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PROGRESS REPORT ON CLAYS OF MONTANA

by

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ILLUSTRATIONS

PROGRESS REPORT ON THE CLAYS AND SHALES OF MONTANA, 1958-1959

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INTRODUCTION

This bulletin is the second progress report on the survey of Montana's clay and shale resources. The first progress report was issued as Information Circular 23 in June 1958. This report is supplementary to the first.

The purpose of this project is to catalog the clay (and shale) deposits of the State, and to make this information available to all concerned. It is intended to sample likely clay (and shale) deposits, and to determine possible uses, if any, of the material sampled. The clays are examined for possible use as ceramic raw materials, as possible sources of expanded shale light-weight concrete aggregate, and as possible sources of alumina for the production of metallic aluminum.

The survey was started in 1956 and will be continued until the readily accessible clay or shale deposits are sampled. Montana is a large state, and it will be many years before the deposits are adequately sampled; therefore, progress reports such as this will be published as frequently as conditions warrant, rather than withhold the results until the entire survey is completed.

Acknowledgments

The geological examinations for this report were made by Uuno M. Sahinen. X-ray analyses and all ceramic tests were made by Ralph I. Smith. Chemical analyses were made by Clem J. Bartzen. Bloating tests were made by Don C. Lawson.

The writers take this opportunity to thank all those who rendered assistance in the field by guiding them to the deposits and providing local information. Many clay samples sent in by the public have been included in the survey, and the source of these are acknowledged in the descriptions.

CLAY AND SHALE FOR CERAMIC USE

Field trips are conducted each summer to gather samples and to get sufficient geologic data to determine if the deposit would warrant further examination if preliminary tests showed evidence of a clay or shale of special economic value. So far all work has been of a preliminary nature.

Four types of tests are conducted in the laboratory. Analyses by X-ray diffraction are made to determine the mineral composition; chemical analyses are made to determine chemical composition; ceramic tests are made to determine the physical properties; and bloating tests are made on the low-fusing clays to determine if they are suitable for the manufacture of expanded shale light-weight aggregate for concrete.

All of the samples collected are crushed to 3/8-inch and cut to about 2 pounds weight by coning and quartering. The 2-pound sample is ground to pass a 20-mesh screen. A small portion of the ground 2-pound sample is ground further to pass a 100-mesh screen. The minus 100-mesh material is used for X-ray and chemical analyses. The minus 20-mesh material is used for water of plasticity determinations, test cones, and test bricks.

Laboratory Procedure in Ceramic Testing

A modified Atterberg test (Kinneson, 1915) is used to obtain the water of plasticity range and indicate the plasticity as follows: A 50-gram sample of the clay is mixed with water from a standard burette. The clay and water are worked with a spatula until the water is evenly distributed. Water is added until the clay-water mixture, when cut with the spatula, does not adhere to the spatula and the clay on the sides of the cut remains standing. This is the lower plasticity limit. Water is again added in small amounts with mixing and working after each addition until the clay sticks to the spatula and the sides of the cut flow together immediately following the cut. This is the upper limit of plasticity. The amount of water used is measured in percent, using one gram as the weight of one cubic centimeter of water. The test shows the plasticity, working range, and roughly the type of clay mineral present. The best working range is found to be close to the lower plastic limit. The percentage of water used is a rough indication of the type of clay mineral present as shown in the following tabulation (Skinner and Kelly, 1949):

Water of Plasticity	Type of Material
Less than 20%	Clay of little plasticity or non-clay mineral
20% to 40%	Clay of moderate plasticity, shale, flint clay
35% to 60%	Plastic clays, kaolin, and ball clays
Above 65%	Montmorillonite (bentonitic clays)

Test cones, made of the raw clay mixed with water, are molded, dried at 105° C. (221° F.), and fired with standard cones to obtain the Pyrometric Cone Equivalent (P.C.E.). When the test-cone fuses, the number of the standard cone which reaches the same state of fusion is noted. Firing up to 2,400° F. is done in a

Hayes Glo-Bar electric furnace equipped with a thermocouple and Pyrometer accurate to 5° C. (9° F.). Firing above 2,400° F. is done in a Denver Fire Clay cone furnace fired with natural gas.

Test bricks 1 by 1 by 2 inches are hand-molded, dried at 105° C. (221° F.) overnight, and fired at temperatures based on the prior P.C.E. determinations. Firing is continued about 8 hours in the Glo-Bar furnace, using the thermocouple pyrometer for temperature control. The bricks are removed from the furnace when the predetermined temperature has been reached and then placed in another furnace at 1,200° F. When the firing is finished, the furnace is turned off and the test bricks allowed to cool overnight. For specimens taking over 2,400° F. the DFC cone furnace is used, and the temperature measured with a standard cone. The specimens are left in the furnace until cool. Although the fast firing in the laboratory furnaces usually gives higher temperature values than would be obtained in the slower-fired commercial furnaces (Table 7), the tests give a good estimation of the firing range and the firing characteristics of the materials.

All test bricks are measured lineally before drying, after drying, and after firing. All shrinkage figures given in the tables are linear.

EXPANDED SHALE AS LIGHT-WEIGHT AGGREGATE

Introduction

Expanded clay and shale as a light-weight aggregate for use in cement products was first produced commercially in 1919. The material was called Haydite after the man who first patented a process for expanding the material. During the years between 1919 and World War II a very slow increase in use of expanded clay and shale for light-weight aggregate took place. From the start of the war until 1946 there was a tremendous upswing in value of light-weight clay and shale products. According to Conley and others (1948) this value increased from $1,713,347 in 1936 to $140,000,000 in 1946. This growth is partially explained by the tremendous growth in building, but was also due to the discovery of its advantages for use in structural concrete in large buildings and its sound-proofing qualities when used in ceilings and partitions.

Considerable research has been done on light-weight aggregate material in the past 19 years by many people with the following generalized conclusions:

1. That in order to be classified as a light-weight aggregate, it must weigh not more than 55 pounds per cubic foot for fine material and 70 pounds per cubic foot for coarse material.

2. That the bloating characteristics of a material are determined not by the basic clay mineral structure, but by other minerals and clays associated with the clay as impurities. These minerals are carbonaceous material, different iron compounds, limestone, dolomite, and gypsum, which produce gases on heating.

There are two necessary conditions to bring about bloating in shales:

1. When the bloating temperature is reached, the general clay mass must be in a semi-molten condition;

2. At the same time gases must be evolving throughout the mass.

If the above stated conditions exist, the developed gases are entrapped in the fusion and cause the bloating.

In California and North Dakota pH* tests on a mud slurry of different clays and shales were found to be 90 percent accurate in determining the bloating and non-bloating clays. If the slurry has a pH above 5, the clay would bloat, but if it was under 5, it would not. This was found not to apply in all areas as tests run on Indiana shales by Murray and Smith (1958) showed no connection between pH and bloating ability. Tests run on water slurries of 27 Montana clay and shale samples by the Montana Bureau of Mines and Geology also showed no connection between bloating ability and pH.

