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Bentonite Resources in the Winkleman Dome—Bighorn Ridge, Arapahoe Reservoir, and Blue Ridge Areas on the Wind River Indian Reservation, Wyoming

by Joseph Gersic and June B. Worthington

Reprinted from: Administrative Report to the Bureau of Indian Affairs and Shoshone - Arapahoe Tribes
Report BIA 8-III, B (Wind River)
1984
United States Department of the Interior
Bureau of Mines

Reprint No. 60 • 1995

Laramie, Wyoming

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Prepared under the authority of Resolution No. 4767 of the Joint Business Council of the Shoshone and Arapahoe Tribes, Wind River Indian Reservation, Wyoming, dated June 10, 1981, and Interagency Agreements No. 28 and 31 between the Bureau of Indian Affairs and the Bureau of Mines.

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by

Joseph Gersic[1] and June B. Worthington[2]

ABSTRACT

One hundred and six bentonite samples, collected by trenching and drilling in three areas on the reservation, were analyzed, chemically enhanced, and reanalyzed. Field examinations and laboratory analyses indicated that bentonite deposits in the Winkleman Dome-Bighorn Ridge area and the Arapahoe Reservoir area are subeconomic resources and have little development potential. Only the deposits in the Blue Ridge area are classified as demonstrated marginal reserves that may have development potential. Development of the Blue Ridge deposits depends largely upon future market demands, particularly in the steel and petroleum exploration industries.

As much as 20 million tons of strippable bentonite reserves may exist in two beds in the Blue Ridge area. Most of the samples from the Blue Ridge area responded well to treatment with soda ash and organic polymer. In order to prove the overall quality and to determine whether the grade of the bentonite can be improved by chemical treatment in the field, a study would have to be done on a much larger scale. Overburden covering several acres of bentonite would have to be removed. Samples of raw bentonite would have to be analyzed; then, the bentonite would have to be treated with soda ash and allowed to age for two to six months. Finally, samples of the treated and aged bentonite would have to be analyzed, and the results evaluated.

INTRODUCTION

This report was prepared by the Bureau of Mines for the Bureau of Indian Affairs (BIA) under interagency agreement to investigate the potential for economic development of mineral resources on certain Indian lands. The administrative report BIA No. 8-II, Part 1 (Wind River)(9)[3], recommended that bentonite resources be further evaluated on the Wind River Indian Reservation in three areas--Winkleman Dome-Bighorn Ridge, Arapahoe Reservoir, and Blue Ridge. This report presents the results of the evaluation of the bentonite resources in the three areas.

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[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

Previous Investigations

Although many published and unpublished reports have been written concerning the geology, structure, and mineral resources on the Wind River Indian Reservation, only a few reports discuss bentonite resources on the reservation. In 1965, Slaughter and Earley (12) published a report describing bentonite beds in the Mowry Shale and the lower part of the Frontier Formation within a 40,000-square-mile area of north-central Wyoming, including the Wind River Indian Reservation. The report discusses aspects of the bentonite--such as mineralogy, petrology, petrogenesis, and tectonic history --that are more of scientific than economic interest. Four unpublished Bureau of Mines administrative reports either mention or discuss the bentonite resources on the reservation. A 1949 report by Everett (6) mentions that bentonite occurs on the reservation and that the bentonite is believed to be inferior in quality to bentonite being mined in other parts of Wyoming. Bolmer and Biggs (4) in 1965 and Seeland and Brauch (10) in 1975 inventoried and evaluated the economic potential of mineral resources on the reservation. Both reports contain short sections on bentonite resources and both recommend further investigation to determine the areal extent and quality of the bentonite beds. Partly in response to the earlier reports, bentonite resources were studied more fully by Bureau of Mines personnel during the summer of 1982, and an administrative report BIA No. 8-II, Part 1 (Wind River), by Roberts, Worthington, and Nonini (9) was printed in June 1983. The report recommended further investigation in three separate areas on the reservation.

Present Investigation

The present study and report resulted from the recommendations that additional field work be done to determine the extent, structural attitude, and quality of two bentonite beds in the Winkleman Dome-Bighorn Ridge area, of four bentonite beds in the Arapahoe Reservoir area, and of one bentonite bed, or possibly more, along the northern slope of Blue Ridge. Two other recommendations were: (1) chemically treat and retest samples collected in 1982 from beds in the Winkleman Dome-Bighorn Ridge area to determine whether such treatment would enhance their physical properties, and (2) chemically treat and test samples collected during future studies to determine whether such treatment would upgrade their quality.

A small amount of field work was done in the Winkleman Dome-Bighorn Ridge area and nine bentonite samples were chemically treated and tested in the spring of 1983. Test results showed that treating the bentonite did not markedly enhance the physical properties of seven (77 percent) of the samples, and Kenneth E. Tanner, a geological consultant, stated that the bentonite probably could not be treated economically. Because of the apparent low quality of the bentonite in this area, no further field work or sampling was done; maps, stratigraphic sections, and tonnage estimates were not made.

The area north of Arapahoe Reservoir was investigated in June and July of 1983. Twenty-four samples were taken from four bentonite beds that were mapped in the area. Laboratory analyses showed that 15 (62 percent) of the samples responded well to chemical treatment meaning that the physical properties of the bentonite were enhanced enough to make it usable for some major commercial applications. Seven (29 percent) of the treated samples met specifications for all major commercial applications. Maps, cross sections, and tonnage estimates were made for two beds in the study area.

The Blue Ridge area was investigated in July and August of 1983. Seventy-three samples were taken from two bentonite beds that were mapped in the area. Laboratory analyses indicated that 57 (78 percent) of the the samples responded well to chemical treatment. Twenty-seven (37 percent) of the treated samples met specifications for all major commercial applications. Maps, cross sections, and tonnage estimates were made for two beds in the study area.

Acknowledgments

The authors gratefully acknowledge the assistance provided by W. L. Collier, Superintendent of the BIA Wind River Indian Agency at Fort Washakie, Wyo., and three members of his staff--Arthur Hallett, Richard Harbour, and Bob Robertson. Dan Brown and Merton Trosper provided valuable assistance by bulldozing roads into areas that otherwise would have been inaccessible to the Bureau of Mines drilling crew.

GEOLOGY

Most of the Wind River Indian Reservation lies in the western half of the Wind River Basin, but the northeastern part of the reservation lies along the southern edge of the Bighorn Basin (fig. 1). Both the Wind River and Bighorn Basins are large, structurally complex sedimentary basins as well as topographic basins. Margins of the basins are delineated by groups of complexly folded and faulted Precambrian, Paleozoic, and Mesozoic rocks that are exposed in the surrounding ranges and uplifts, such as the Wind River, Absaroka, and Owl Creek Mountains. Altitudes in these mountains range from about 6,000 feet to 13,785 feet.

Interiors of the basins contain less disturbed rocks of Cenozoic age. The central parts of the basins are rolling plains dissected by generally broad valleys formed by ephemeral and perennial streams. Altitudes on the plains within the reservation range from about 4,700 feet to about 6,000 feet. Toward the margins of the basins where the bentonite-bearing formations are exposed, the rolling plains give way to buttes, ridges, and some badlands.

Between 50 million and 100 million years ago, most of the major structural features now present throughout the Rocky Mountain region were created during a major mountain-building episode called the Laramide Orogeny. Mountains were uplifted, basins were formed, volcanoes were active, and shallow seas repeatedly inundated Wyoming and then retreated. Volcanoes intermittently spewed large volumes of ash high into the air, and prevailing westerly winds carried the ash over large areas of Wyoming. Much of the volcanic ash was deposited in the shallow seas where it reacted with salt water and altered into clays called bentonites (12).

EVALUATION OF BENTONITE

Important factors in evaluating a bentonite deposit are: (1) quality of the bentonite; (2) structural attitude of the beds, and amount and type of overburden; (3) size of the deposit and possibly its relationship to other deposits; and (4) availability of processing facilities and transportation. Quality depends upon whether the physical properties of the bentonite meet specifications for industrial uses. The attitude of the beds and amount and type of overburden control the mining method and equipment that can be used and, therefore, determine whether a deposit can be mined economically. At existing operations, bentonite is recovered from shallow, strip-mined pits ranging in size from less than one acre to several hundred acres by using some combination of scrapers, rippers, bulldozers, power shovels, front-end loaders, and trucks; explosives are not required in any phase of the operation (3, 5, 14). Bentonite is carefully removed from the pit and generally stockpiled according to the grade of the raw material (5, 14). Bentonite is generally transported by truck to a mill. Haulage is done during the summer and early fall, because the roads are slippery and impassable during the rest of the year. Although some bentonite is hauled as far as 80 miles, average haulage distances from most pits to mills are considerably shorter, that is, 12 miles or less (11, 14). Although some crude bentonite is sold, more than 90 percent of all bentonite is milled prior to shipment (14). Existing mills generally are capable of processing several hundred thousand tons of bentonite per year and are located adjacent to railroads (5, 11). Railroads provide the cheapest form of transportation available for shipping the processed bentonite to oilfields and industrial centers.

Bentonite predominantly consists of clay minerals (the smectite group) having complex chemical compositions and multilayered molecular structures that cause them to exhibit numerous physical properties. Although bentonite is common throughout the world, very little bentonite has physical properties that make it valuable. Relative amounts of exchangeable sodium and calcium ions present in a particular bentonite greatly influence the physical properties of the bentonite and thereby determine its potential usefulness.

Since World War II, the major uses of bentonite have been bleaching agents, drilling muds, foundry sand binders, and iron-ore pellet binders. Bentonites also have hundreds of other uses, including filtering agents for clarifying wine or treating waste water; waterproof sealants for reservoirs, irrigation ditches, waste-disposal ponds, basements, and tunnels; and ingredients in cosmetics, pharmaceuticals, animal feeds, paints, and insecticides (7).

Wyoming has led the Nation in the production of bentonite for many years, and in 1981, about 3.6 million short tons of bentonite was produced in the State (13, 17). The sodium-rich, swelling bentonite was used in making drilling muds (59 percent), pelletizing iron ore (21 percent), binding foundry sands (16 percent), producing waterproof sealants (1 percent), binding animal feed (1 percent), and a variety of other uses (2 percent) (13). In 1982, bentonite production in Wyoming dropped to about 2 million short tons because of the reduced demand for bentonite in the petroleum exploration and steel industries (oral communication, Karl E. Starch, Bureau of Mines, Denver, Colo., September 1983).

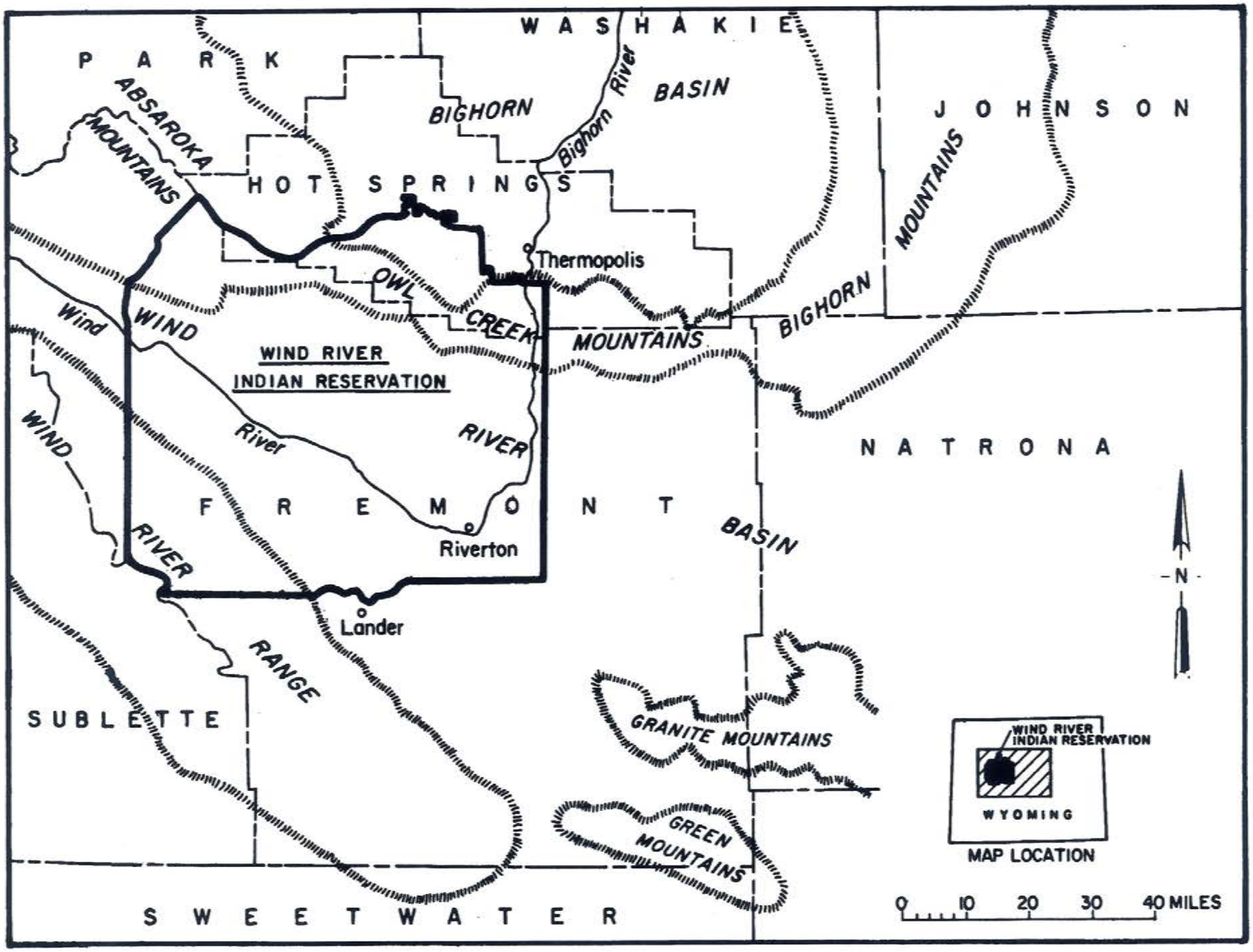

FIGURE 1.—Physiographic features of Wind River Basin and location of Wind River Indian Reservation, Wyoming.

