,4 5 43 17 W.4	Edmonton	4-11	17-21	48-64	1.27-4.00 - -	Viscosity 9-19 cp (8-12% bentonite); pH 8.4.	2
30	8 19 43 17 W.4	Edmonton	5-7	9	64	0.56 - -	Estimated reserves more than one million tons. Viscosity 10 cp (8% bentonite); pH 8.7.	2,3
31	3 25 43 18 W.4	Edmonton	2.5	15	48	1.22 - -	Viscosity 21 cp (12% bentonite); pH 9.1.	2
32	SE 1/4 21 46 20 W.4 (3 mi. S of Camrose, along creek running into Battle River)	Edmonton	3	Overlain by dark bentonitic clay under thick overburden	~50-60	3.0 - -	Poor outcrops; unknown tonnage available. Decolorizing ability poor.	1,2
33	Along several Foothills rivers, from S of Nordegg to near Crowsnest (Lynx Creek Area)	Upper Cretaceous (lower part of Alberta group, Vimy member)	Up to 4	-	-	-	Light cream and grey in color.	3
34	NE 1/4 6 52 18 W.5 (Along McLeod river, near Bickerdike, about 15 mi. SW of Edson)	Saunders Group (Paleocene or Upper Cretaceous)	6-8	Thick	27	0.1 - -	Almost pure white in color; probably could be found nearby under lighter overburden; small amounts mined about 1930 for use in cosmetics. Chemical analysis no. 16.	1,2,3,8

35	15, 16	8	56	1	W.5	Edmonton	1.3-9	17.7 max.	38-71.6	-		2
36	NW 1/4	9	56	1	W.5	Edmonton	1.3-3	18.3 max.	44.5-54	-		2
37	9	9	56	1	W.5	Edmonton	5.7-23.3	15 max.	43.4-54	-		2
38	NW 1/4	10	56	1	W.5	Edmonton	3-29	26.7 max. (~10)	41.2-60	-		2
39	4	15	56	1	W.5	Edmonton	2-7.7	18.3 max.	37.5-60.8	-		2
40	7	16	56	1	W.5	Edmonton	1.7-31	18.5 max.	42-72.5	-		2
41	10	16	56	1	W.5	Edmonton	2-27.7	21.7 max.	42-83	-		2
42	15, 16	16	56	1	W.5	Edmonton	2.3-6	27.7 max.	40-59	-		2
43	SW 1/4 NE 1/4 7	6 6 6	56 56 56	2 2 2	W.5 W.5 W.5	Edmonton	Trace-5.3	12-17	-	-	Of low quality mainly due to co-mingling of outer surface of bentonite lenses with top soil, etc.	2
44	NW 1/4 (About 12 mi. NW of Onoway)	7	56	2	W.5	Edmonton	Up to 5	2-50	-	-	Greenish-cream, buff when dry; in scattered lenses; at main zone being mined, overburden about 6-7 ft.; estimated reserves more than 300,000 tons; production by Baroid started in 1960.	3
45	NW 1/4	7	56	2	W.5	Edmonton	0.7-11.7	18.7 max.	-	-		2
46	9	7	56	2	W.5	Edmonton	-	-	-	- 2.30-2.38 17.15-19.07	31-54 ml gel vol. (B.P.); 22-23 ml apparent swelling vol. (B.P.); pH 9.18-9.22.	5
47	NE 1/4 (Busby)	7	56	2	W.5	Edmonton	1.3-10	16.7 max.	35-56	- 1.37 11.30	20 ml gel vol. (B.P.); 23 ml apparent swelling vol. (B.P.); pH 9.03.	2,5
48	SW 1/4	7	56	2	W.5	Edmonton	1-11.7	10-13 avg.	-	-		2
49	1,2 7,8	7 7	56 56	2 2	W.5 W.5	Edmonton Edmonton	2-9 1.7-22.7	20.0 max. 17.7 max.	34-55 38-62.5	- -		2
50	5	8	56	2	W.5	Edmonton	4-14	16.7 max.	38-58	-		2

Summary of Bentonite Deposits in Alberta (Cont'd.)