Each clay or shale deposit is a problem in itself, and before any plant or operation is set up a detailed geologic examination, economic study, and further testing should be made. The work done by the Bureau as described in this report is necessarily of a preliminary nature, and testing is done on many clays and shales to establish which ones are most favorable for bloating.

The bloated clay or shale produced by the expanding procedure show which clays or shales are most favorable for use as light-weight aggregate. In general, expanded clay or shale in well-rounded pellets, partly glazed, and with a uniform fine cell structure is considered ideal for light-weight aggregate. The final test, however, is whether a concrete block in which the light-weight aggregate is used will meet all required specifications. Light-weight aggregates must weigh not over 75 and not less than 55 pounds per cubic foot, and load-bearing hollow concrete blocks in which it is used should have a minimum compressive strength of 800 pounds per square inch (total area), maximum water absorption of 15 pounds per cubic foot, and maximum moisture content of 40 percent.

Nonload-bearing blocks using this material should have a minimum compressive strength of 600 pounds per square inch, maximum water absorption of 15 pounds per cubic foot, and maximum moisture content of 40 percent. The 8- by 8- by 16-inch blocks can range between 24 and 40 pounds in weight.

Laboratory Procedure in Expanding Tests

After the ceramic tests are run and tabulated, the clays that show P.C.E values of less than cone 6 are tested for bloating properties to determine if they could be used as raw materials for expanded shale light-weight aggregate for concrete building masonry units.

The material used for bloating is minus 3/4-inch plus 1/2-inch except in such cases where the original sample fragments are of a smaller size.

The firing is done in a heavy-duty Glo-Bar electric muffle furnace with an automatic temperature control thermostat which allows only a 5° C. (9° F.) drop in temperature. The samples require preheating. The firing is done at ranges from 2,000° F. to 2,400° F. in steps of 100° F. for 20 minutes per run.

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*pH is a measure of acidity or alkalinity. Materials with a pH below 7 are acidic, those above 7 are alkaline.

There seems to be no uniformity as to temperature scale used in expandability tests. Some authors use the Centigrade scale, others, the Fahrenheit. Ceramic data, on the other hand, is commonly given in degrees Fahrenheit. As this report covers both types of testing, the Fahrenheit scale will be used for sake of uniformity in this and future reports. For those readers accustomed to thinking in terms of the Centigrade scale, the corresponding temperature in Centigrade can be readily obtained by subtracting 32° from the Fahrenheit reading and multiplying the remainder by 5/9.

Specific gravity determinations are made on a Jolly balance for those specimens of expanded shale that do not float in water. A specific gravity of minus one (—1) is assigned to those bloated specimens that float.

X-RAY DIFFRACTION DATA

Each sample of clay is air dried, cut, and ground to minus 20-mesh for ceramic tests. A smaller portion is ground to minus 100-mesh for X-ray and chemical analyses. The X-ray determinations are made with a Phillips-Norelco diffractometer. Cobalt and copper radiations were tried. Copper was selected as the more suitable, and it is used for all the determinations. One trace of each clay is made using a speed of 2° Theta per minute. The sample is then deflocculated with sodium metaphosphate, and the clay minerals separated by filtration. The filtered clay minerals are centrifuged for fifteen minutes and a new trace made. If necessary, further treatments are made, such as saturation with glycerene for montmorillonite materials, solution of chlorite with warm dilute hydrochloric acid, an ammonium solution for vermiculite, and heat treatments to distinguish kaolin group minerals. Standard procedure for these treatments can be found in X-ray Identification and Crystal Structures of Clay Minerals, edited by G. W. Brindley, published by the Mineralogical Society of London. Results are shown in table 4 appended to this report.

CHEMICAL ANALYSES

The chemical analyses are run primarily to determine the alumina content; however, analyses are also made for silica, iron, lime, magnesia, soda, potassium, and titania. Standard methods are used throughout. Analyses are given in table 5 in the Appendix. Those which show high alumina content (20% or over) are reanalyzed for acid-soluble alumina according to the standard procedure as described by Skinner and Kelly (1949). These results are shown in table 6.

DESCRIPTION OF CLAYS AND DEPOSITS

Sample 86

This sample was submitted by Mr. Harold Kelley of the U. S. Bureau of Mines from a deposit east of Whitehall. The material is a poorly sorted coarse arkosic, clayey sand composed mainly of sub-angular to rounded quartz grains, considerable feldspar, and some white mica. Some of the quartz is smoky. It appears to be poorly consolidated Tertiary sandstone.

It has no plasticity and is of no use for ceramic purposes. (See table 2.)

Because of the nature of the material, no bloating tests were run on it.

Sample 87

The material was sent in by Mr. H. Daems of Whitehall. It is a soft white material composed essentially of calcium (lime) carbonate with some clay and fine quartz. Minor amounts of hornblende, feldspar, and mica are present. The material is probably of Tertiary "lake bed" origin. It is not suitable as a ceramic material.

Sample 88

This sample was submitted by Don Albright and is from the Ruby Mountains. It is a consolidated pumicite composed essentially of fine-grained volcanic glass.

It has but little plasticity; and on firing, it vitrifies but does not bond until almost melted. It is not a suitable ceramic material. (See table 2.)

The material showed no appreciable change when tested for bloating properties, and is not suitable for light-weight aggregate.

Sample 89

The material is a light- to medium-grey shale, fairly hard, from the Greyson formation (Precambrian) taken from a road cut along U. S. 91, 8 miles due north of Helena. Quantity available is large.

It has good plasticity and green strength. The P.C.E. is cone 2 (2,129° F.), and the firing range, 2,000° to 2,075° F. With careful firing the material could be used for common brick and like products.

The shale expanded very slightly when tested, but is not suitable for a light-weight aggregate.

Sample 90

The material was submitted by R. T. Chew (no. 57-124) and is from the Northern Pacific right-of-way in sec. 35, T. 18 N., R. 56 E., near Intake in Dawson County.

Ceramically, it is soft, grey, fine-grained, with good plasticity, and green strength. The P.C.E. is cone 2, and the firing range is 1,950° to 2,050° F. The clay can be used for common brick and similar grade products.

No bloating tests were run on this material.

Sample 91

This sample was cut from a steep bank on the southeast side of an unnamed gulch in the SW¼ sec. 25, T. 2 N., R. 4 W., northeast of Whitehall, in Jefferson

County. The material is indurated shale from the North Boulder group (La Hood ? formation) in the Belt series of Precambrian age. The sample represents the next 6 feet above the first dark band exposed. The material is a variegated micaeous shale, sandy in places, and locally containing minute seams of magnetite.

As a ceramic material it would need grinding; the plasticity and green strength are fair. P.C.E. is cone 11 (2,345° F.), and the firing range is 2,050° to 2,200° F. The fired bricks show a slight alkali scum over an orange to red color. With careful working and firing the shale could be used for common brick and similar ceramic products.

Because of the high P.C.E., no bloating tests were run on this clay.

Samples 92 and 93

These two samples were taken from below (92) and above (93) the coal seam in the Hegg coal mine in the southern part of sec. 13, T. 4 N., R. 2 E., 1 mile west of Lombard, in Broadwater County. The samples were taken in the main entry a few feet in from the portal. The mine has been abandoned for many years.