Evaluation Procedures

Maps and stratigraphic sections were prepared showing sample localities, bentonite outcrops, measured thicknesses of beds, and areas underlain by potentially strippable bentonite resources in the Arapahoe Reservoir and Blue Ridge areas (pls. 1-8). Bentonite deposits in the two areas were classified and tonnage estimates were made. Potential uses of the bentonite (tables A-1, A-2, and A-3 in appendix A) are given on the basis of apparent quality as indicated by laboratory analyses (tables B-1, B-2, and B-3 in appendix B).

Maps, stratigraphic sections, and tonnage estimates were not prepared for the Winkleman Dome-Bighorn Ridge area because laboratory analyses indicated that the quality of the bentonite in this area was low and the deposits were classified as subeconomic.

Quality Assessment

Bentonites that are useful and valuable have in common such physical properties as high viscosity, plasticity, gel strength, and bond strength; however, product specifications for swelling bentonite used by industry may vary substantially according to both the use and the user. The American Petroleum Institute (API) (2) publishes specifications for bentonite used in making drilling mud. In 1975, Patterson and Murray (7) tentatively listed standardized specifications for bentonite used for drilling mud, foundry-sand binder, absorbent granules, and oil bleaching. In 1978, Regis (8) listed specifications for the most common uses of bentonite on the basis of a survey of 20 companies representing the various industries that use the bentonite. Specifications used for evaluating the bentonite from the reservation (table 1) were compiled from the preceding sources.

The quality of bentonite deposits on the Wind River Indian Reservation was assessed in the following manner:

1. Individual sample analyses (tables B-1, B-2, and B-3) were compared with product specifications (table 1) and the samples were assigned to potential usage categories (tables A-1, A-2, and A-3).

2. The overall quality of a bentonite bed was characterized according to the number of samples falling into the various usage categories.

TABLE 1. - Specifications used for evaluating bentonite from the Wind River Indian Reservation, Wyoming

(In general, uses are listed in order of importance on the basis of market demand and stringency of specifications for a particular use.)

Uses	Grit, pct	Minimum viscometer reading, 600 rpm	Minimun yield, bbl/ton	Yield point, $lb/100ft^2$	Maximum water loss, ml	Minimum plate water absorption, wt pct
Drilling mud....	4.0	30	92	3xPV	15.0	NS
Iron ore pelletizing...	4.0	27	89	NS	16.0	[1]750
Steel foundry sand binder...	NS	13	70	NS	15.0	600
Civil Engineering...	NS	16	75	NS	15.0	600
Waterproof sealant.......	NS	NS	NS	NS	30.0	400
Gray-iron foundry sand binder........	NS	NS	NS	NS	NS	100
Animal feed binder........	NS	NS	NS	NS	NS	100

bbl/ton = barrels per ton; $lb/100ft^2$ = pounds per 100 square feet; ml = milliliters; min = minimum; NS = no specification; pct = percent; wt pct = weight percent; xPV = times plastic viscosity; 600 rpm = 600 revolutions per minute.

[1]Although 750 weight percent is considered acceptable for pelletizing iron ore, bentonite now being sold for this purpose has water absorption values of 800 to 850 weight percent. (Oral communication, Kenneth E. Tanner, geological consultant, Ten Sleep, Wyo., September 1982)

Sources:

American Petroleum Institute. API Specifications for Oil-Well Drilling-Fluid Materials. API Spec 13A, 8th ed., 1981, 14 pp.

Patterson, S. H., and H. H. Murray. Clays. Ch. in Industrial Minerals and Rocks (Nonmetallics Other than Fuels) ed. by S. J. Lefond and others. AIME, New York, N.Y., 4th ed., 1975, pp. 519-585.

Regis, A. J. Correlation Between Physical Properties and Exchangeable Chemistry of Bentonites from the Western United States. U.S. Bureau of Land Management, Tech. Note 313, January 1978, 56 pp.; available from Denver Service Center, Federal Center, Bldg. 50, Denver, CO 80225.

Strippable Resource Criteria

Criteria used in this report are those in U.S. Geological Survey (USGS) Circular 831, Principles of a Resource/Reserve Classification for Minerals and those observed at commerical bentonite operations in the Bighorn Basin. The average minimum thickness for a single bed is 2 feet. Maximum allowable overburden thickness is 50 feet with 30 to 35 feet being the average cutoff depth. Maximum overburden-to-bentonite-thickness ratio (stripping ratio) is 15 to 1.

Resource Calculation Methodology

Demonstrated strippable bentonite resource tonnages were calculated by the following procedures:

1. Maps were constructed showing the areas underlain by bentonite beds that met the previously described strippable-bentonite-resource criteria.

2. Acreage for each area was determined by using an electronic digital planimeter.

3. Average bentonite thickness computed for each area was the arithmetic mean of all the measured thicknesses for a bentonite bed.

4. Assuming a specific gravity of 2.5 for bentonite, an approximate weight-per-unit volume conversion factor of 3,400 short tons per acre-foot was computed.

5. Estimated resource tonnage for each bed was computed by multiplying acreage by average bed thickness in feet by the conversion factor in short tons per acre-foot. All tonnages were rounded to two significant figures.

Bentonite Resource Areas

The areas are presented in the order in which they were studied in the field: the Winkleman Dome-Bighorn Ridge area, the Arapahoe Reservoir area, and the Blue Ridge area.

Winkleman Dome-Bighorn Ridge

Location

The Winkleman Dome-Bighorn Ridge area is located 5 to 10 miles northeast of Fort Washakie along the northeast limb of the Sage Creek Anticline, in T 1 N, Rs 1 E and 1 W, and in T 2 N, Rs 1 and 2 W (pl. 1). The nearest railhead is more than 25 miles away in Riverton. The nearest mill is in Lucerne about 62 miles by rail from Riverton.

Bentonite Beds

Several beds occur in the Thermopolis, Mowry, and Frontier Formations, but none crop out continuously along the dome and ridge.

Sampling and Test Results

Six drill-hole and three trench samples were analyzed (table B-1).

Quality

The overall quality of the bentonite in the area is poor compared to the bentonite produced elsewhere in Wyoming. Just one sample (W 321) met more than the specifications for minor commercial uses (table A-1), which means that the bentonite probably would never attract commercial producers. Only three (33 percent) of the samples responded well to treatment with soda ash and/or polymer. Grit content was high on seven (78 percent) of the samples, but part of the grit was hard clay that should not detract from the quality of the sample. Clay quality is poor even if grit content is disregarded.

Potential Uses

Waterproof sealant, gray-iron foundry sand binder, or animal feed binder are the only potential uses for this bentonite. These uses do not provide a large market, and bentonite of this quality is not likely to attract commercial producers.

Classification

The bentonite beds in this area are classified as inferred subeconomic resources (15).

Tonnage

Tonnage estimates were not determined.

Development Potential

The area has very litle potential for development because of the low quality of the bentonite. No additional field work was done; maps and stratigraphic sections were not made.

Arapahoe Reservoir Area

Location

The Arapahoe Reservoir study area lies 2 to 3 miles north of Arapahoe Reservoir on the northeast limb of the West Sheep Creek Anticline in secs 8, 9, 16, and 17, T 6 N, R 2 E (pls. 1 and 2). The nearest railhead is 47 miles away in Riverton. The nearest mill is in Lucerne about 62 miles by rail from Riverton.

Bentonite Beds

Several bentonite beds are present in the area and four prominent beds are designated informally from the stratigraphically lowest (oldest) to the stratigraphically highest (youngest) as the 'A,' 'B,' 'C,' and 'D' bentonites (pls. 3 and 4). The 'A' bed crops out over greater distances than the other beds, and it ranges from 3.5 to 5.9 feet in thickness and averages 4.6 feet. The 'B' bed lies about 6 to 10 feet above the 'A' bed, occurs intermittently along the ridge, and is less than 3 feet thick in the four drill holes in which it was measured. The 'C' bed lies about 16 to 22 feet above the 'A' bed, and is less persistent than the 'B' bed. The 'C' bed is about 1.5 feet thick in the two drill holes in which it was measured and is up to 2.5 feet thick along the outcrop at the northeast end of the area. The 'D' bed lies more than 100 feet above the 'A' bed; it is the second most laterally persistent of the beds, and it ranges from 2.9 to 6.7 feet in thickness and averages 4.7 feet.

Overburden

The beds generally dip about 14 to 16 degrees to the southeast (pl. 3). The 'A' and 'D' beds are overlain by differing amounts of porcelanite, shale, mudstone, and sandstone (pl. 4). Most of the overburden in this area probably could be removed by conventional stripping methods using bulldozers and other earthmoving equipment. The sandstone overlying the 'D' bed on the northeast end of the study area is particularly thick and it could require blasting which would be expensive.

Sampling and Test Results

Fourteen drill-hole samples (D1 through D14) and ten trench samples (T1 through T10) were analyzed (table B-2).

Quality

The overall quality of the bentonite can be characterized as slightly inferior compared to bentonite produced elsewhere in Wyoming. Most of the raw bentonite met only the lower specifications for commercial uses (table A-2). Sixty-two percent of the samples responded well to treatment with soda ash and/or polymer, and 29 percent of the treated samples met specifications for all major commercial applications.

Potential Uses

Raw bentonite could be used for waterproof sealant, gray-iron foundry sand binder, or animal feed binder. Treated bentonite probably could be used for some major commercial applications such as civil engineering projects and steel foundry sand binder. It possibly could be used for iron ore pelletizing and drilling mud.

Classification

The bentonite deposits in the 'A' and 'D' beds were classified as demonstrated subeconomic resources (15).

Tonnage

Tonnage is estimated by multiplying acreage by average bed thickness in feet by a conversion factor of 3,400 short tons/acre-foot as follows:

'A' bed: 53 acres x 4.6 feet x 3,400 = 830,000 short tons
'B' bed: 23 acres x 4.7 feet x 3,400 = 370,000 short tons

Total estimated tonnage = 1,200,000 short tons

Tonnages were estimated only for beds 'A' and 'D' because beds 'B' and 'C' were considered too small to have any economic significance (pl. 5). Some bentonite might be recovered from the 'B' bed during the stripping of overburden from the 'A' bed. The 'C' bed is thinner than the average minimum stripping thickness in much of the area and probably would not be recoverable.

Development Potential

The Arapahoe Reservoir deposits probably would not be of interest to commercial producers because of the following factors. The deposit is small compared to deposits being mined commerically. Mining would be expensive because as much as 50 feet of overburden would have to be removed, and the mining would have to be done on steeply pitching slopes (pls. 3 and 4). No bentonite mills are close to this area. Therefore, the bentonite either would have to be sold in raw bulk form for about $20 per ton f.o.b. at the nearest railhead (assuming that the price would be similar to what commercial producers were receiving in 1982); would have to be shipped to existing plants in the Bighorn Basin or Casper, Wyo.; or would have to be processed at a newly constructed plant at the railhead in Riverton. Transportation costs would be prohibitively high; for example, assuming an estimated cost of 15 cents per ton per mile, it would cost about $7 per ton just to transport raw bentonite to Riverton (this transport cost at a commercial operation in 1982 typically was less than $2 per ton).