Loc. No.	Location Lsd.	Sec.	Tp.	R.	Mer.	Formation	Thickness Bentonite (Feet)	Thickness Overburden (Feet)	Yield (Bbl/Ton)	Sand and Silt Per Cent >74µ >48µ 2-48µ	Other Information	Reference
51	12	8	56	2	W.5	Edmonton	6-8.3	9 max.	-	-		2
52	13, 14	8	56	2	W.5	Edmonton	1.3-8.7	20 max.	-	-		2
53	NE 1/4	18	56	2	W.5	Edmonton	0.3-0.7	19 max.	-	-		2
54	NW 1/4	18	56	2	W.5	Edmonton	0.3	23 max.	-	-		2
55	SW 1/4	19	57	1	W.5	Edmonton	1	22.3 max.	-	-		2
56	16	19	57	1	W.5	Edmonton	8	35	-	-		2
57	16	20	57	1	W.5	Edmonton	0.3	20	-	-		2
	NW 1/4	20	57	1	W.5	Edmonton	3.0	2-5	-	-		2
	SW 1/4	20	57	1	W.5	Edmonton	0.7	18	-	-		2
58	NW 1/4	21	57	1	W.5	Edmonton	0.3	10	-	-		2
	SW 1/4	21	57	1	W.5	Edmonton	1.5-20.5	18	-	-		2
	9, 10	21	57	1	W.5	Edmonton	0.7-25.0	27 avg.	35-89	-		2
59	2	22	57	1	W.5	Edmonton	7	38	23	-		2
60	12	22	57	1	W.5	Edmonton	1-15	Thick	-	-		2
61	13	22	57	1	W.5	Edmonton	12	5	-	-		2
62	15	27	57	1	W.5	Edmonton	22.3	20	-	-		2
63	S 1/2	29	57	1	W.5	Edmonton	Trace-3	5-39	-	-		2
64	SE 1/4	30	57	1	W.5	Edmonton	13-52	6-45	-	-	Low grade.	2
65	SE 1/4	30	57	1	W.5	Edmonton	15	15-18	-	-	Greenish-grey when moist.	2
	(About 4 mi. N of Sion)											

66	1	30	57	1	W.5	Edmonton	4.7-28.2	9-50	25-43	-		2
67	SW 1/4	30	57	1	W.5	Edmonton	0.5-16.0	2-20	-	-		2
68	– (Busby area)	36	57	1	W.5	Edmonton	5	Light	78	-	No outcrops; substantial reserves. Viscosity 15 cp (7% bentonite); filter cake 3/32 inch; pH 8.9.	1,2
69	SW 1/4	11	57	2	W.5	Edmonton	1.3-5.3	10	-	-	Clean bentonite encountered in only one location of several tested.	2
70	SE 1/4	25	57	2	W.5	Edmonton	0.7-2.0	10	-	-		2
71	4 (Majeau Lake-Lac La Nonne area)	28	57	3	W.5	Edmonton	-	26-40 depths reached	37	Too silty	Brown bentonitic clay; high water loss after aging 60 hours; low quality, not clean.	2
72	15 (Highridge-Busby area)	3	58	2	W.5	Edmonton	10	3	-	-		2
73	7	7	58	2	W.5	Edmonton	14	16	-	-		2
74	1 (near Highridge, Alberta, E of Newton Lake)	11	58	2	W.5	Edmonton	2-8	6-11	60	-	>50,000 tons yellow bentonite indicated	2
							7	24	-	-	>25,000 tons blue bentonite indicated	2
75	6 (Smoky River)	35	69	4	W.6	Edmonton	-	-	-	- 3.65 30.60	99 ml gel vol. (B.P.); 35 ml apparent swelling vol. (B.P.); pH 9.7.	5
76	4 (Smoky River)	2	70	3	W.6	Edmonton	-	-	-	- 45.10 11.05	38 ml gel vol. (B.P.); 47 ml apparent swelling vol. (B.P.); pH 9.8.	5
77	– (Kleskun Hills)	15	72	4	W.6	Wapiti Group	-	-	-	- 9.46 49.90	25 ml gel vol. (B.P.); 25 ml apparent swelling vol. (B.P.); pH 9.83.	5
78	– (Kleskun Hills)	21, 22, 23	72	4	W.6	Wapiti Group	-	-	-	- 0.88-10.48 27.93-41.06	34-81 ml gel vol. (B.P.); 22-48 ml apparent swelling vol. (B.P.); pH 9.49-9.70.	5

Summary of Bentonite Deposits in Alberta (Cont'd.)