Sample 92 is soft medium-grey to tan shale from the Kootenai (?) formation of Lower Cretaceous age. The plasticity is only fair, but the green strength is good. The P.C.E. is cone 10, and the firing range, 2,000° to 2,200° F. A slight scum formed on the dried brick. With careful working and drying, the shale could be used for common brick and products of similar grade.

Sample 93 is quite similar to sample 92, but contains a slight amount of coaly matter. However, it is more refractory (P.C.E. over 12) and forms less alkali scum. The firing range is 2,000° to 2,300° F.

Samples 94 and 95

Samples 94 and 95 are shales from the Kootenai formation taken from a road cut on the south side of U. S. 10 in the NE¼NE¼ sec. 25, T. 2 S., R. 6 E., about 5.8 miles east of Bozeman, in Gallatin County. Sample 94 represents 4 feet of the upper red beds, and sample 95, 10 feet of green shale in the second shale band above the base as exposed in this cut. The beds here strike N. 70° W. and dip 50° NE. The material is present in large quantity and is easily accessible.

Both red (94) and green (95) shales have low drying and firing shrinkage and good green strength, with fair to low plasticity. The red has a P.C.E. of cone 8, and the green, of cone 11. The firing range of sample 94 is about 1,950° to 2,150° F., and sample 95, 1,900° to 2,200° F. Both can be used for products of common brick grades.

Sample 94 did not bloat well, and sample 95 yielded an expanded product with a low specific gravity (1.3), but did not give a uniform product.

Sample 96

Sample 96 is light olive-grey shale from the Hell Creek formation (Upper Cretaceous). The sample was taken from a road cut on the north side of U. S. 10 in sec. 31, T. 1 S., R. 19 E., about 7 miles east of Reed Point, in Stillwater

County. It represents about 6 feet of shale below an overburden of about the same amount of sandstone. The beds are flat-lying. The shale is bentonitic.

The material is quite sticky when wet. The firing characteristics are not good; the brick cracked when fired. The clay is unsuitable for ceramic use. (See table 2.)

When tested for expansion, this clay turned dark brown and yielded a very light product (Sp. Gr. -1.0) that resembles glazed popcorn. It showed a uniform fine porosity over a temperature range of 2,070° to 2,190° F. It showed some spalling but should make a quite satisfactory expanded shale light-weight concrete aggregate.

Sample 97

This sample was taken from a road cut north of U. S. 10 in sec. 13, T. 2 S., R. 19 W., about 2 miles west of Columbus, in Stillwater County. It represents the top 5 feet of a 10-foot shale bed in the Hell Creek formation at road level. The overburden at the sample-site is great, but around the bend of the road to the east, much material could be obtained with little or no overburden. The shale is light-olive grey in color and quite bentonitic in composition.

The material is not suitable for ceramic use. (See table 2.)

It might make an excellent light-weight aggregate if fired below 2,192° F. Above that temperature the material fuses into a froth; but below that temperature the material resembles glazed dark-brown popcorn. Temperatures would have to be watched in order that the material would not expand too much and thus lose strength.

Sample 98

Sample 98 is a grab-sample of Judith River shale (Upper Cretaceous) from a shallow road cut in sec. 22, T. 3 S., R. 21 E., 13 miles southeast of Columbus on the road to Joliet. The shale is pale brown to pale-yellowish brown in color, is slightly sandy (arkosic), and contains some coaly matter.

The shale has good working properties and medium plasticity, but the firing characteristics are poor. (See table 2.) It is unsuitable for ceramic ware.

Under bloating tests, the material gave a product that was well-rounded, glazed, and grey to brown in color. The expanded material was very light in weight, but the pores were quite large at the minimum temperature used (2,192° F.). Firing at a lower temperature would probably give a denser and stronger product and still satisfy the requirement of light weight.

Sample 99

This sample was taken on the Pat Billingsley ranch, about 4 miles west of Joliet, in Carbon County. The sample represents 10 feet of shale from a shale bank on the northeast side of Squaw (?) Creek drainage. The shale is light-olive grey in color and bentonitic in composition. The bed is overlain by about 5 feet of sandstone and sandy shale of the Judith River formation (Upper Cretaceous).

The shale is not suitable for ceramic ware. (See table 2.)

It could be used for the manufacture of light-weight concrete aggregate. Fired to 2,192° F., the shale yields a porous product which is dark-chocolate brown in color, but variable in porosity. It may be that firing to a slightly lower temperature might give a more uniform product.

Samples 100 and 101

The two samples are from a road cut just east of the Smith coal mine in sec. 5, T. 8 S., R. 21 E., on the Red Lodge-Bridger road. Sample 100 represents 4 feet of shale above a sandstone bed, and sample 101, 3 feet of shale below the same sandstone. The beds are in the Fort Union formation of early Tertiary age.

Sample 100, a medium-grey shale with some carbonaceous matter and bentonite, is not suitable for ceramic ware and spalled badly when tested for expandability.

Sample 101, a light olive-grey slightly calcareous shale, has low plasticity, but the material works well, and the green strength is good. The P.C.E. is cone 8, and the firing range, 1,950° to 2,050° F. With careful handling and firing, the material could be used for common brick.

Bloating tests on sample 101 were run at temperatures of 2,192° and 2,282° F. At these temperatures the products were very light and porous, but the cell-structure was too coarse for good strength. Bloating at a lower temperature might give a finer and stronger cell structure.

Sample 102

Sample 102 is from a road cut on the Red Lodge-Bridger road at the east end of the village of Bear Creek, in sec. 4, T. 8 S., R. 21 E. The sample represents 5 feet of clay and carbonaceous shale below a sandstone in the Fort Union formation. The beds lie nearly horizontal, and overburden is thin.

The material is buff to brown in color and contains much organic material. It is not suitable for ceramic ware. (See table 2.)

At 2,160° F. the shale bloated to a very light-colored and light-weight product with a coarse cell structure. Bloating at lower temperatures might have yielded a finer and stronger cell structure.

Samples 103 and 104

These samples were cut from a broad back-slope of U. S. Highway 310, 14 miles south of Bridger in the SE¼ sec. 16, T. 8 S., R. 24 E. The shale is from the Cody (Colorado) formation which here strikes about N. 45° W. and dips 10° SW. Sample 104 is 10 feet stratigraphically above 103. Shale outcrops westward for many miles.

Sample 103 is a medium dark-grey uniform shale with medium plasticity and good working qualities. The test brick had good green strength and fired well. The drying and firing shrinkages are both medium. The P.C.E. is cone 11 (2,345° F.), and the firing range is 1,900° to 2,100° F. Above the firing range, the test brick bloated. With careful handling and firing the shale could be used for common brick.

No bloating tests other than that mentioned above were made.

Sample 104 had an excessively heavy alkali scum and is not suitable for ceramic use; but tested at 2,100° F. for bloating, the resultant material showed a fine, uniform cell structure, and a specific gravity of about one. With careful control it might make a good light-weight concrete aggregate.

Sample 105

This sample is a grab-sample from near the top of the Frontier formation (Upper Cretaceous) about 0.7 mile southeast of samples 103 and 104. It was taken in the SE¼ sec. 15, T. 8 S., R. 24 E., in a dry gulch east of U. S. Highway 310. The material is an olive-grey micaceous shale underlying a sandstone capping.