Blue Ridge

Location

The Blue Ridge area is located about 2 miles south of Arapahoe Ranch headquarters on the first cuesta north of Blue Ridge in T 8 N, Rs 3 and 4 E (pls. 1 and 6). (A cuesta is an asymmetrical ridge with one very steep side called the 'face' and one gently sloping side called the 'dip slope.') The nearest railroad is more than 18 miles away in Thermopolis, and the nearest mill is in Lucerne about 7 miles north of Thermopolis.

Bentonite Beds

Several bentonite beds occur in the area, but only two beds met the strippable resource criteria. They were designated informally the "lower" and "upper" beds. The lower bed crops out for about 6 miles on the face of the first cuesta north of Blue Ridge itself (pls. 6 and 7). The lower bed ranges from 1.8 to 5 feet in thickness and averages 3.6 feet (pl. 8). The upper bed crops out for about 6 miles on the dip slope of the same cuesta; it ranges from 1.8 to 12.0 feet in thickness and averages 6.0 feet (pl. 8).

Overburden

The beds dip to the northeast at angles ranging from 7 to 15 degrees. The lower bed could be difficult to mine because of the amount and type of overburden. In the western one-quarter of the study area, rocks overlying the lower bed are interbedded shale and mudstone, and siliceous sandstone ranging in overall thickness from 22 to more than 50 feet. In the eastern three-quarters of the study area, the lower bed is overlain in turn by porcelanite ranging from 2 to 6 feet in thickness, by gray to black shale ranging from 30 to 45 feet in thickness, and by siliceous sandstone ranging from 8 to 12 feet in thickness. The siliceous sandstone could be a major problem for anyone attempting to strip mine the lower bed because, in many areas, the sandstone may be too massive to be removed simply by using earthmoving equipment. The upper bed probably could be mined by conventional strip mining methods that use bulldozers and other earthmoving equipment. The rocks above the upper bed consist of a white siliceous shale ranging from 2 to 6 feet in thickness overlain by black, gray, and brown shale up to 50 feet or more in thickness. The overburden thickens markedly in a short distance downdip in the eastern half of the study area; in the western half, the overburden does not thicken as rapidly. The upper bed has been eroded from the saddle of the ridge at the western end of the area.

Sampling and Test Results

Fourteen drill-hole samples (D15 - 21 and D23 - 29) and 59 trench samples (T11 - 16, T21 - 24, and T26 - 74) were analyzed (table B-3).

Quality

The overall quality of the bentonite can be characterized as fair compared to bentonite produced elsewhere in Wyoming. Most of the raw bentonite met only lower specifications for commercial uses (table A-3). Seventy-eight percent of the samples, however, responded well to chemical treatment with soda ash and/or polymer, and 37 percent of the treated samples met specifications for all major commercial applications.

Potential Uses

Raw bentonite could be used for waterproof sealant, gray-iron foundry sand binder, or animal feed binder. Treated bentonite probably could be used for major commercial applications such as civil engineering projects, steel foundry sand binder, drilling mud, and iron ore pelletizing.

Classification

The bentonite deposits in the lower and upper beds were classified as demonstrated marginal reserves (15).

Tonnage

Tonnage is estimated by multiplying acreage by average bed thickness in feet by a conversion factor of 3,400 short tons/acre-foot as follows:

Upper bed:	514 acres x 6.0 feet x 3,400 =	10,000,000 short tons
Lower bed:	862 acres x 3.6 feet x 3,400 =	10,000,000 short tons
Total estimated tonnage	=	20,000,000 short tons

Development Potential

If bentonite deposits are developed on the reservation, they probably will be those in the Blue Ridge area. The deposits are larger and higher in quality than other deposits on the reservation examined during this study. If the bentonite were treated with the proper amounts of soda ash and polymer and then blended, it probably could be used for all industrial applications. Transportation costs could be a problem in developing the deposits because the nearest railroad is more than 18 miles away in Thermopolis. A bentonite mill owned by Wyo-Ben Inc., the second largest bentonite producer in Wyoming, is located in Lucerne, but the mill is supplied raw bentonite from lands that Wyo-Ben already owns or leases (11). The mill presently operates only intermittently because of the lessened demand for bentonite in both the steel and petroleum exploration industries. Demand is an important factor in the development of deposits on the reservation, and the deposits probably will not be developed until the demand increases greatly.

CONCLUSIONS

The bentonite deposits in the Winkleman Dome-Bighorn Ridge and Arapahoe Reservoir areas are classified as subeconomic resources. Of the three areas studied on the reservation, only the Blue Ridge area has bentonite deposits classified as demonstrated marginal reserves. As much as 20 million tons of marginal, strippable bentonite reserves may exist in two beds in the Blue Ridge area. Although the raw bentonite in the area met only specifications for lesser commercial uses, 78 percent of the bentonite samples from the Blue Ridge area responded well to chemical treatment with soda ash and organic polymer. Chemical treatment and mechanical blending of the Blue Ridge bentonite could result in a product comparable in quality with bentonite produced from the Bighorn Basin.

RECOMMENDATIONS

Further study of the bentonite deposits in the Blue Ridge area, in particular the upper bed, could be worthwhile. In order to prove the overall quality and the treatability of the bentonite, a field study on a much larger quantity of bentonite would need to be undertaken. Such a study would require removing the overburden from several acres of bentonite; analyzing samples of the bentonite collected from holes augered on a regular grid pattern with spacings of 50 feet or less; treating the bentonite with soda ash; aging the bentonite for 2 to 6 months; and analyzing samples collected from another set of regularly spaced auger holes. Results of such a study would be valuable to any company that might be interested in leasing tribal deposits.

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APPENDIX A.--POTENTIAL USES OF RESERVATION BENTONITE

Bentonite samples are classified according to their potential uses by comparing laboratory analyses against specifications for seven common uses of bentonite.

TABLE A-1. - Suitable uses for bentonite samples from the Winkleman Dome-Bighorn Ridge area, Wyoming

(Specifications given in table 1)

Sample number	Treatment	Drilling mud	Iron ore pelletizing	Steel foundry sand binder	Civil engineering	Waterproof sealant	Gray-iron foundry sand binder	Animal feed binder
WR 306	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 307	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 319	Raw					x	x	x
	+1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 321	Raw			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
WR 322	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 323	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 345	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
WR 346	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
WDS 1	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x

pct s.a. = percent soda ash; polymer = 0.5 pounds per ton of commercial polymer

See explanatory note on following page.

TABLE A-1. - Suitable uses for bentonite samples from the Winkleman Dome-Bighorn Ridge area, Wyoming--Continued

NOTE.--Grit content was high for most samples. Part of the grit is hard clay that does not detract from the quality of the sample. Grit influences the physical and chemical properties of bentonite by acting as a diluent of the clay minerals. It can cause excessive wear on drilling equipment but it does not greatly influence the behavior of bentonite as a binder. Plate water absorption tests were not made on these samples. Suitability for listed uses could be affected by this test. In order to produce this table, the assumption was made that the plate water absorption values would be in the acceptable range.

TABLE A-2. - Suitable uses for bentonite samples from the Arapahoe Reservoir area, Wyoming

(Specifications given in table 1; samples subdivided by bed)

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
BED A								
D3	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D8	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D11	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D13	Raw					x	x	x
	+ polymer			x	x	x	x	x
D14	Raw					x	x	x
	+ polymer			x	x	x	x	x
T2	Raw					x	x	x
	+ 1.0 pct s.a.		x	x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T3	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T4	Raw			x	x	x	x	x
	+ 0.5 pct s.a.	x	x	x	x	x	x	x
T7	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T8	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x

See explanatory notes at end of table.

TABLE A-2. - Suitable uses for bentonite samples from the Arapahoe Reservoir area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
BED A--Continued								
T9	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T10	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
BED B								
D6	Raw			x	x	x	x	x
	+ polymer			x	x	x	x	x
D7	Raw					x	x	x
	+ polymer			x	x	x	x	x
D10	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D12	Raw			x	x	x	x	x
	+ polymer			x	x	x	x	x
BED C								
D5	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D9	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
BED D								
D1	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D2	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D4	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x

See explanatory notes at end of table.

TABLE A-2. - Suitable uses for bentonite samples from the Arapahoe Reservoir area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
				BED D--Continued				
T1	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T5	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T6	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x

pct s.a. = percent soda ash; polymer = 0.5 pounds per ton of commercial polymer

NOTE.--Grit content was high for most samples. Part of the grit is hard clay that does not detract from the quality of the sample. Grit influences the physical and chemical properties of bentonite by acting as a diluent of the clay minerals. It can cause excessive wear on drilling equipment but it does not greatly influence the behavior of bentonite as a binder. Enhanced samples were not tested for plate water absorption. Suitability for the listed uses may be affected by this test. In order to produce this table, the assumption was made that the plate water absorption values would be in the acceptable range.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming

(Specifications given in table 1; samples subdivided by bed)

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
			LOWER BED					
D15	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D16	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D17	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D18	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
D28	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
T26	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T27	Raw						x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T28	Raw					x	x	x
	+ 0.5 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T29	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
LOWER BED--Continued								
T30	Raw					x	x	x
	+ 1.0 pct s.a.			x		x	x	x
	+ polymer			x	x	x	x	x
T31	Raw					x	x	x
	+ polymer	x	x	x	x	x	x	x
T32	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T33	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
T34	Raw					x	x	x
	+ 0.5 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T35	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T36	Raw						x	x
	+ 1.5 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T37	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T38[1]	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
T39[1]	Raw						x	x
	+ 1.5 pct s.a.			x		x	x	x
	+ polymer		x			x	x	x
T40	Raw			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water proof sealant	Gray-iron foundry sand binder	Animal feed binder
				LOWER BED--Continued				
T41[1]	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
T42[1]	Raw					x	x	x
	+ 0.5 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T43[1]	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T44	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
T45	Raw					x	x	x
	+ 1.0 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T46	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T47[1]	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer		x			x	x	x
T48	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T49	Raw					x	x	x
	+ 1.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T50	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand	Animal feed binder
			LOWER BED--Continued					
T51	Raw					x	x	x
	+ 1.0 pct s.a.			x		x	x	x
	+ polymer			x	x	x	x	x
T52	Raw						x	x
	+ 1.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T53	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T54	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer					x	x	x
T55	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T56	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T57	Raw						x	x
	+ 0.5 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T58	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer		x			x	x	x
T59	Raw					x	x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer		x			x	x	x
T60	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binding	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand	Animal feed binder
	LOWER BED--Continued							
T61	Raw						x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer			x	x	x	x	x
T62	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T63	Raw					x	x	x
	+ 0.5 pct s.a.			x		x	x	x
	+ polymer		x			x	x	x
T64	Raw			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T65	Raw					x	x	x
	+ polymer	x	x	x	x	x	x	x
T66	Raw						x	x
	+ 0.5 pct s.a.		x			x	x	x
	+ polymer	x	x	x	x	x	x	x
T67	Raw					x	x	x
	+ polymer		x			x	x	x
T68	Raw					x	x	x
	+ 0.5 pct s.a.			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
T69	Raw					x	x	x
	+ polymer			x	x	x	x	x
T70	Raw						x	x
	+ 1.0 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x
T71	Raw					x	x	x
	+ 1.0 pct s.a.			x		x	x	x
	+ polymer	x	x	x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
				LOWER BED--Continued				
T72	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer	x	x	x	x	x	x	x
T73[1]	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
T74	Raw			x	x	x	x	x
	+ polymer	x	x	x	x	x	x	x
				UPPER BED				
D19	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
D20	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
D21[1]	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
D23	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
D24	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
D25	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer					x	x	x
D26	Raw					x	x	x
	+ 1.0 pct s.a.			x	x	x	x	x
	+ polymer					x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
			UPPER BED--Continued					
D27	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer		x	x	x	x	x	x
D29	Raw					x	x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T11	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T12	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T13	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T14	Raw						x	x
	+ 2.0 pct s.a.						x	x
T15	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T16	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T21	Raw						x	x
	+ 1.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T22	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x
T23	Raw						x	x
	+ 1.0 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x

See explanatory notes at end of table.

TABLE A-3. - Suitable uses for bentonite samples from the Blue Ridge area, Wyoming--Continued

Sample number	Treatment	Drilling mud	Iron ore pel-letiz-ing	Steel foundry sand binder	Civil engi-neering	Water-proof sealant	Gray-iron foundry sand binder	Animal feed binder
				UPPER BED--Continued				
T24	Raw					x	x	x
	+ 0.5 pct s.a.					x	x	x
	+ polymer			x	x	x	x	x

pct s.a. = percent soda ash; polymer = 0.5 pounds per ton of commercial polymer

[1]Sample enhanced with soda ash was tested for plate water absorption.