Loc. No.	Location					Formation	Thickness		Yield (Bbl/Ton)	Sand and Silt Per Cent >74µ >48µ 2-48µ	Other Information	Reference
	Lsd.	Sec.	Tp.	R.	Mer.		Bentonite (Feet)	Overburden (Feet)				
79	SE 1/4 (N flank, Kleskun Hills, about 12 mi. NE of Grande Prairie)	27	72	4	W.6	Upper Wapiti Group	4	2-5	52-64	0.46-0.85 - -	Lithologically similar to Edmonton Formation; under and overlain by silty bentonites and bentonitic sands; if laterally persistent, should occur under light overburden.	1,2
80	SW 1/4	27	72	4	W.6	Upper Wapiti Group	Trace-<1	-	43	-	Small scattered thin lenses; small tonnage available.	2

Table 2. Chemical Data on Bentonites

	1	2	3	4	5	6	7
SiO_2	36.49	50.50	51.50	52.34	52.73	54.88	57.18
TiO_2	-	0.15	0.17	0.19	0.37	0.25	0.11
Al_2O_3	13.48	24.00	27.00	24.98	23.43	19.92	20.25
Fe_2O_3	} 1.80	} 3.90	} 2.80	} 4.22	} 4.34	4.10	2.08
FeO						0.22	0.51
MnO	-	0.05	0.02	0.11	0.01	-	-
MgO	0.66	-	-	2.30	2.36	2.83	2.72
CaO	2.03	1.25	0.85	0.54	0.80	2.22	1.09
Na_2O	-	-	-	} 4.69	} 3.85	1.75	2.21
K_2O	-	3.05	4.65			0.26	0.30
H_2O^-	-	-	-	4.19	5.86	8.10	8.44
H_2O^+	-	-	-	6.63	6.16	4.28	4.79
L.O.I.	44.32	-	-	-	-	-	0.67
Rem.	-	-	-	0.10	0.09	0.69	-
	98.78	82.90	86.99	100.19	100.00	99.50	100.35
Si	3.94	3.68	3.59	3.55	3.63	3.82	3.99
Al^{IV}	0.06	0.32	0.41	0.45	0.37	0.18	0.01
	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Al^{VI}	1.65	1.74	1.81	1.54	1.53	1.45	1.56
Fe^{+3}	0.15	0.21	0.15	0.22	0.22	0.21	0.11
Fe^{+2}	-	-	-	-	-	0.01	0.03
Mg	0.10	-	-	0.23	0.24	0.29	0.28
Mn	-	-	-	0.01	-	-	-
	1.90	1.95	1.96	2.00	1.99	1.96	1.98
Ca	0.47	0.20	0.13	0.08	0.12	0.33	0.16
Na	-	-	-	} 0.62	} 0.51	0.23	0.29
K	-	0.28	0.42			0.03	0.03
	0.47	0.48	0.55	0.70	0.63	0.59	0.48
Total	6.37	6.43	6.51	6.70	6.62	6.55	6.46
Ratios:							
Si:Al^{IV}	6.79	-	-	-	-	20.74	51.18
Total Al:Mg	16.43	-	-	8.60	7.79	5.59	5.92
Ca:Na	-	-	-	0.12	0.23	1.41	0.55

Chemical Data on Bentonites (Cont'd.)