The plasticity is medium. Working properties and green strength of bricks are good. Drying and firing shrinkages are medium. The P.C.E. is cone 10, and the firing range, 2,100° to 2,200° F. Although the firing range is narrow, the material could be used for common brick.

This shale was not tested for bloating because of the high P.C.E. (cone 10).

Sample 106

This is a sample of shale from the clay pit of the old Fromberg brick yard (abandoned) in the E½SE¼ sec. 18, T. 5 S., R. 23 E., about a mile west of the town of Fromberg, in Carbon County. The shale is from near the top of the Niobrara formation (Upper Cretaceous) which here strikes about N. 23° W. and dips 5° SW. The sample was grabbed in the darkness of an approaching rain storm and cannot be considered very representative. The sample is from a different horizon than previously tested. (See samples 75-78, I.C. 23.)

The material was not suitable for ceramic ware, nor for light-weight aggregate. (See tables 2 and 3.)

Sample 107

Sample 107 was taken from a shale exposure just east of U. S. Highway 87, 1.2 miles north of its junction with U. S. Highway 10, east of Billings. The sample represents 9 feet of shale below a sandstone horizon near the base of the Judith River formation (Upper Cretaceous).

The dried brick has an alkali scum, and the firing range is narrow (about 50° F.); because of this, the shale is not a good ceramic raw material.

This sample was tested for bloating, but at the temperatures used (2,100° to 2,280° F.) it showed considerable fusion. It is possible that close control at a lower temperature would yield a satisfactory product for use as a light-weight aggregate. Specific gravity of the bloated material was less than one, i.e., it floated on water.

Samples 108, 109, and 110

These three samples were cut in a shale exposure west of U. S. Highway 87, in sec. 15, T. 5 N., R. 26 E., 28 miles due north of Billings, in Yellowstone

County. Sample 108 represents 2 feet of shale; 109; 5 feet of shale directly below 108; and 110, 5 feet of shale about 25 feet stratigraphically below 109; all in the Fort Union formation.

Samples 108 and 110 are not suitable for ceramic ware because of scumming, poor firing characteristics, and narrow firing range. Sample 109, a soft light olive-grey shale, has low plasticity, medium shrinkage in drying and firing, and good green strength. The P.C.E. is cone 11 (2,345° F.), and the firing range, 2,050° to 2,175° F. The material could be used for common brick.

Sample 108, a very light-grey shale, bloated easily, but fused to the roasting dish at 2,102° F. It is likely that a good product could be secured by close control at temperatures below 2,102° F., but further testing is necessary before utilization is attempted. No bloating tests were made on sample 109. Sample 110, a light-grey shale, gave a good hard glazed product with fine cell structure and a specific gravity of 1.65 when fired to 2,192° and 2,282° F.

Sample 111

This sample was taken from an exposure on the south side of U. S. Highway 87 in the W½ sec. 23, T. 6 N., R. 26 E., about 20 miles south of Roundup. It represents 9 feet of shale above a dirty coal seam and below a massive sandstone, all in the Fort Union formation (Tertiary). The shale is very light grey or yellow brown on fresh exposures, the lighter shale containing much bentonite and some gypsum.

The shale is unsuitable for ceramic use because of excess alkali scum and a narrow firing range. (See table 2.)

The shale will expand, but the bloating range is very narrow; 2,102° F. is too low, and 2,192° F. is too high.

Sample 112

This sample was taken from a road cut on the north side of State Highway 6, in sec. 29, T. 10 N., R. 31 E., a mile east of Melstone, in Musselshell County. It is olive-grey clay shale from near the top of the Bearpaw formation (Upper Cretaceous).

The clay has medium plasticity, medium-high shrinkage in drying and firing. The dried brick shows an alkali scum, but fires well. The P.C.E. is cone 9 (2,345° F.), and the firing range, 1,950° to 2,150° F. The material could be used for common brick.

The material was not tested for expansion.

Sample 113

This sample was taken in a road cut on the south side of State Highway 6, in sec. 13, T. 9 N., R. 35 E., about 6 miles southeast of Ingomar, in Rosebud County. It is an olive-grey shale from the Bearpaw formation (Upper Cretaceous) which here contains concretions, some of which have cores of fossil cephalopods.

The clay is not suitable for ceramic use. (See table 2.)

At the temperatures used (2,192° to 2,282° F.), the material spalled badly, but each spalled particle bloated to a very light-weight glazed rounded pellet with a coarse brittle cell structure. It may be that at lower temperatures, the material would give a finer and stronger cell structure. The bloated color is moderate brown.

Sample 114

This sample was taken from a road cut on the west side of the Forsyth-Colstrip road in sec. 7, T. 3 N., R. 41 E., about 10 miles north of Colstrip. It is pale olive-grey shale from the Lebo member of the Fort Union formation (Upper Cretaceous). The shale is quite bentonitic and contains some plant remains.

It was not fired for ceramic tests because the bricks cracked on drying, no doubt because of the high bentonite content. It is not suitable for ceramic ware.

No significant bloating occurred until a temperature of 2,372° F., the maximum economic bloating temperature, was reached. The product appeared to be of good quality, and if the demand were great enough, a satisfactory product could be obtained; however, material that will bloat at a lower temperature can be found less than a mile away. (See sample 115 below).

Sample 115

This sample was taken in a road cut in sec. 6, T. 3 N., R. 41 E., about a mile north of sample 114. It is also in the Lebo member of the Fort Union formation, but a little lower stratigraphically than sample 114. The clay is light-brownish grey in color, and bentonitic in composition.

This, like 114, is unsuitable for ceramic use for the same reason: bricks cracked on drying.

When tested for bloating, the only expansion of consequence was at 2,192° F., at which temperature, the shale yielded a product with a slight glaze and a greenish-brown color, and which should make a satisfactory light-weight aggregate.

Samples 116 and 117

Samples 116 and 117 were taken from a road cut on the northeast side of State Highway 6, about 10 miles northwest of the bridge over Yellowstone River at Forsyth. The light olive-grey shales are from the upper part of the Judith River formation, which here is very flat lying. Sample 116 is from below a sandstone bed, and 117, stratigraphically somewhat lower.

Sample 116 cracked on drying and was not fired for ceramic tests. Sample 117 showed excessive scum and had a short firing range. Neither shale is suitable for ceramic ware. (See table 2.)

Sample 116 yielded a well-bloated grey-green glazed product at 2,192° F. Sample 117 yielded a well-expanded material at a fairly low temperature (2,100°

to 2,192° F.), but had a very narrow range between bloating and complete fusion. Both shales could yield a satisfactory light-weight aggregate, but only under strict temperature control.

Sample 118

This sample is from a road cut in sec. 1, T. 6 N., R. 39 E., on the northeast side of State Highway 6, 5.3 miles north of the Yellowstone bridge at Forsyth. The brownish-grey shale is from the flat-lying Bearpaw formation (Upper Cretaceous) in an area of little or no overburden.