NOTE.--Grit content was high for most samples. Part of the grit is hard clay that does not detract from the quality of the sample. Grit influences the physical and chemical properties of bentonite by acting as a diluent of the clay minerals. It can cause excessive wear on drilling equipment but it does not greatly influence the behavior of bentonite as a binder. Enhanced samples were not tested for plate water absorption unless otherwise noted. Suitability for the listed uses may be affected by this test. In order to produce this table, the assumption was made that the plate water absorption values would be in the acceptable range.

APPENDIX B--BENTONITE ANALYSES FROM THE RESERVATION

Description of sampling and testing methods
and laboratory analyses of 106 bentonite samples
from the Wind River Indian Reservation done
by Kenneth E. Tanner, geological consultant,
Rt. 1, Box 1550, Ten Sleep, Wyo.

Sampling

Bentonite beds on the reservation were sampled by either trenching or drilling. Picks and shovels were used to dig trenches in bentonite outcrops, and then vertical channel samples were dug from the freshly exposed surface of the outcrops. Drilling was done with a small rotary rig using compressed air to blow the cuttings to the surface where they were observed, logged, and sampled. Both trenching and drilling are necessary because bentonite near the surface weathers intensely and generally increases in quality and, if samples were taken only from trenches, the bentonite deposit could be characterized as being higher in quality than it really is.

Both sampling techniques had good points and shortcomings. Trenching exposed the bentonite bed well, so that it could be described fully, measured precisely, and sampled completely; drilling did not expose the bentonite bed to direct observation, so that it was more difficult to describe, measure, and sample. Drill-hole data, however, supplied information about the structural attitude and thickness of a bed away from the outcrop. Although measures were taken to control sample contamination, contaminants in the form of blowing dust, dirt, and cuttings did get into samples collected by both methods. Drill-hole samples generally were more contaminated than trench samples. High grit content in the laboratory analyses probably reflect the contamination.

Testing

The economic potential of a bentonite deposit must be evaluated by performing tests to determine certain physical properties of the clay, such as grit content, viscosity, yield, water loss, and plate water absorption; however, as Wolfbauer (16) stated in 1975, the potential economic value of bentonites may be difficult to determine on the basis of physical tests because:

1. Physical properties of bentonite samples may vary greatly even though the samples were collected at slightly different localities in the same bed.

2. Product specifications differ considerably from use to use and indi-individual consumers generally have their own sets of specifications that the bentonite must meet.

3. To meet specifications of users, producers stockpile bentonite according to its physical properties; and then they may either blend the raw bentonite from different stockpiles to provide a uniform product, treat the bentonite with chemicals, such as soda ash and organic polymers, or use both of these processes.

The bentonite was analyzed using specifications issued by the American Petroleum Institute (API) (1-2). Grit was determined by wet screen analysis. Viscometer reading and water loss were measured on a suspension of 22.5 grams of bentonite in 350 milliliters of distilled water. Yield was determined from the 600-revolutions-per-minute viscometer reading by using unpublished data supplied by the Bureau of Land Management, Worland, Wyo. The plate water absorption (Enslin) test was done according to specifications proposed by the Bentonite Users Committee to the American Society for Testing Materials (ASTM) in 1981; the ASTM has not yet published the proposed procedure, but a copy of it is printed in appendix C.

Bentonite commonly is enhanced chemically by producers to obtain the desired properties; therefore, bentonite samples collected during this study also were treated with soda ash and a commercial organic polymer. Soda ash ranging in amount from 0.5 to 1.5 percent was added to raw bentonite to alter physical properties enough to meet or exceed product specifications. Sodium cations from the soda ash replace some exchangeable calcium cations from the bentonite, and the resulting increase in exchangeable sodium cations on the bentonite may result in a decrease in water loss and in increases in viscosity, yield, and water absorption. Organic polymers attach themselves to exchange sites on molecular sheets of smectite minerals and cause large increases in viscosity and yield. The amount of organic polymer added to each bentonite sample was equivalent to adding one-half pound of polymer to one ton of bentonite.

Laboratory analyses were performed by Kenneth E. Tanner, a geological consultant who has more than 20 years experience in the Wyoming bentonite industry. One hundred and twelve samples were to have been analyzed, but six samples apparently were lost in shipment. Analyses of 106 samples are shown in tables B-1, B-2, and B-3 in this appendix.

TABLE B-1. - Analyses of bentonite samples from the Winkleman Dome-Bighorn Ridge area, Wyoming[1]

Sample number	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml
WR-306	Raw	14.0	6/3	51	15.0
	+ 0.5 pct soda ash		6/3	51	20.8
	+ polymer		8/5	58	24.2
WR-307	Raw	9.0	6/4	51	22.0
	+ 1.5 pct soda ash		6/4	51	23.6
	+ polymer		13/8	70	18.8
WR-319	Raw	10.0	6/4	51	23.6
	+ 1.5 pct soda ash		6/3	51	25.2
	+ polymer		7/4	55	22.2
WR-321	Raw	1.5	19/11	80	12.8
	+ polymer		45/32	103	12.4
WR-322	Raw	4.0	5/3	46	18.0
	+ 1.0 pct soda ash		5/3	46	18.4
	+ polymer		7/4	55	18.8
WR-323	Raw	5.0	4/2	40	22.8
	+ 1.5 pct soda ash		4/2	40	19.8
	+ polymer		8/5	58	20.4
WR-345	Raw	5.0	5/3	46	38.8
	+ 1.5 pct soda ash		9/5	61	16.0
	+ polymer		34/25	96	15.6
WR-346	Raw	6.0	5/3	46	28.4
	+ 1.5 pct soda ash		9/5	61	15.2
	+ polymer		41/32	101	13.2
WDS-1	Raw	6.0	6/3	51	36.0
	+ 1.5 pct soda ash		12/8	68	15.6
	+ polymer		24/17	86	17.2

bbl/ton = barrels per ton; ml = milliliter; pct = percent; polymer = 0.5 pounds per ton of commercial polymer; + = plus; 600/300 rpm = 600 and 300 revolutions per minute.

[1]Analyses performed by Kenneth E. Tanner, Ten Sleep, Wyo.

TABLE B-2. - Analyses of bentonite samples from the Arapahoe Reservoir area, Wyoming[1]

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
D1	D	Raw	4.0	6/3	51	20.4	626
		+ 1.0 pct soda ash		10/6	63	16.4	
		+ polymer		20/14	81	16.0	
D2	D	Raw	7.0	6/3	51	21.2	631
		+ 1.0 pct soda ash		11/6	65	17.6	
		+ polymer		24/18	86	17.6	
D3	A	Raw	7.0	6/3	51	26.0	511
		+ 1.5 pct soda ash		14/9	71	17.6	
		+ polymer		19/13	80	18.4	
D4	D	Raw	4.0	8/5	58	16.4	611
		+ 0.5 pct soda ash		10/5	63	15.6	
		+ polymer		22/14	84	14.8	
D5	C	Raw	14.0	4/2	40	23.6	261
		+ 1.0 pct soda ash		14/9	71	15.6	
		+ polymer		16/10	75	16.0	
D6	B	Raw	9.0	23/14	85	12.4	626
		+ polymer		65/50	113	12.4	
D7	B	Raw	6.0	19/12	80	12.8	476
		+ polymer		43/20	102	12.8	
D8	A	Raw	7.0	10/6	63	18.4	621
		+ 0.5 pct soda ash		16/10	75	16.0	
		+ polymer		32/22	94	16.4	
D9	C	Raw	17.0	5/3	46	26.8	406
		+ 1.0 pct soda ash		7/4	55	22.0	
		+ polymer		25/19	87	18.8	
D10	B	Raw	7.0	11/6	65	16.0	701
		+ 0.5 pct soda ash		12/7	68	16.4	
		+ polymer		18/12	78	16.8	
D11	A	Raw	10.0	9/5	61	19.2	536
		+ 0.5 pct soda ash		10/6	63	18.0	
		+ polymer		15/8	73	16.0	

See explanatory notes at end of table.

TABLE B-2. - Analyses of bentonite samples from the Arapahoe Reservoir area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
D12	B	Raw	5.0	21/13	82	12.0	711
		+ polymer		104/84	121	12.0	
D13	A	Raw	5.0	12/6	68	14.0	641
		+ polymer		53/42	108	14.8	
D14	A	Raw	9.0	17/10	76	14.4	596
		+ polymer		39/29	99	15.0	
T1	D	Raw	2.0	5/3	46	29.6	231
		+ 1.0 pct soda ash		20/12	81	15.2	
		+ polymer		72/58	115	14.4	
T2	A	Raw	4.0	11/6	65	22.8	506
		+ 1.0 pct soda ash		27/15	89	14.8	
		+ polymer		66/50	113	14.0	
T3	A	Raw	5.0	3/2	30	40.0	146
		+ 1.5 pct soda ash		22/12	84	16.0	
		+ polymer		38/26	99	14.8	
T4	A	Raw	2.5	23/13	85	14.0	706
		+ 0.5 pct soda ash		76/60	116	14.4	
T5	D	Raw	1.0	10/6	63	17.6	501
		+ 0.5 pct soda ash		16/10	75	14.4	
		+ polymer		63/47	112	14.0	
T6	D	Raw	2.0	7/5	55	66.0	166
		+ 1.5 pct soda ash		20/14	81	16.4	
		+ polymer		45/38	103	16.8	
T7	A	Raw	4.0	6/4	51	23.2	286
		+ 1.0 pct soda ash		24/16	86	15.2	
		+ polymer		70/55	114	13.2	
T8	A	Raw	4.0	13/9	70	16.8	541
		+ 0.5 pct soda ash		24/14	86	14.2	
		+ polymer		59/45	110	14.0	
T9	A	Raw	4.0	5/3	46	30.0	271
		+ 1.5 pct soda ash		16/9	75	16.0	
		+ polymer		34/23	96	14.8	

ee explanatory notes at end of table.

TABLE B-2. - Analyses of bentonite samples from the Arapahoe Reservoir area, Wyoming[1]--Continued

Sample	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T10	A	Raw	5.0	18/11	78	16.8	586
		+ 0.5 pct soda ash		21/15	82	14.8	
		+ polymer		42/32	101	14.8	

bbl/ton = barrels per ton; ml = milliliter; pct = percent; polymer = 0.5 pounds per ton of commercial polymer; + = plus; 600/300 rpm = 600 and 300 revolutions per minute; wt pct = weight percent.

[1]Analyses performed by Kenneth E. Tanner, Ten Sleep, Wyo.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
D15	L	Raw	19.0	6/3	51	22.0	458
		+ 1.5 pct soda ash		7/4	55	21.2	
		+ polymer		8/5	58	20.8	
D16	L	Raw	7.0	9/5	61	20.4	573
		+ 1.0 pct soda ash		8/5	58	20.0	
		+ polymer		11/6	65	17.6	
D17	L	Raw	6.0	8/5	58	19.6	553
		+ 1.0 pct soda ash		8/4	58	18.0	
		+ polymer		11/6	65	17.0	
D18	L	Raw	11.0	5/3	46	26.0	433
		+ 1.5 pct soda ash		5/3	46	23.6	
		+ polymer		6/4	51	20.0	
D19	U	Raw	6.0	12/7	68	17.6	593
		+ 1.0 pct soda ash		8/5	58	18.4	
		+ polymer		20/12	81	13.8	
D20	U	Raw	3.0	7/4	55	16.4	498
		+ 0.5 pct soda ash		9/5	61	14.0	
		+ polymer		19/12	80	12.0	
D21	U	Raw	4.0	7/4	55	16.5	Not reported
		+ 0.5 pct soda ash		7/4	55	16.4	
		+ polymer		21/12	82	12.0	
D23	U	Raw	5.0	6/3	51	20.0	478
		+ 1.0 pct soda ash		8/5	58	15.8	
		+ polymer		30/22	92	13.2	
D24	U	Raw	5.0	6/4	51	18.8	393
		+ 1.0 pct soda ash		8/5	58	16.8	
		+ polymer		29/20	91	12.0	
D25	U	Raw	10.0	5/3	46	20.4	503
		+ 1.0 pct soda ash		7/4	55	17.6	
		+ polymer		17/9	76	16.0	
D26	U	Raw	4.0	6/4	51	18.8	478
		+ 1.0 pct soda ash		7/4	55	19.2	
		+ polymer		20/12	81	12.8	