	8	9	10	11	12	13	14
SiO_2	59.80	60.78	63.61	65.74	68.88	69.14	69.46
TiO_2	0.05	0.22	0.24	0.33	-	-	-
Al_2O_3	16.36	17.08	17.37	13.89	16.34	14.50	16.25
Fe_2O_3	2.23	3.67	3.18	3.32	2.86	2.56	3.35
FeO	3.52	0.43	0.60	0.09		-	
MnO	-	-	0.01	0.01	-	-	-
MgO	2.67	2.16	1.86	1.75	1.32	1.14	2.76
CaO	1.82	2.84	1.19	1.10	2.18	2.45	2.06
Na_2O	2.00	1.54	2.18	2.40	2.15	1.25	1.08
K_2O	0.27	0.46	0.63	0.69		0.19	
H_2O^-	5.18	5.94	4.16	6.00	-	-	-
H_2O^+	4.91	3.70	3.99	3.89	-	-	-
L.O.I.	-	-	1.11	0.93	6.27	7.71	5.04
Rem.	0.81	1.32	-	-	-	2.22	-
	99.62	100.14	100.13	100.14	100.00	101.16	100.00
Si	4.06	4.07	4.15	4.35	4.30	4.41	4.27
Al^{IV}	-	-	-	-	-	-	-
	4.06	4.07	4.15	4.35	4.30	4.41	4.27
Al^{VI}	1.31	1.35	1.34	1.08	1.20	1.09	1.18
Fe^{+3}	0.11	0.19	0.16	0.17	0.14	0.12	0.16
Fe^{+2}	0.20	0.02	0.03	-	-	-	-
Mg	0.27	0.22	0.18	0.17	0.12	0.11	0.25
Mn	-	-	-	-	-	-	-
	1.89	1.78	1.71	1.42	1.46	1.32	1.59
Ca	0.27	0.41	0.17	0.16	0.29	0.34	0.27
Na	0.26	0.20	0.27	0.31	0.26	0.15	0.13
K	0.02	0.04	0.05	0.06	-	0.02	-
	0.55	0.65	0.49	0.53	0.55	0.51	0.40
Total	6.50	6.50	5.95	6.30	6.31	6.24	6.26
Ratios:							
$Si:Al^{IV}$	-	-	-	-	-	-	-
Total Al:Mg	4.87	6.21	7.42	6.32	9.67	10.18	4.69
Ca:Na	1.02	2.02	0.62	0.52	1.11	2.20	2.12

Chemical Data on Bentonites (Cont'd.)

	15	16	17	18	19	20	21	22
SiO_2	69.52	69.97	49.20	51.64	53.50	55.44	59.72	61.47
TiO_2	-	-	-	-	0.11	0.10	-	0.09
Al_2O_3	21.64	18.27	17.60	18.25	21.57	20.14	18.22	22.17
Fe_2O_3	3.06	1.90	1.60	1.24	3.28	3.67	4.15	4.32
FeO		-	-	1.40	-	0.30	-	-
MnO	-	-	-	-	-	-	-	-
MgO	0.21	1.50	5.08	3.41	1.89	2.49	2.08	2.73
CaO	-	0.50	1.52	2.18	1.25	0.50	1.46	0.14
Na_2O	-	0.76	-	2.09	1.94	2.75	2.70	3.18
K_2O	-	0.30	-	0.12	1.04	0.60	0.54	0.03
H_2O^-	-	5.24	25.52	13.22	15.20	14.70	5.87	6.02
H_2O^+	-			6.33			5.55	
L.O.I.	5.45	-	-	-	-	-	-	-
Rem.	-	-	-	-	-	-	0.73	-
	99.88	98.44	100.52	99.88	99.78	100.69	101.02	100.15
Si	4.23	4.32	3.85	3.85	3.78	3.86	4.00	3.88
Al^{IV}	-	-	0.15	0.15	0.22	0.14	-	0.12
	4.23	4.32	4.00	4.00	4.00	4.00	4.00	4.00
Al^{VI}	1.55	1.33	1.48	1.45	1.58	1.51	1.44	1.53
Fe^{+3}	0.14	0.09	0.09	0.07	0.17	0.19	0.21	0.21
Fe^{+2}	-	-	-	0.09	-	0.02	-	-
Mg	0.02	0.14	0.59	0.38	0.20	0.26	0.21	0.26
Li	-	-	-	-	-	-	0.04	-
	1.71	1.56	2.16	1.99	1.95	1.98	1.90	2.00
Ca	-	0.07	0.25	0.35	0.19	0.08	0.21	0.02
Na	-	0.09	-	0.30	0.26	0.37	0.35	0.39
K	-	0.02	-	0.01	0.09	0.05	0.04	-
	-	0.18	0.25	0.66	0.54	0.50	0.60	0.41
Total	5.94	6.06	6.41	6.65	6.49	6.48	6.50	6.41
Ratios:								
Si:Al^{IV}	-	-	26.40	25.32	17.43	27.17	-	32.06
Total Al:Mg	-	9.70	2.74	4.21	8.99	6.37	6.88	6.39
Ca:Na	-	0.74	-	1.16	0.73	0.20	0.60	0.05