The bricks cracked on firing. The clay is not suitable for ceramic ware, but when tested for bloating, it yielded a well-expanded product, red brown in color. This should be a satisfactory material for making light-weight aggregate.

Sample 119

Sample 119 was taken from a road cut on the north side of U. S. Highway 10, in sec. 22, T. 6 N., R. 43 E., about 17 miles east of Forsyth. It represents 3 feet of sandy shale from the Fort Union formation (Tertiary). The shale is yellowish grey in color and is quite bentonitic in composition.

When tested ceramically, the brick fired well, but showed excessive alkali scum. It is not suitable for ceramic ware.

The material was not tested for its bloating properties because of the high P.C.E. (cone 9).

Sample 120

This sample is from a road cut along U. S. Highway 10, in sec. 12, T. 6 N., R. 44 E., about 1.5 miles northeast of Hathaway in the extreme eastern part of Rosebud County. The material is pale yellowish-brown sandy shale containing some bentonite, and is from the Fort Union formation of Tertiary age.

When tested ceramically, the brick showed a light scum and cracked on drying. It is not suited for ceramic use.

Fragments of the shale, heated to 2,100° to 2,192° F., bloated to a product with a purplish-grey color and a specific gravity of 1.1. It should make a satisfactory light-weight aggregate.

Sample 121

This sample was taken on Moon Creek in sec. 32, T. 7 N., R. 46 E., about a quarter of a mile north of U. S. Highway 10, where the creek has cut a bank 70 feet high. It represents 3 feet of dark shale between two 1-foot coal seams in the Lebo (?) member of the Fort Union formation. The shale is dark grey in color and quite bentonitic in composition.

The clay is unsuited for ceramic use as the bricks cracked on drying.

Expansion tests show this material to be satisfactory for light-weight aggregate, as it bloats well through a temperature range of 360° F. (2,010° to

2,370° F.). As the temperature was increased, the color changed from buff to greenish grey, and the surface glaze improved. All of the bloated material had a specific gravity less than one.

Samples 122 and 123

Sample 122 is from a clay bank just north of U. S. Highway 12, in sec. 26, T. 8 N., R. 48 E., about 8 miles east of Miles City, in Custer County. It is a grab-sample from a 10-foot bed of bentonitic shale in the Fort Union formation. The fresh shale is light-olive grey and flaky; it weathers to a gumbo soil. Sample 123 was cut about a quarter of a mile east of sample 122 and about 200 yards south of the highway, and is also from the Fort Union formation of Tertiary age, but is stratigraphically lower than sample 122. Both shales are quite bentonitic.

Neither 122 nor 123 are suitable for ceramic use (see table 2); but both showed good expansion characteristics.

Tested over a temperature range of 360° F. (2,012° to 2,372° F.), they yielded well-rounded and slightly glazed pellets which deepened in color from light brown to greyish brown as the temperature increased. The cell structure of the bloated material was better (more uniformly fine-grained) at the lower temperatures. Both shales should make quite satisfactory light-weight aggregates.

Sample 124

This sample was taken from a cut along U. S. Highway 12, in sec. 12, T. 7 N., R. 58 E., 5.7 miles west of Baker, in Fallon County. It represents a 5-foot cut in a 15-foot clay bank in the Fort Union formation. The light olive-grey clay-shale is overlain by light-colored siltstone and underlain by brownish siltstone. The strata are flat-lying.

The clay is not suited for ceramic use, but has definite possibilities for light-weight aggregate. The expanded pellets are well-rounded and well-glazed, and range in color from medium brown at the lower temperatures to brownish grey at the higher temperatures. The specific gravity of all material is less than one, but the cell structure is better at the lower temperatures. The material was expanded at temperatures from 2,012° to 2,192° F.

Sample 125

Sample 125 was taken in a road cut on the west side of State Highway 7, in sec. 31, T. 8 N., R. 60 E., 2 miles north of Baker, in Fallon County. The sample represents an 8-foot cut in Pierre shale (Upper Cretaceous). The shale is light-olive grey in color and quite bentonitic in composition.

The material is unsuited for ceramic use. (See table 2.)

The clay fragments were fired to temperatures from 2,012° to 2,192° F., and yielded well-rounded and well-glazed pellets ranging in color from moderate brown to brownish grey. The specific gravity of the bloated pellets is less than one; and the cell structure is fairly uniform. The shale should make a satisfactory light-weight aggregate.

Sample 126

This sample was taken just below a thick coal seam in a deep road cut along State Highway 7, in sec. 6, T. 10 N., R. 60 E., 20.5 miles north of Baker, in the extreme northern part of Fallon County. The coal is in the Fort Union formation, which here is very flat-lying. The clay is light-olive grey in color and slightly bentonitic.

The material sampled is not suitable for ceramic use.

The shale was not tested for expansion.

Samples 127, 128, and 129

These three samples were taken in sec. 36, T. 16 N., R. 56 E., just north of U. S. Highway 10, 6 miles east of Glendive, in Dawson County. The flat-lying Fort Union formation here is eroded into a bare bluff and shale-covered slopes. Along the face of the bluff a 3-foot seam of coal outcrops. Sample 127 represents 3 feet of shale above the coal, and sample 128, 3 feet of shale below the coal. Between the bluff and the highway is a low knob on which the coal bed has been burned, and the crest is marked by an outcrop of orange-red baked shale, represented by sample 129, which corresponds to the bed cut in sample 127.

Samples 127 and 128 are light-olive grey to light-yellowish brown in color and are bentonitic in composition. Neither one is suited for ceramic use, as the high bentonite content causes the brick to crack on drying. Sample 129, already baked by nature, has no plasticity, but could be used as grog.

Sample 127 has a wide bloating range, but the best product was made below 2,192° F.; the pellets were light brown in color, well-rounded, and slightly glazed. Sample 128 is unsuited for light-weight aggregate because of erratic expansion. Sample 129 (already baked by nature) did not expand.

Samples 130 and 131

These two samples were taken in a road cut on the north side of State Highway 20, in sec. 12, T. 22 N., R. 58 E., about 3 miles southwest of Sidney, in Richland County. Sample 130 is yellowish-grey shale taken above a coal seam, and sample 131 is light-grey shale taken below the same coal seam. They occur in the flat-lying Fort Union formation. Sample 130 is not appreciably bentonitic, but 131 is locally quite bentonitic.

The working, drying, and firing characteristics of both shales are good, but excessive scum forms on the bricks, which makes them unsuitable for ceramic use.

Expansion tests on sample 130 showed a fairly wide bloating range (2,100° to 2,282° F.), but the best material was formed at 2,192° F. The pellets are greenish grey and well glazed, and have a specific gravity less than one. This shale should be satisfactory for expanded light-weight aggregate. Sample 131 showed little change except in color when tested for expansion. It is not suitable for light-weight aggregate.