[1]See explanatory notes at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
D27	U	Raw	4.0	8/5	58	17.6	458
		+ 0.5 pct soda ash		11/6	65	14.4	
		+ polymer		29/20	91	12.0	
D28	L	Raw	7.0	7/4	55	24.8	508
		+ 1.5 pct soda ash		8/4	58	17.6	
		+ polymer		15/8	73	17.6	
D29	U	Raw	7.0	6/4	51	22.0	433
		+ 1.0 pct soda ash		8/4	58	19.6	
		+ polymer		47/37	105	14.2	
T11	U	Raw	4.5	6/4	51	23.6	191
		+ 1.0 pct soda ash		10/6	63	15.6	
		+ polymer		28/20	90	14.2	
T12	U	Raw	4.5	5/3	46	34.0	356
		+ 1.5 pct soda ash		9/6	61	19.2	
		+ polymer		39/30	99	14.0	
T13	U	Raw	4.0	5/3	46	26.0	347
		+ 1.5 pct soda ash		8/5	58	22.8	
		+ polymer		20/13	81	13.6	
T14	U	Raw	9.0	5/3	46	80.0	156
		+ 2.0 pct soda ash		10/7	63	42.0	
T15	U	Raw	4.0	6/4	51	17.6	341
		+ 1.0 pct soda ash		8/5	58	20.0	
		+ polymer		26/19	88	14.0	
T16	U	Raw	6.5	9/5	61	16.0	541
		+ 0.5 pct soda ash		8/5	58	20.0	
		+ polymer		36/26	97	12.4	
T21	U	Raw	12.0	4/2	40	33.0	266
		+ 1.5 pct soda ash		10/6	63	18.8	
		+ polymer		33/23	95	14.8	
T22	U	Raw	8.0	11/6	65	15.2	556
		+ 0.5 pct soda ash		12/7	68	16.2	
		+ polymer		33/23	95	13.4	

See explanatory notes at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T23	U	Raw	5.0	4/2	40	74.0	311
		+ 1.0 pct soda ash		7/4	55	17.4	
		+ polymer		16/9	75	14.4	
T24	U	Raw	10.5	13/7	70	16.0	581
		+ 0.5 pct soda ash		10/6	63	16.8	
		+ polymer		33/22	95	12.8	
T26	L	Raw	4.0	11/6	65	17.2	461
		+ 0.5 pct soda ash		16/9	75	14.8	
		+ polymer		45/32	103	13.2	
T27	L	Raw	3.0	4/2	40	24.8	251
		+ 0.5 pct soda ash		17/10	76	14.0	
		+ polymer		68/54	114	13.0	
T28	L	Raw	4.0	13/7	70	17.2	441
		+ 0.5 pct soda ash		15/8	73	13.8	
		+ polymer		57/45	110	12.4	
T29	L	Raw	5.0	10/6	63	16.4	406
		+ 0.5 pct soda ash		17/9	76	14.8	
		+ polymer		68/53	114	13.2	
T30	L	Raw	5.5	9/5	61	20.0	551
		+ 1.0 pct soda ash		14/8	71	14.8	
		+ polymer		48/36	105	14.0	
T31	L	Raw	3.5	16/9	75	14.8	511
		+ polymer		57/45	110	14.0	
T32	L	Raw	4.0	10/5	63	18.4	566
		+ 1.0 pct soda ash		12/7	68	14.8	
		+ polymer		34/23	96	13.2	
T33	L	Raw	5.0	12/6	68	18.8	496
		+ 1.0 pct soda ash		16/8	75	14.6	
		+ polymer		75/60	115	12.8	
T34	L	Raw	3.0	15/8	73	15.6	551
		+ 0.5 pct soda ash		15/8	73	14.2	
		+ polymer		60/41	111	12.8	

See explanatory notes at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T35	L	Raw	3.0	13/7	70	16.4	521
		+ 0.5 pct soda ash		12/7	68	15.2	
		+ polymer		35/24	96	14.0	
T36	L	Raw	3.0	4/2	40	27.2	171
		+ 1.5 pct soda ash		13/7	70	14.0	
		+ polymer		40/30	100	14.0	
T37	L	Raw	4.0	15/8	73	15.2	551
		+ 0.5 pct soda ash		16/9	75	13.2	
		+ polymer		40/28	100	12.8	
T38	L	Raw	4.5	13/7	70	20.0	701
		+ 1.0 pct soda ash		22/12	84	14.0	689
		+ polymer		43/30	102	14.0	
T39	L	Raw	2.5	4/2	40	25.6	233
		+ 1.5 pct soda ash		15/8	73	14.4	701
		+ polymer		41/30	101	15.2	
T40	L	Raw	2.0	20/13	81	13.2	638
		+ polymer		53/39	108	12.8	
T41	L	Raw	4.5	18/10	78	15.6	623
		+ 0.5 pct soda ash		17/10	76	13.0	728
		+ polymer		35/24	96	13.2	
T42	L	Raw	3.0	12/7	68	16.4	513
		+ 0.5 pct soda ash		15/8	73	13.6	671
		+ polymer		33/22	95	13.8	
T43	L	Raw	5.0	16/9	75	15.6	488
		+ 0.5 pct soda ash		15/9	73	14.0	581
		+ polymer		42/32	101	15.0	
T44	L	Raw	7.5	13/7	70	18.8	616
		+ 1.0 pct soda ash		17/10	76	14.4	
		+ polymer		53/40	108	14.0	
T45	L	Raw	4.0	9/6	61	20.4	601
		+ 1.0 pct soda ash		14/8	71	14.8	
		+ polymer		38/28	99	14.2	

See explanatory notes at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T46	L	Raw	3.0	11/6	65	19.2	696
		+ 1.0 pct soda ash		20/12	81	14.4	
		+ polymer		47/33	105	14.0	
T47	L	Raw	3.0	3/2	30	51.6	121
		+ 1.5 pct soda ash		13/8	70	14.0	426
		+ polymer		38/28	99	15.2	
T48	L	Raw	3.0	13/7	70	15.2	686
		+ 0.5 pct soda ash		17/9	76	14.0	
		+ polymer		50/37	106	13.2	
T49	L	Raw	3.5	5/3	46	28.0	442
		+ 1.5 pct soda ash		17/9	76	14.0	
		+ polymer		39/28	99	14.4	
T50	L	Raw	4.0	17/9	76	15.4	731
		+ 0.5 pct soda ash		21/12	82	14.0	
		+ polymer		62/47	112	14.0	
T51	L	Raw	5.0	8/5	58	20.0	466
		+ 1.0 pct soda ash		13/8	70	14.2	
		+ polymer		36/25	97	14.8	
T52	L	Raw	2.5	4/2	40	31.2	243
		+ 1.5 pct soda ash		17/9	76	13.6	
		+ polymer		41/30	101	13.8	
T53	L	Raw	10.0	8/4	58	20.8	568
		+ 1.0 pct soda ash		11/6	65	13.6	
		+ polymer		21/12	82	13.6	
T54	L	Raw	4.0	7/4	55	82.0	448
		+ 1.5 pct soda ash		23/18	85	28.0	
		+ polymer		24/19	86	31.2	
T55	L	Raw	2.0	7/4	55	18.8	448
		+ 1.0 pct soda ash		19/12	80	13.6	
		+ polymer		36/26	97	14.0	
T56	L	Raw	9.0	18/10	78	18.4	488
		+ 1.0 pct soda ash		20/11	81	15.2	
		+ polymer		38/26	99	14.2	

See explanatory note at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T57	L	Raw	2.5	10/6	63	16.0	273
		+ 0.5 pct soda ash		13/7	70	13.2	
		+ polymer		45/33	103	12.8	
T58	L	Raw	4.0	4/2	40	13.8	448
		+ 1.5 pct soda ash		14/8	71	15.2	
		+ polymer		28/20	90	15.6	
T59	L	Raw	3.5	5/3	46	26.4	588
		+ 1.5 pct soda ash		11/7	65	16.4	
		+ polymer		31/22	93	15.6	
T60	L	Raw	5.0	7/4	55	17.6	413
		+ 0.5 pct soda ash		10/6	63	15.6	
		+ polymer		20/12	81	14.0	
T61	L	Raw	5.5	9/6	61	22.8	231
		+ 1.0 pct soda ash		17/12	76	14.4	
		+ polymer		37/29	98	15.0	
T62	L	Raw	4.0	17/9	76	17.6	641
		+ 0.5 pct soda ash		14/8	71	15.6	
		+ polymer		39/28	99	14.8	
T63	L	Raw	4.0	13/7	70	18.8	621
		+ 0.5 pct soda ash		15/8	73	14.2	
		+ polymer		35/24	96	15.2	
T64	L	Raw	3.0	30/17	92	14.0	716
		+ polymer		88/69	118	13.6	
T65	L	Raw	3.5	15/8	73	14.8	581
		+ polymer		56/42	109	13.6	
T66	L	Raw	4.0	11/7	65	17.6	256
		+ 0.5 pct soda ash		27/21	89	15.2	
		+ polymer		36/29	97	14.8	
T67	L	Raw	3.0	14/8	71	14.8	556
		+ polymer		63/55	112	15.2	

See explanatory notes at end of table.

TABLE B-3. - Analyses of bentonite samples from the Blue Ridge area, Wyoming[1]--Continued

Sample number	Bed	Treatment	Grit, pct	Viscometer reading, 600/300 rpm	Yield, bbl/ton	Water loss, ml	Plate water absorption, wt pct
T68	L	Raw	4.0	10/5	63	16.8	411
		+ 0.5 pct soda ash		16/10	75	12.8	
		+ polymer		40/30	100	13.2	
T69	L	Raw	5.0	9/4	61	14.0	406
		+ polymer		41/31	101	14.0	
T70	L	Raw	3.5	7/4	55	24.0	371
		+ 1.0 pct soda ash		13/8	70	14.4	
		+ polymer		33/24	95	14.2	
T71	L	Raw	3.0	8/4	58	20.0	421
		+ 1.0 pct soda ash		14/9	71	14.4	
		+ polymer		31/21	93	14.4	
T72	L	Raw	3.0	8/4	58	20.0	386
		+ 1.0 pct soda ash		11/7	65	14.6	
		+ polymer		46/34	104	14.0	
T73	L	Raw	4.5	12/8	68	20.0	301
		+ 1.0 pct soda ash		21/15	82	17.6	439
		+ polymer		36/30	97	18.0	
T74	L	Raw	3.5	19/11	80	14.0	621
		+ polymer		64/52	112	12.8	

bbl/ton = barrels per ton; ml = milliliter; pct = percent; polymer = 0.5 pounds per ton of commercial polymer; + = plus; 600/300 rpm = 600 and 300 revolutions per minute; wt per = weight percent; L = lower; U = upper.

[1]Analyses performed by Kenneth E. Tanner, Ten Sleep, Wyo.

APPENDIX. C--PLATE WATER ABSORPTION TEST PROCEDURE

Standard test method for plate water absorption determination of bentonite as proposed by the Bentonite Users Committee to the American Society for Testing Materials (ASTM) in 1981.

Standard Test Method For
Plate Water Absorption of Bentonite

1. Scope

1.1 This test method covers the determination of water absorbency of bentonite.

1.2 Bentonite is a montmorillonite clay material. It is added to moist iron ore concentrates as a binder in forming balls prior to heat treatment in the agglomerating process for making iron ore pellets.

2. Applicable Documents

2.2 ASTM Standards

C 702 Standard methods for reducing field samples of aggregates to test size.

C 1100 Standard specification for filter paper for use in chemical analysis.

D 1193 Standard specification for reagent water.

E 1 Standard specification for ASTM thermometers.

E 11 Standard specification for wire cloth sieves for test purposes.

E 102 Standard method for sampling iron ores from conveyers.

E 145 Standard specification for gravity convection and forced ventilation ovens.

3. Summary of Method

3.1 The amount of water absorbed over an 18 hour period by a 2 gram sample of processed bentonite is determined gravimetrically by difference under specific fixed conditions and is calculated from the absorption equation in Section 11.2.

4. Significance and Use

4.1 The absorption test relates to the effectiveness of bentonite on the quality of moist iron ore balls prepared for heat-hardening into pellets. The effectiveness of the bentonite is partially due to its water absorption capacity which relates to the quanity of the bentonite required to reach desired wet and dry ball strengths.

4.2 The absorption test aids the supplier in determining his mining and processing requirements for meeting specifications. It aids the user in evaluating the effectiveness of the bentonite when mixed with a particular iron ore concentrate.

4.3 This test is not intended to be used as a vehicle to determine the effectiveness of mixing techniques when using additives to enhance the water absorbing properties of bentonite.

5. Definitions

5.1 Absorption - Plate water absorption expressed as a percentage of the weight of the bentonite sample held at 20 degrees centigrade (68 degrees fahrenheit) for a period of 18 hours under fixed conditions.