Descriptive Notes to Accompany Table 2

1. Edmonton, Alberta. "Soap clay", 6 to 8 inches thick, above coal seam, along river bank 1 1/2 miles below old Fort Edmonton. (Harrington, 1874, pp. 38, 64). G. C. Hoffmann, analyst.

2. Along Bow River, Alberta; west of Calgary, east of front range of Rocky Mountains. (Maiklem and Campbell, 1965, p. 369). Sample 4132, X-ray fluorescence analysis. Probably a mixed layer clay.

3. Along Bow River, Alberta; west of Calgary, east of front range of Rocky Mountains. (Maiklem and Campbell, 1965, p. 369). Sample 4154, X-ray fluorescence analysis. Probably a mixed layer clay.

4. Along Bow River, Alberta; west of Calgary, east of front range of Rocky Mountains. (Maiklem and Campbell, 1965, p. 369). Sample 4156, wet chemical analysis. A. Stelmach, analyst. Rem. (0.10) is P_2O_5. Probably a mixed layer clay.

5. Along Bow River, Alberta; west of Calgary, east of front range of Rocky Mountains. (Maiklem and Campbell, 1965, p. 369). Sample 4138, wet chemical analysis. Rem. (0.09) is P_2O_5. Probably a mixed layer clay.

6. Rosedale, Alberta; sample from a surface outcrop. (Spence, 1924, p. 14). A. Sadler, analyst. Rem: P_2O_5, 0.09%; CO_2, 0.37%; SO_3, 0.16%; S, nil; C, 0.07%.

7. Rosedale, Alberta; Aetna coal mine, bentonite parting 6 to 8 inches thick in No. 1 coal seam. (Byrne, 1955, p. 19). Analysis by Rock Analysis Laboratory, Univ. of Minnesota.

8. Rosedale, Alberta; Rosedale coal company's mine. (Spence, 1924, p. 14). A Sadler, analyst. Rem: P_2O_5, trace; CO_2, 0.72%; SO_3, nil; C, 0.09%.

9. Camrose, Alberta. (Spence, 1924, p. 14). A. Sadler, analyst. Rem: P_2O_5, 0.03%; CO_2, 1.11%; SO_3, 0.01%; S, 0.04%; C, 0.13%.

10. Beynon, Alberta; bentonite lens along Rosebud river. (Byrne, 1955, p. 19). Analysis by Rock Analysis Laboratory, Univ. of Minnesota.

11. Dorothy, Alberta; along banks of Red Deer river. (Byrne, 1955, p. 19). Analysis by Rock Analysis Laboratory, Univ. of Minnesota.

12. Michichi Creek, Alberta; bentonite bed 3 feet thick between coal seams Nos. 5 and 6, Kidd pit, Drumheller. Used in Turner Valley oil wells in drilling fluid. (Allan and Sanderson, 1945, p. 51).

13. Camrose, Alberta; bentonite bed about 2 feet thick, yellow when fresh, weathers dirty white, taken from 20 feet below soft yellowish shales near Camrose. (Ries and Keele, 1913, p. 89). G.E.F. Lundell, analyst. Rem: CO_2, 0.52%; SO_3, 1.70%.