Samples 132, 133, 134, and 135

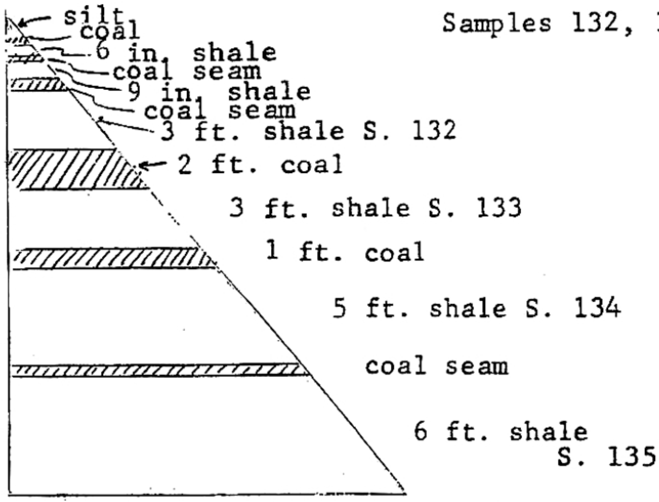

Figure 1.--Sketch of section through cut.

These samples were taken in a large road cut in sec. 4, T. 22 N., R. 54 E., about 35 miles west of Sidney, in Richland County. Fig. 1 shows a section across the cut and the relation of the samples. The strata shown are in the Fort Union formation of Tertiary age. The shales are light grey in color and quite bentonitic.

Sample 132 has good working, drying, and firing characteristics; the P.C.E. is cone 2, and the firing range, 1,950° to 2,050° F. The clay can be used for common brick and like products. Sample 133 has good working, drying, and firing qualities, but forms excessive alkali scum so is not suitable for ceramic use. Sample 134 has medium plasticity, fair working properties, and low drying and firing shrinkage. The P.C.E. is cone 2, and the firing range, 2,000° to 2,050° F. With careful firing, the material can be used for common brick and like products. Sample 135 has medium plasticity, good green strength, and working qualities, but forms excessive alkali scum when fired, so is not suitable for ceramic use.

These four samples were not tested for expansion.

Sample 136

This specimen (not a sample) of moderate orange-pink naturally baked shale (clinker formed over a burning coal bed), was taken in sec. 16, T. 18 N., R. 43 E., about 34 miles east of Jordan, in Garfield County. It has no plasticity so was not tested for ceramic brick. If ground and blended with other clays, it probably could be used as a grog.

The specimen was not tested for expansion.

Samples 137 and 138

Sample 137 is light olive-grey highly bentonitic shale from the Fort Union formation in sec. 9, T. 18 N., R. 39 E., about 8 miles east of Jordan. The bed is about 15 feet thick and very extensive. Sample 138 is a grab sample of the siltstone underlying the bentonitic shale.

Sample 137 is not suitable for either ceramic use or for expanded lightweight aggregate.

Sample 138 contains just enough bentonitic clay to give the material enough plasticity to hold it together. The drying shrinkage is medium high, and the firing shrinkage is low. The P.C.E. is cone 12, and the firing range, 2,100° to 2,250° F. The material could be used for ceramic products of common brick grade.

Sample 138 was not tested for expandability.

Samples 139 and 140

These two samples were taken from an exposure of the Fort Union formation on the McDonald ranch west of Jordan, in Garfield County. The exposure is between the ranch buildings and Smoky Butte.

Briquettes from sample 139 cracked on drying. Although the working qualities of sample 140 are fair, the briquettes showed excessive scum on firing. Neither shale is suitable for ceramics.

Sample 139 gave a fair expanded product at temperatures from 2,012° to 2,372° F. At the lower temperatures, the pellets were light brown in color and denser than at higher temperatures. As the temperature was increased, bloating increased, and the color changed from light brown to dark-chocolate brown. With careful temperature control the material should yield a satisfactory light-weight aggregate.

Sample 140 gave unsatisfactory results when tested for expansion.

Sample 141 and 142

These samples were taken in a road cut through Colorado shale, 1 mile east of Mosby, in sec. 11, T. 14 N., R. 30 E., in Garfield County. Sample 141 represents 7 feet of an upper sandy bed of medium light-grey shale, and sample 142, 7 feet of a lower bed of fissile medium-grey shale. Both are slightly bentonitic.

These two shales had such a heavy alkali scum on drying that firing tests for ceramic properties were not made. They are not suitable for ceramic use.

Sample 141 shows good expanding qualities at a narrow and low temperature range (2,012° to 2,102° F.). The pellets are very slightly glazed and pale brown in color, with an average specific gravity of 1.1. The material should be suitable for making light-weight aggregate. Sample 142 was over expanded at 2,102° F. Further work at lower temperatures would be necessary to determine if this material is suitable for light-weight aggregate.

Sample 143

This is a grab sample of weathered Claggett shale taken from a field north of State Highway 6, 1.7 miles west of Lavina, in Golden Valley County. The material is a light-olive calcareous clay.

The dried brick had such a heavy alkali scum that firing tests for ceramic properties were not made.

Expanding tests resulted in pellets which were moderate brown in color and well glazed. Expansion occurred at 2,012° F., but at 2,102° F. the material was over-bloated. With careful temperature control, it should make a satisfactory aggregate.

Sample 144

Sample 144 represents 4 feet of light olive-grey, slightly bentonitic shale from the Judith River formation exposed in a road cut along State Highway 6, 4.9 miles west of Harlowton, in Wheatland County.

Although the working and drying characteristics are good, the firing range is narrow, and the brick developed excessive scum. The clay is not suitable for ceramic use.

Tests on this clay resulted in dark yellowish-brown glazed pellets with a specific gravity less than one. The material was fired at 2,102° to 2,192° F., which apparently was a little too high. The material would probably make quite satisfactory aggregate at temperatures below 2,102° F.

Sample 145

Sample 145 represents 5 feet of light olive-grey bentonitic and calcareous shale from the Eagle formation, 9.8 miles west of Harlowton, in Wheatland County. The sample was taken along a cut bank below thin bedded sandstone.

For ceramic use the shale would require grinding. The drying and firing shrinkages are low, as is also the plasticity. The P.C.E. is cone 2 (2,129° F.), and the firing range, 2,000° to 2,050° F. The shale could be used for ceramic products of common brick grade.

When tested for expansion at 2,102° F., the shale was over-bloated; but it might yield a satisfactory product at lower temperatures.

Sample 146

This sample represents about 6 feet of red clay, the weathered sub-soil over red Spokane shale of Precambrian age. The sample was cut from a clay bank along State Highway 6, in sec. 9, T. 9 N., R. 10 E., about 33 miles west of Harlowton. The clay is in Meagher County. It is pale brown in color when dry.

The working and drying characteristics are fair, and when fired hard enough, the bricks are good. The P.C.E. is above cone 12, and high firing is necessary. Below 2,000° F. the brick shows excessive scum. The material can be used for common brick.

This shale was not tested for expansion.

Sample 147

Sample 147 is hard grey shale from a talus slope along a 20-foot bank on the south side of State Highway 6, about a quarter of a mile west of sample 146. It is of Precambrian (Belt) age.

The plasticity of the material is so low that the molded brick would not hold its shape. It is not suited for ceramic ware.

This shale gave fairly good expansion over a temperature range of 2,012° to 2,102° F., but at 2,282° F. it fused badly. The material should make a satisfactory aggregate at the temperatures indicated.