5.2 Bentonite - Montmorillonite-form of absorptive colloidal clay used in processing iron ore concentrates in peparation for heat-hardening. Bentonite is processed by drying and grinding to approximately 80 percent, plus or minus 5.0 percent, of minus 200 mesh material.

5.3 Plate - Sintered alumina plate.

6. Interferences

6.1 The accumulation of soluble salts and fungal growth in the water may affect the absorption properties of bentonite. Changing the distilled water after each test will prevent this accumulation.

6.2 Absorption is temperature sensitive. The test should, therefore, be conducted in a relatively constant temperature environment of 20 degrees centigrade plus or minus 3.0 degrees centigrade and all elements should be stabilized at that temperature. Temperature corrections are given in Section 11.

6.3 The absorption value is affected by time. A period of 18 hours will provide reproducible results and will be regarded as standard for this test. Also, it is a convenient time period for most process laboratories working schedules.

6.4 Since loading density in grams per square centimeter has an important bearing on the sensitivity of the test, it is important that the dried bentonite is spread evenly within the prescribed circular template on the filter paper.

6.5 Since water level has a significant effect on test results, it is mandatory to start the test with water at the prescribed level.

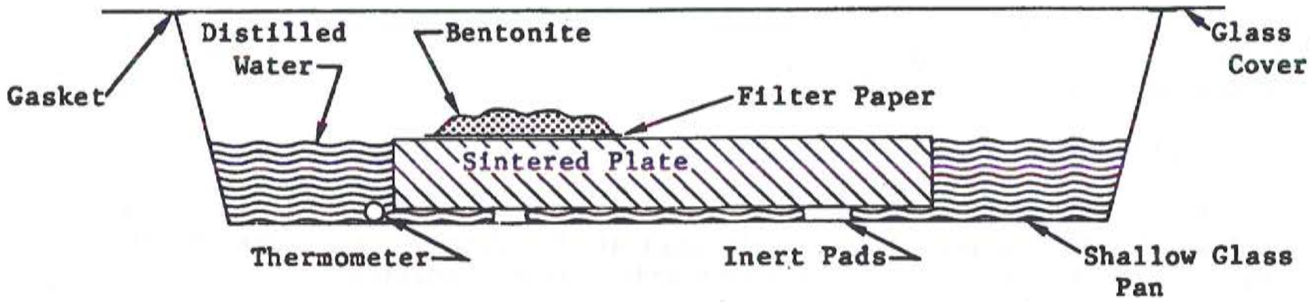
7. Apparatus

7.1 Sintered medium coarse aluminum oxide plate, 12 inches by 12 inches by 1 inch[1] having 19 permeability units per plate, an approximate pore size of 164 microns and a particle retention of 68 microns.

7.2 Inert support pad, 1/4 inch thick by 1 inch square.

7.3 Shallow base glass pan, approximately 16 inches by 16 inches by 3 inches[2].

[1]Norton Industrial Ceramics Division, 50 N.W. Bond Street, Worchester, Mass. 01606. Product #P-260 has been found satisfactory for this purpose.
[2]Glass pans available from Scientific Supply Houses.



Sketch Apparatus

7.4 Glass cover, 17 inches by 17 inches having a soft gasket strip to form a seal against the pan.

7.5 Hardened filter paper, 9 centimeters diameter. Specification D 1100.

7.6 Drying oven, controllable to 105 degrees centigrade. Specification E 145.

7.7 Balance, plus or minus 0.001 gram sensitivity.

7.8 Tared covered containers, 10 centimeters diameter[1].

7.9 Thermometer, plus or minus 1.0 degree centigrade sensitivity. Specification E 1.

8. Materials

8.1 Bentonite samples from the supplier or user inventory, ground to approximately 80 percent of minus 200 mesh and dried to a constant weight at 105 degrees centigrade (221 degrees fahrenheit)[2]. The bentonite is described in Section 1.2.

8.2 Distilled water - ASTM Type II. Specification D 1193.

9. Preparation of Apparatus

9.1 Place a clean alumina plate, which is supported by 1/4 inch thick pads, in the center of the pan and ensure the top of the plate is level. Before each test, add distilled water to within 1/4 inch of the top of the plate, measuring to the water-plate contact, at least 3/8 inch away from the edge of the plate, and then place the glass cover over the pan.

9.2 Allow the system sufficient time to reach ambient temperature.

[1]Reference Fischer Scientific Catalogue 81, Reusable Petri Dish, Catalogue No. 08-747-C, 100 millimeter by 15 millimeter set has been found satisfactory for this purpose.
[2]ASTM E 102 and ASTM C 702 are referenced for sampling procedures.

9.3 Provide a washer-type template with a 5-centimeter diameter cut out for use in depositing the bentonite on the 9-centimeter filter paper.

9.4 Following each test the water should be changed and the plate and pan cleaned.

10. Procedure

10.1 Determine the average weight of the hydrated filter paper from the lot used in the absorbency test by allowing four papers to absorb water on the the alumina plate for 18 hours and then weighing the papers.

10.2 Weigh 2 grams (plus or minus 1 milligram) of processed bentonite, previously dried to constant weight at 105 degrees centigrade (220 degrees fahrenheit) onto the dry filter paper and spread it evenly within the 5-centimeter circle of the template on the 9 centimeter diameter paper. This can best be accomplished by using a vibrating spatula. Remove the template.

Record the initial water temperature.

10.3 Place the paper and bentonite on the alumina plate. Up to four samples can be placed on the plate at one time.

10.4 After 18 hours record the final water temperature and note the surface condition of the bentonite. Carefully lift the filter paper and place it in a pre-weighed glass dish. Place a cover on the dish until ready to weigh.

10.5 Weigh the covered glass dish containing the hydrated paper and the hydrated bentonite.

11. Calculation

11.1 Determine the net weight of the hydrated bentonite by subtracting the glass dish weight and the average weight of the hydrated paper, as directed in 10.1, from the total weight.

11.2 Calculate and report the absorbed moisture as to the percent weight increase over the dry bentonite weight as follows:

$$\text{Absorption percent} = \frac{(Ww - Wd)}{Wd} \times 100 - (K\ (Ta - Tr))$$

Absorption = plate water absorption (percent weight) at 20 degrees centigrade per 18 hours
Ww = net weight of hydrated bentonite (grams)
Wd = net dry weight of dry bentonite (grams)
Ta = average of initial and final water temperature (degrees centigrade)
Tr = reference temperture = 20 degrees centigrade
K = temperature co-efficient (percent weight per degrees centigrade) equals 3.30

Bentonite Resources in the Winkleman Dome—Bighorn Ridge, Arapahoe Reservoir, and Blue Ridge Areas on the Wind River Indian Reservation, Wyoming

R 60

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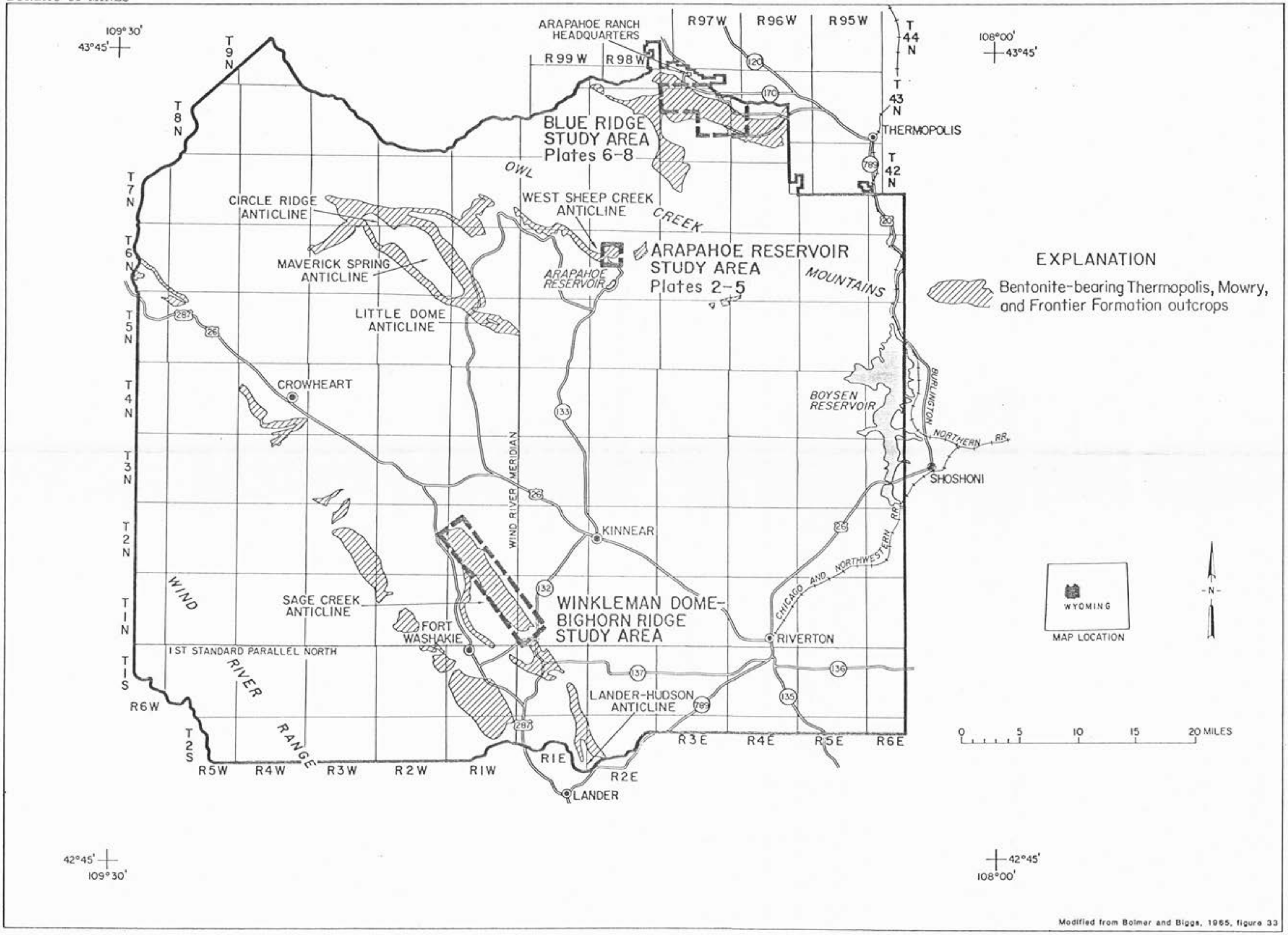
Geology -- Interpreting the past to provide for the future



Study areas, selected structural features, and areas where the bentonite-bearing Thermopolis, Mowry, and Frontier Formations crop out on the Wind River Indian Reservation, Wyoming.

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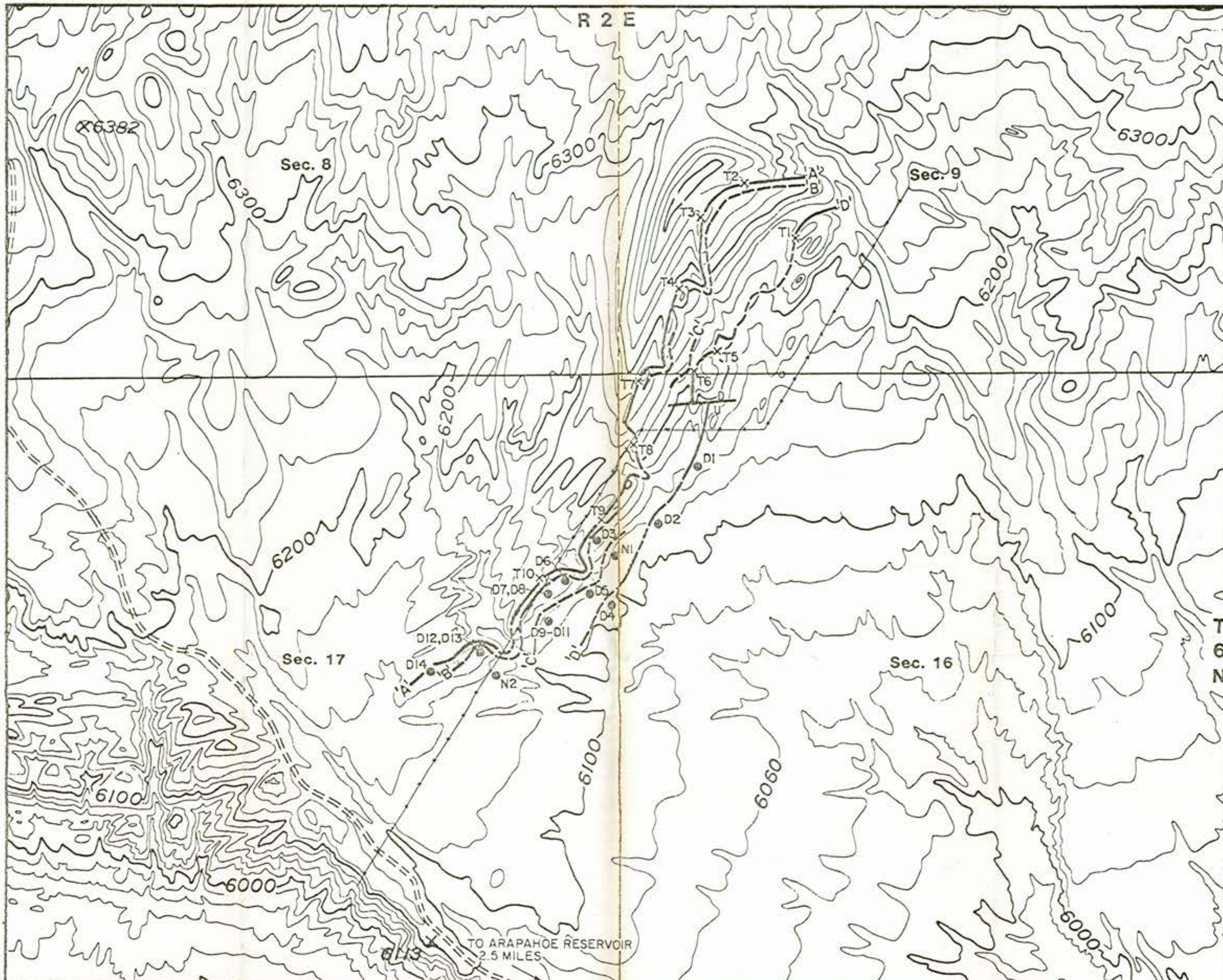