14. Rosedale, Alberta; sample from Rosedale coal mine; bentonite parting up to 2 inches thick in No. 1 coal seam. (Allan, 1922, p. 36). J. A. Kelso, analyst.

15. Gibson mine, Alberta; bentonite 3 to 6 feet thick between coal seams Nos. 6 and 7, about 1/2 mile south of Drumheller. (Allan, 1922, p. 36). J. A. Kelso, analyst.

16. Bickerdike, Alberta. Analysis from Industrial Minerals files, Research Council of Alberta.

17. Fort Steel, Wyoming. Cited in Ross and Hendricks, 1945, pp. 31, 34.

18. Ardmore, South Dakota. Used in making a water softener. Cited in Ross and Hendricks, 1945, pp. 30, 34.

19. Osage, Wyoming; bentonite, lower part of Belle Fourche shale (early Upper Cretaceous), about 20 feet above Clay Spur bentonite (uppermost Lower Cretaceous). Cited in Ross and Hendricks, 1945, pp. 31, 34.

20. Upton, Wyoming. Cited in Ross and Hendricks, 1945, pp. 31, 34.

21. Colony, Wyoming. Swelling bentonite, essentially montmorillonite. Rem: Li_2O, 0.14%; SO_3, 0.59%. Cited in Ross, 1964, p. 8.

22. Clay Spur, Wyoming. Cited in Murray, 1960, p. 263.

Table 3. Exchangeable Ions and Cation-Exchange Capacities for Some Alberta Bentonites (after Anderson and Plein, 1962, 1963)

Location						Formation	Exchanged Ions in Leachate (Meq. per 100 gm)				Cation Exchange Capacity (Meq. per 100 gm)
Lsd.	Sec.	Tp.	R.	Mer.	Area		Na^{+}	Ca^{++}	K^{+}	Mg^{++}	
NE 1/4	2	8	7	W.4	Bullshead Butte	Bearpaw	57.88	56.31	2.59	5.48	61.15
NE 1/4	3	27	17	W.4	Dorothy	Bearpaw	61.80	13.80	3.26	4.06	66.10
NW 1/4	14	29	20	W.4	Drumheller	Edmonton	40.19	26.38	0.76	2.47	54.73
15	31	42	17	W.4	Rosalind	Edmonton	33.98	26.32	0.50	6.65	64.27
15	31	42	17	W.4	Rosalind	Edmonton	28.09	27.83	0.52	8.64	59.17
15	31	42	17	W.4	Rosalind	Edmonton	36.94	33.89	0.40	7.70	75.06
15	31	42	17	W.4	Rosalind	Edmonton	36.51	23.32	0.58	6.00	66.65
9	7	56	2	W.5	Onoway	Edmonton	27.55	51.97	0.60	10.17	66.47
9	7	56	2	W.5	Onoway	Edmonton	24.33	71.40	0.63	13.50	66.08
— — —	21, 22, 23	72	4	W.6	Kleskun Hills	Wapiti	36.59	44.59	1.00	3.60	58.87

Table 4. Physical Properties of Some Alberta Bentonites (after Ross 1964; Banks and Watts, 1965)

Sample Number		Swelling Index (ml)	Colloidal Content (%)	Yield (bbl/ton)	Gel Strength ($lb/100 ft^2$) 6% Bentonite		Apparent Viscosity (cp) 6% Bentonite 10 Min. Mix	Liquid Limit*	Surface Tension (dynes/cm) after 10 Min.	Foundry Tests			Pelletizing Tests			
										Green Compressive Strength (psi)	Dry Compressive Strength (psi)	Green Tensile Strength (oz/in^2)	Green Compressive Strength (psi)		Dry Compressive Strength (psi)	
Ross (1964)	Banks and Watts (1965)				Initial	10 Min. Mix							Natural	Modified with $NaCO_3$	Natural	Modified with $NaCO_3$
1	8	23	77	97-112	14	33	35 1/2	-	104.4	-	-	-	3.09	4.54	11.27	8.78
2	5	24	73	105-107	10	28	26 1/2	-	95.0	-	-	-	3.55	3.06	14.44	15.19
3	2	15	55	48	1	1	2 1/2	-	74.4	-	-	-	2.99	-	12.66	-
4	9	18	78	111-112	10	14	15	-	105.8	-	-	-	2.87	3.40	13.27	9.13
5	4	16	81	88-105	1	2	9	632	70.2	10.2	104	26.0	2.86	-	11.00	-
6	3	13	64	60-61	1	1	3 1/2	337	73.7	11.4	95	27.8	2.99	-	12.76	-
-	20	25	77	61	-	1	5 1/2	-	71.5	-	-	-	3.00	-	9.23	-