Sample 148

Sample 148 is a grab sample of greyish-green argillite (Belt) along State Highway 6, 18.4 miles east of White Sulphur Springs, in Meagher County.

For ceramic use, grinding is necessary. Plasticity is extremely low, but the brick will hold together. The drying shrinkage is medium; the firing shrinkage, low. The fired color is not pleasing. The P.C.E. is cone 6 (2,246° F.), and the firing range, 2,050° to 2,150° F. The material could be used for common brick, preferably blended with a more plastic clay.

The material was not tested for expansion.

Sample 149

This sample was sent in by Brook Taylor of Paulsbo, Washington, but the clay sample is from near Mildred, in Prairie County, in an area of the Fort Union formation. It is a soft tan-colored clay.

The plasticity is fair, working characteristics good, and the dried brick has good green strength. The P.C.E. is cone 5 (2,201° F.), and the firing range, 1,850° to 2,050° F. Drying and firing shrinkages are low. The material could be used for common brick and like products.

Sample 150

Sample 150 was taken from a road cut along U. S. Highway 93, about 1 mile north of Polson, in Lake County. It represents silty glacial lake clay of Pleistocene age. The material does not have enough plasticity for the test bricks to hold their shape.

The clay is unsuitable for ceramic use.

It was not tested for bloating.

Sample 151

This sample was submitted by R. E. Logan of Deer Lodge, Montana. It is highly calcareous and not suited to ceramic use.

Expansion tests resulted in highly glazed dusky-yellow pellets, with considerable fusion. It is doubtful if this material would be satisfactory for light-weight aggregate because of its tendency to form a glass at low temperatures.

Sample 152

This sample was submitted by Roger Craig of Darby, Montana. The material is composed essentially of quartz and feldspar, has no plasticity, and is not suitable for ceramic use.

The material was not tested for bloating.

Sample 153

This sample was submitted by C. V. Brady of Butte, Montana. It has so little plasticity that the brick will just hold together. It is a hard white material that would require grinding; because of this and its low plasticity, it is not considered suitable for ceramic use.

Sample 154

Sample 154 was sent in by H. E. Bartram of Columbus, Montana; but the clay is from a source near Glendive, Montana. The material is a brownish-grey highly bentonitic clay-shale, probably from the Fort Union formation.

The brick cracked on drying; it is not suitable for ceramic use.

The resulting products from expansion tests were glazed pellets ranging in color from light brown to dark-yellowish brown. Below 2,282° F. the pellets were well rounded and showed uniform strong cell structure, but above that temperature, over-bloating and excessive fusion took place. The material should make an excellent light-weight aggregate at the temperature indicated.

Sample 155

Sample 155 was submitted by Jerry Supola, and is dark-colored Colorado shale typical of the area around Vaughn in Teton County. The bricks cracked on drying, so were not fired. The material is unsuitable for ceramic use.

The material was not tested for expansion.

Samples 156, 157, 158, and 159

These four samples were submitted by Mr. Abbey of Hamilton, and the material comes from his ranch south of Grantsdale. All of the material is highly bentonitic.

None of the samples were of material suitable for ceramic use.

All four samples were tested for expandability; nos. 156, 158, and 159 were unsuitable, but no. 157 has possibilities. With this sample, the tests yielded a well-glazed and expanded dark-chocolate brown product, but at a relatively short temperature range. The material should make a satisfactory light-weight aggregate, but strict temperature control will be necessary to secure the desired product.

Samples 160, 161, 162, and 163

These four samples were collected by R. T. Chew, III, geologist for the Northern Pacific Railway. No. 160 is a 12-foot channel sample from a road cut on U. S. Highway 10, about 3 miles northwest of Plains, in Sanders County. This sample was taken from very near the same place as sample 5 described in the preveous progress report (I.C. 23, p. 7). The material is a yellowish kaolin type of clay.

The plasticity is good; the P.C.E. is over cone 12, and the drying and firing shrinkages are moderate. The firing range is 2,100° to 2,400° F. It is a good ceramic clay and could be used for common brick, pottery, and other good quality ceramic products.

When tested for expandability, sample 160 showed only a change in color from white to buff, with no appreciable expansion.

Sample 161 is a composite of two 8-foot channel samples of glacial lake Missoula beds of Pleistocene age, taken in sec. 4, T. 18 N., R. 21 W. Chew states the clay came from Ravalli County, but the land description indicates it came from Sanders County, about 6 miles northwest of the town of Ravalli. It is a kaolin type of clay. It has good plasticity and moderate drying and firing shrinkages, but the firing range is narrow (1,900° to 2,000° F.). With careful firing, it could be used for common brick and similar products.

When tested for expandability, sample 161 yielded a fair product within a narrow temperature range of 2,012° to 2,100° F. The pellets were well glazed and brownish black in color. The cell structure was fairly coarse, but strong.

Sample 162 is a composite of over 60 feet of shale beds 2 miles northeast of Drummond, in Powell County. The material was taken in sec. 21, T. 11 N., R. 12 W. The material was medium plasticity, but the firing characteristics are not good. The brick swelled and cracked when fired. When tested for expansion, the shale spalled into numerous light-weight dark-brown colored flakes. The flaky product is very brittle and crumbly at all temperatures used (2,012° to 2,192° F.). The shale is suited neither for ceramic use nor for light-weight aggregate.

Sample 163 is a grab-sample of altered Tertiary pumicite, taken in the SE¼ sec. 16, T. 9 S., R. 2 W., in Madison County. The land description places the location of the sample near the crest of the Gravelly Range in southern Madison County. The material was not fired for ceramic properties. When tested for expansion it gave only fair results with considerable spalling. The resultant product was crumbly and very porous. The material is unsuited for light-weight aggregate.

Sample 164

Sample 164 is a grab sample of silty glacial lake clay (Pleistocene) from a large road cut along the NE side of U. S. Highway 2, about 1 mile northwest of the Yaak River bridge, in sec. 5, T. 32 N., R. 34 W., in westernmost Lincoln County. The material is light-pinkish tan in color when dry.

This clay was not fired for ceramic tests.

When tested for expansion, it yielded a well-glazed, dark-brown bloated material at 2,282° F. only. It would yield a satisfactory aggregate only if the temperatures used were kept within a very narrow range.

Sample 165

This sample was sent into the Bureau by Mr. Tomlin of Fort Benton, Montana. Location of the deposit is unknown.

When tested ceramically the bricks cracked on drying due to the excessive bentonite content. The clay is unsuited for ceramic use.

This shale spalled badly when fired for expansion. It did yield a well-expanded, but brittle, product, and it fused considerably at all temperaturesused. It might be of limited use as an aggregate, but probably would be unsatisfactory for load-bearing units.

Sample 166

This sample was submitted by Kay Smith and is a yellow-brown clay containing some felsitic weathered rock fragments, and is reported to be from the Georgetown Lake area in Granite County.

It has low plasticity and a moderate drying and firing shrinkage. The firing range is narrow, 2,100° to 2,200° F., but with careful firing it could be used for common brick and like products.

No expansion tests were made on the material.