Base map from USGS Shotgun Butte and Sheep Ridge Quadrangles, Wyo., 7.5 Minute Series (Topographic).

EXPLANATION

×T3 Test-pit locality and sample number (T1–T10)

●D6 Drill-hole locality and sample number (D1–D14)

●N2 Drill-hole locality from which no sample was recovered (N1 and N2)

D/U Fault (U-upthrown side; D-downthrown side)

'A' Bentonite bed (solid where crops out; dashed where inferred; letter designates individual bed)

====== Unimproved road

—•—•— Fence

MAP LOCATION (SEE PLATE I)

-N-

0 500 1,000 2,000 FEET

Bentonite outcrops and sample localities in the Arapahoe Reservoir study area, Wind River Indian Reservation, Wyoming

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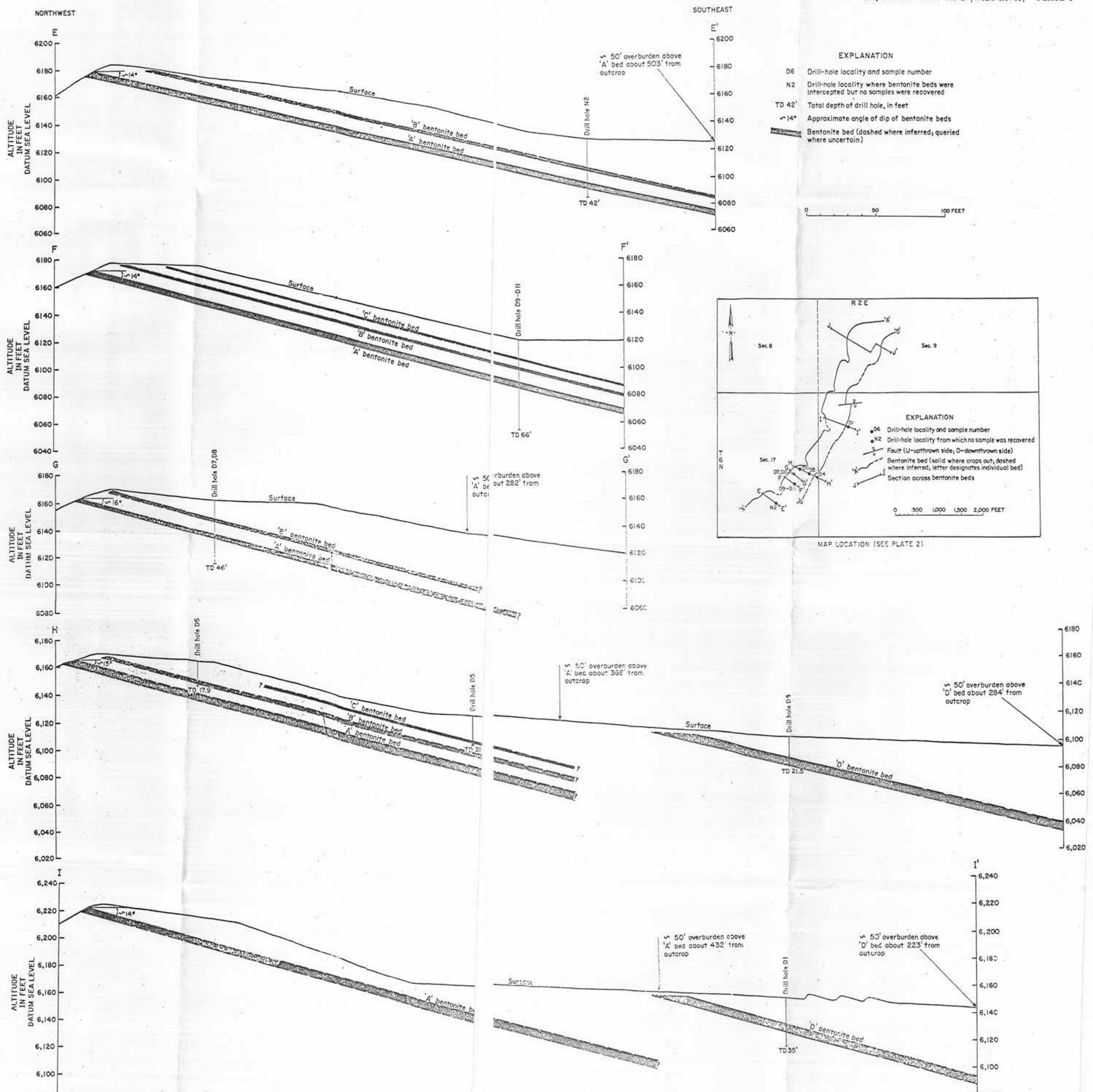
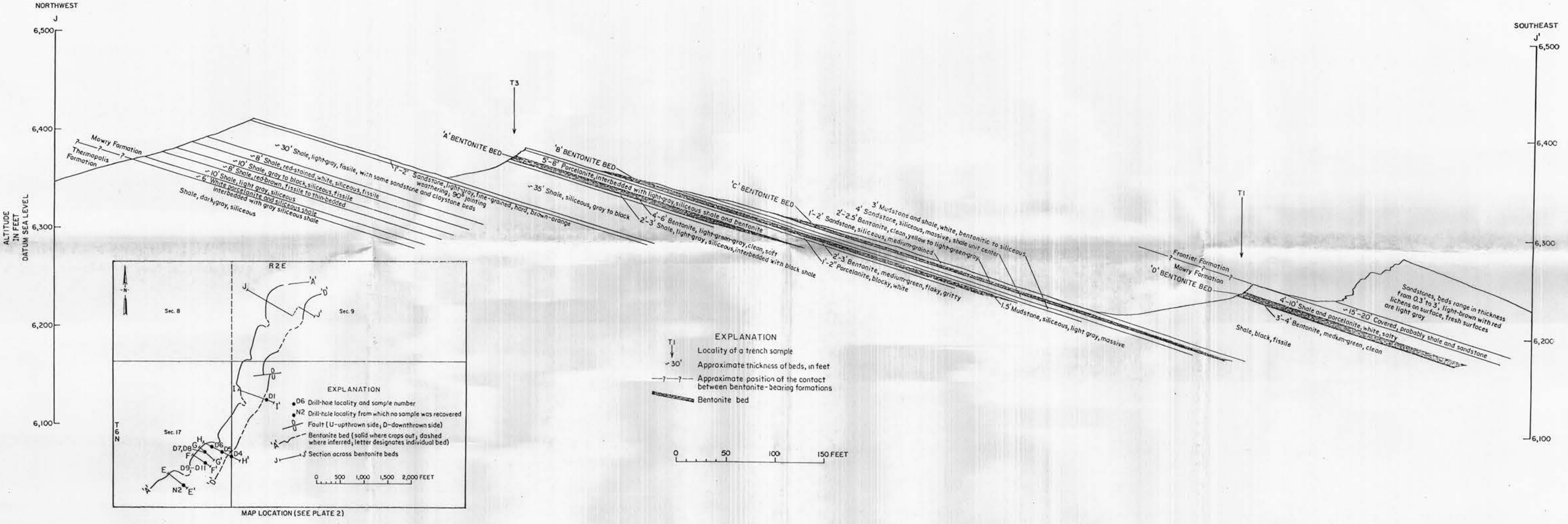


Schematic se   ross bentonite outcrops in the Arapahoe Re ervoir
stu   Wind River Indian Reservation, Wyoming



Stratigraphic section in the Arapahoe Reservoir study area, Wind River Indian Reservation, Wyoming

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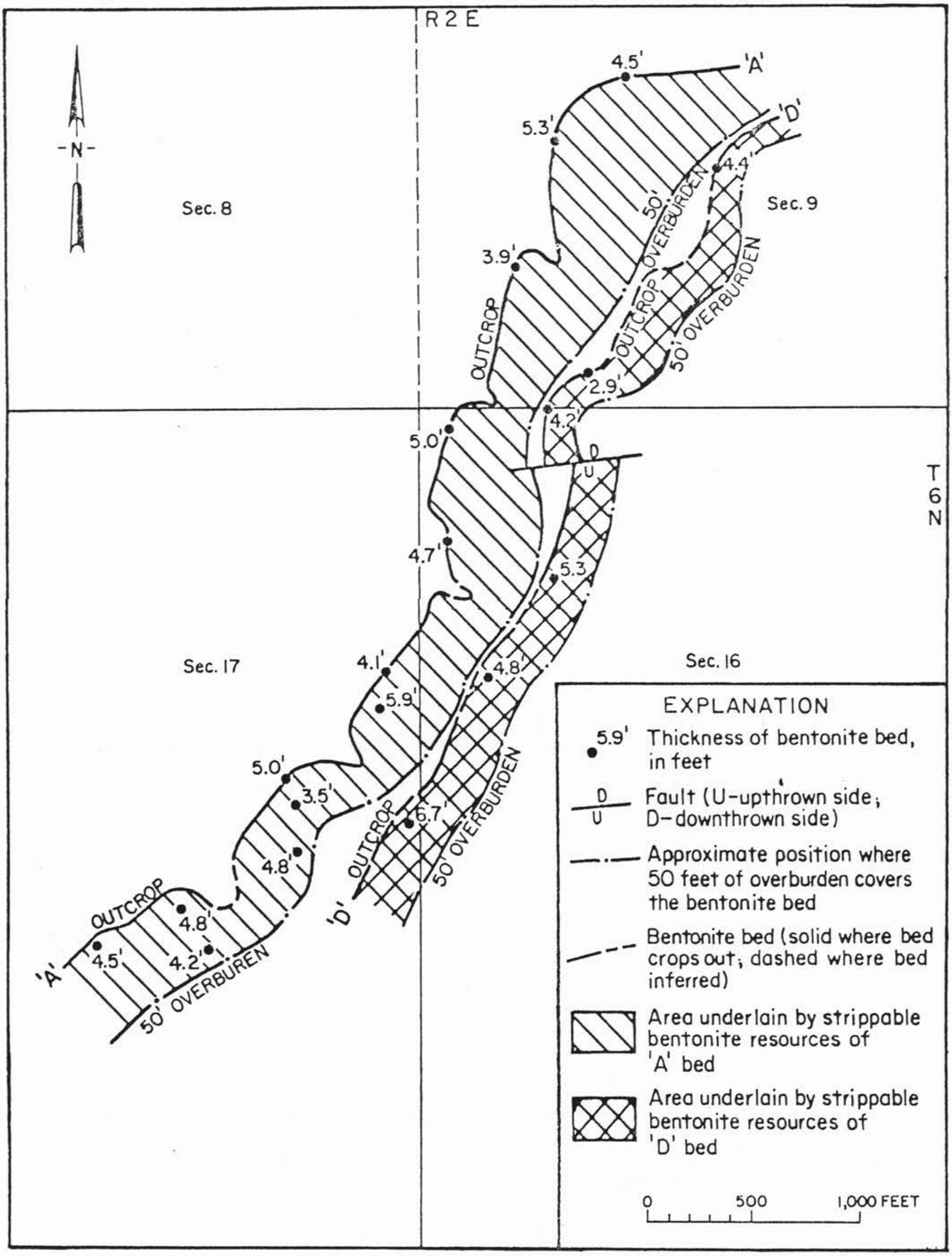