* Minimum weight per cent of moisture which causes bentonite-water mixture to flow.

Table 5. Comparison of Bentonites from Alberta and Wyoming-South Dakota

	Alberta	Wyoming-South Dakota
Stratigraphic position	Edmonton Formation (commercial bed: uppermost Upper Cretaceous) Bearpaw Formation (Upper Cretaceous)	Mowry Formation, Clay Spur Member (commercial bed: uppermost Lower Cretaceous) Newcastle Formation (Lower Cretaceous
Depositional environment	Edmonton Formation: brackish, deltaic Bearpaw Formation: mainly marine	Mowry Formation: marine Newcastle Formation: brackish
Pleistocene environment	Area glaciated	Area unglaciated
Bentonite thickness	Rosalind 8 - 10 feet Onoway up to 5 feet Dorothy 20 - 29 feet Others up to 20 feet	Clay Spur Member: Northern Black Hills 1/2 - 5 feet Wyoming 3 - 4 feet Local thickening up to 30 feet Average thickness about 2 1/2 feet
Strippable overburden	Up to 40 feet	Up to 25 feet; average about 15 feet
Structural relations	Strata nearly flat-lying; lateral continuity uncertain near surface; bentonite beds covered by thick overburden within short distances of outcrop faces.	Strata generally a broad northwest-plunging anticline interrupted by several minor folds which bring the bentonite beds to surface; produced economically if regional dip less than 5°; average dip in Clay Spur district 2-3°; lateral continuity good.

Average annual precipitation	About 17 inches	About 16 inches
Exchangeable cations	Available determinations (Table 3): Ratio of Ca : Mg : Na : K 5.29 : 1 : 1.80 : 0.05 to 3.40 : 1 : 15.22 : 0.80 (Average 6.26 : 1 : 7.59 : 0.22)	Clay Spur Member: Ratio of Ca : Mg : Na : K 0.22 : 1 : 7.56 : 0.11 to 1.0 : 1 : 64.0 : 2 (Average 1.8 : 1 : 10.8 : 0.33)
Physical properties:		
Grit % (>44μ)	0.2 - 12.4	0.4 - 7.4
Swelling capacity (ml)	13 - 25	16 - 45
Yield (bbl/ton)	23 - 112 (average 50)	55 - 119 (average 89)
pH	8.00 - 9.83 (average 9.12)	5.0 - 9.1 (average 8.02)
Apparent viscosity (6% by weight)	2 - 35 1/2 centipoises	3 - 55 centipoises
Gel strength (6% by weight after 10 min.)	1 - 33 lb/100 ft^2	35 lb/100 ft^2 *
Colloidal content (%)	55 - 81	95
Foundry:		
Green compressive strength (psi)	10.2 - 11.4 (average 10.8)	5.8 - 11.0 (average 9.3)
Dry compressive strength (psi)	95 - 104 (average 99.5)	31 - 81 (average 57)
Pelletizing:		
Green compressive strength (lb per 1/2-inch ball)	2.86 - 3.55 (average 3.05, 7 samples)	4.29 (1 sample)
Dry compressive strength (lb per 1/2-inch ball)	9.23 - 14.44 (average 12.09, 7 samples)	18.94 (1 sample)

* Gel strength ranges from 5 - 215 grams (Stormer), according to Knechtel and Patterson, 1962.