Demonstrated subeconomic bentonite resources in the Arapahoe Reservoir study area, Wind River Indian Reservation, Wyoming

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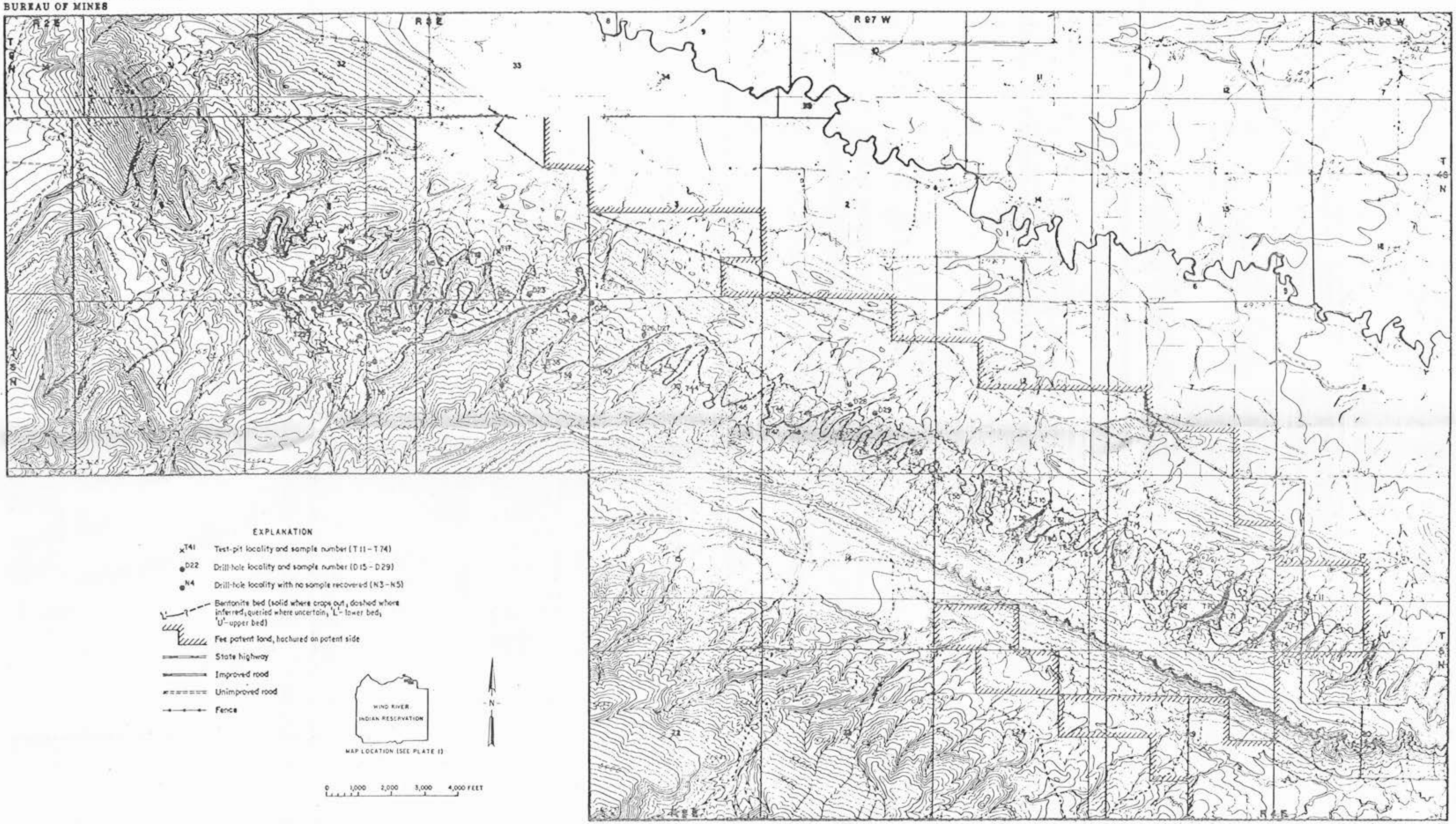

Base map from USGS Arapahoe Ranch and Thompson Reservoirs Quadrangles, Wyo., 7.5 Minute Series (Topographic).

Bentonite outcrops and sample localities in the Blue Ridge study area,
Wind River Indian Reservation, Wyoming

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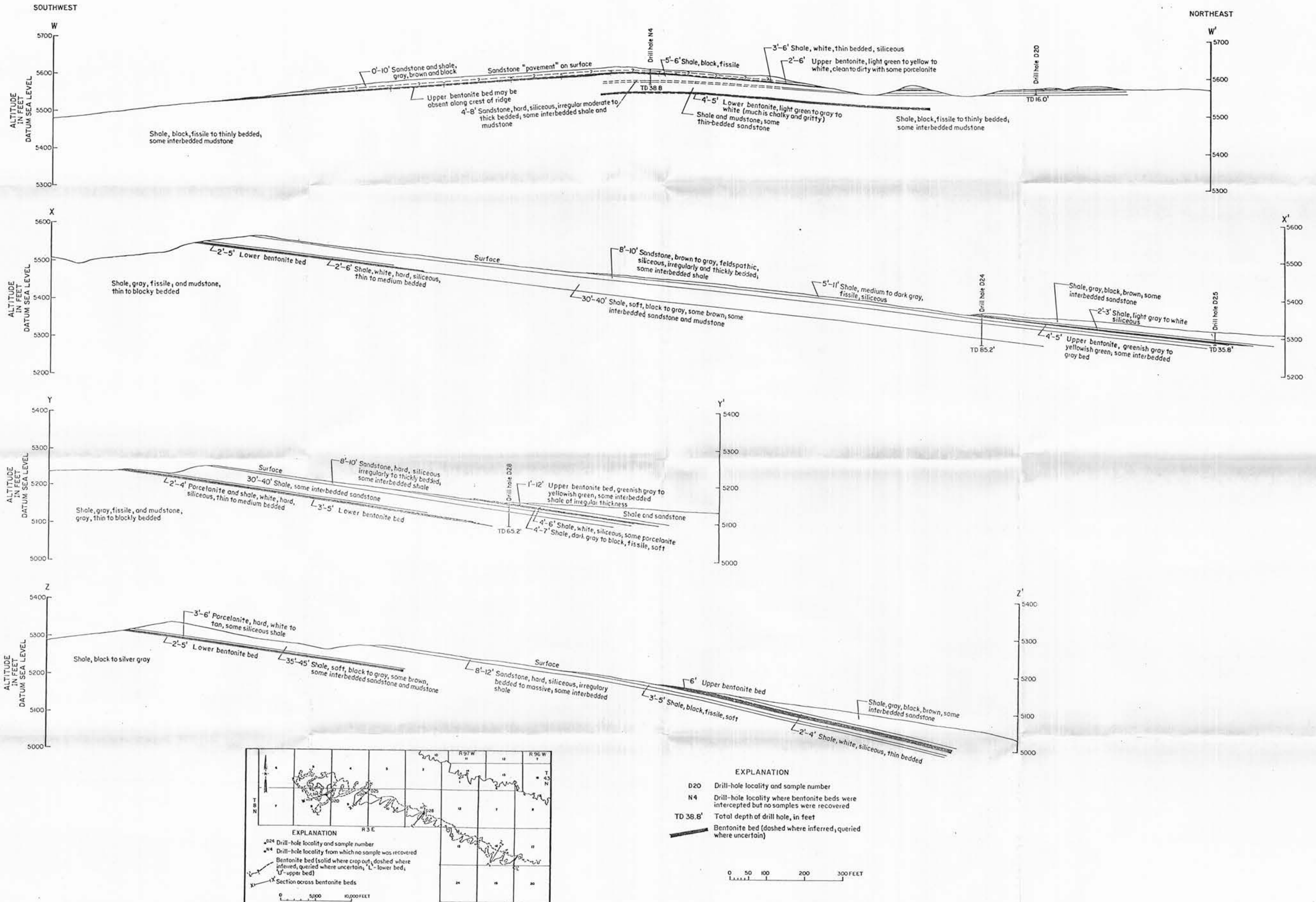
Report BIA No. 8-III B (Wind River) PLATE 7



MAP LOCATION (SEE PLATE 6)

Stratigraphic sections across the bentonite outcrops in the Blue Ridge study area, Wind River Indian Reservation, Wyoming

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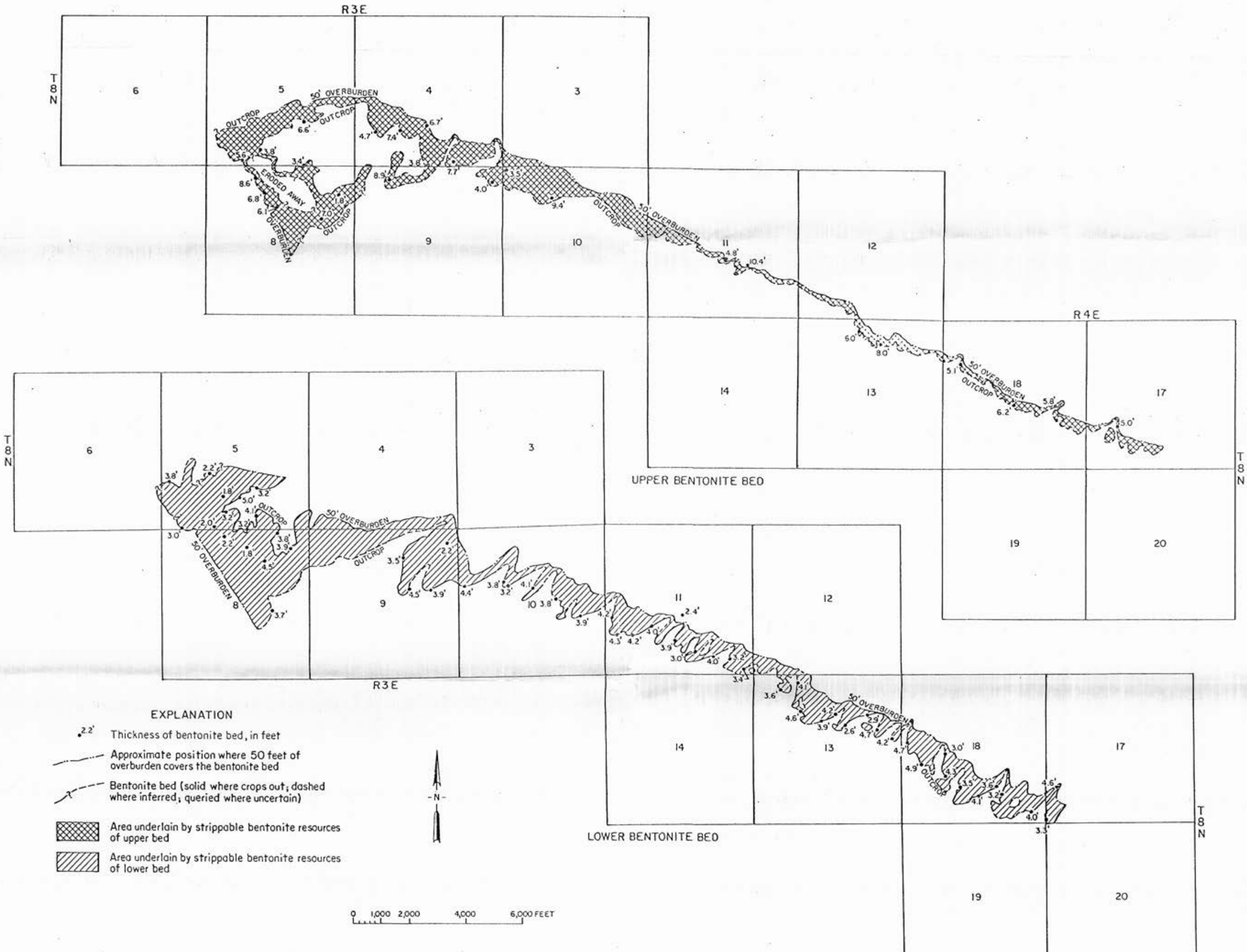
Report BIA No. 8-III B (Wind River) PLATE 8



Marginal bentonite reserves in the Blue Ridge study area, Wind River Indian Reservation, Wyoming