Sample 167

Also submitted by Kay Smith, this sample is a red clay that occurs in lenticular beds in Tertiary sediments on the west side of the Missouri River opposite Townsend, in sec. 36, T. 7 N., R. 1 E. The clay is kaolinitic, brick red when wet, but dries to a moderate-reddish orange.

The firing characteristics are poor (see table 2), but with careful firing, it could be used for products similar to common brick.

Sample 168

Sample 168 is from an extensive remnant of Pleistocene glacial lake clays from a road cut along U. S. Highway 2, in sec. 5, T. 32 N., R. 34 W., about 9 miles northwest of Troy, in Lincoln County. The material is a greyish-yellow silty clay, very friable when dry. It is slightly calcareous. This sample is from the same locality as sample 164.

The ceramic bond is poor, and the firing range narrow. The material is not suited for ceramic use.

When tested for expansion, the material darkened in color, but it showed little if any tendency to expand in a temperature range of 2,100° to 2,300° F.

Sample 169

This sample is also Pleistocene glacial clay, and is similar to sample 168, but less silty. It comes from the Garrison property near Yaak, in northern Lincoln County. The color is yellowish grey, and the material is quite soft.

The clay has good plasticity, but the firing characteristics are poor. The volumn shrinkage is high, and the firing range narrow. With careful firing, it could be used for common brick, but, in general, it is not a good ceramic material.

The clay showed but little tendency to expand at the temperatures used (2,100° to 2,300° F.).

Sample 170

This sample was sent in by R. Ruthmeyer, Hamilton, County Agent-at-Large, Ravalli County. It was taken by Mrs. Elmer Stanley, Home Acres, Stevensville from a deposit in the NW¼NE¼ sec. 23, T. 8 N., R. 20 W. The deposit has been used for some home fired ceramics and is on the bench land about 1¼ miles east of Bell Crossing. It appears to run in an east to west direction being about 25 feet wide and 300 feet long. There are outcroppings to the south of this deposit.

The material is a gritty white sandy clay. The plasticity is low, and the green strength of the brick is low. The firing range is narrow, about 50° F. When well fired the surface of the brick is vitrified and is grey-mottled tan in color. With careful handling the material could be used for common brick or for grog with a more plastic clay.

No tests were made for expansion on this clay.

Sample 171

This sample was received from Mrs. Gus DuPois. It is a light-grey highly calcareous, slightly bentonitic devitrified volcanic dust (pumicite).

The material has fair plasticity, but its firing characteristics are poor. It has a high volume shrinkage and a narrow firing range and is unsuited for ceramic use.

The material was not tested for expansion.

Samples 172 and 173

These two samples are white kaolin submitted by Adolph Beckstrom of Silesia, Montana, who gives the location of the deposit as sec. 9, T. 13 N., R. 25 E., in an area underlain by Colorado shale. Under the microscope the clay shows residual grains of quartz and green pyroxene (?). The two samples are identical and can be described together.

Ceramically the material might be classed as flint clay with very little plasticity. The P.C.E. is cone 33, and the clays fired well. These are high-grade ceramic clays, which, when mixed with a small amount of bonding clay, could be used for refractories, white ware, and a variety of high-grade ceramic products.

Because of the high P.C.E. (cone 33), these clays were not tested for expansion.

Sample 174

This sample is metamorphosed Colorado shale taken from a road cut along U. S. Highway 10 N., 2 miles southeast of Garrison, in sec., 19, T. 9 N., R. 9 W., in Powell County. It is a compact greenish-grey shale, very slightly calcareous.

The test bricks swelled when fired, and did not develop a good ceramic bond. The material is not suited to ceramic use.

Expanding tests gave unsatisfactory results at 2,000° F., no bloating took place; at 2,100° F., only a part bloated; and at 2,300° F., all the material fused. It is not satisfactory for light-weight aggregate.

Sample 175

This sample is light pinkish-grey slightly bentonitic clay from the Nita Robbins Ranch near Creston in Flathead County.

The clay has high plasticity, medium drying shrinkage, high firing shrinkage, and a narrow firing range (1,950° to 2,050° F.). The P.C.E. is cone 5. With careful firing it could be used for common brick and similar products.

When tested for expandability, it did not give a uniform product. It is not satisfactory for light-weight aggregate.

Sample 176

Sample 176 is of silty Tertiary sediments that occur in the bluff to the west of Craig, in sec. 4, T. 15 N., R. 3 W., in northwest Lewis and Clark County.

The material is not suitable for ceramic use.

No expansion tests were made on the material.

Sample 177

This sample was taken from a Colorado shale outcrop just west of the Cascade school in sec. 35, T. 18 N., R. 8 W., in Cascade County. It represents 8 feet across a bed which strikes N. 60° E. and dips 70° NW. underlying a white bentonitic horizon. The shale is a mottled-yellow grey to medium grey in color and is slightly bentonitic.

Both the dried and fired brick show alkaline scum, making the material unsuited for ceramic use. See table 2 for other firing characteristics.

When tested for expansion, the material bloated nicely at temperatures used (2,000° to 2,200° F.). The pellets were well rounded and had a fair glaze. The cell structure was fairly uniform and of moderate size indicating good strength. The bloated material floated on water indicating a bulk specific gravity of less than one. The color ranged from a moderate brown at 2,000° F. to olive grey at 2,200° F. The material should make a satisfactory light-weight aggregate.

Sample 178

Sample 178 is weathered shale from the Clagget formation 5.5 miles south of Havre in sec. 32, T. 32 N., R. 16 E., in Hill County. The shale is yellowish grey in color and quite bentonitic.

The high bentonite content renders the clay unsuitable for ceramic use. See table 2 for firing characteristics.

Expansion tests were run at 2,000°, 2,1000°, and 2,200° F. At 2,000° there was little, if any, expansion. At 2,100° the expansion was good, with uniform fine cell structure, and a chocolate-brown color, but the pellets were very irregular in shape. At 2,200° it fused to a frothy slag. The material could be used for making light-weight aggregate under very strict temperature control, but in view of the widespread occurrence of better quality material, this shale can hardly be considered as commercial.

Sample 179

This sample was taken from a shale exposure at the crest of the divide between Clear Creek drainage and Little Box Elder Creek in sec. 19, T. 29 N., R. 17 E., in southeastern Hill County, 27 miles bv road south of Havre. The shale is in the upper part of the Colorado group (Carlile or Niobrara). It is medium dark-grey in color and is quite sandy and somewhat calcareous.

The lack of plasticity and the narrow firing range, 2,050° to 2,100° F., makes the material unsuitable for ceramic use. (Table 2).

No expanding tests on this material were run because of poor accessibility.

Sample 180

The sample represents 20 feet of medium-grey bentonitic shale from the Bearpaw formation exposed about 2 miles north of Harlen in sec. 4, T. 32 N., R. 23 E., in Blaine County. The Bearpaw here is overlain by 5 to 20 feet of glacial till and gravel. Bedrock strata are flat-lying.

The test bricks cracked on drying. Due to the high bentonite content, the shale is not a ceramic material.

When tested for expansion, the material did not bloat uniformly, but yielded a fairly well-rounded and glazed product with fair cell structure. Material expanded at a temperature of 2,100° F. Most of the product floated on water. This material would probably yield a satisfactory light-weight aggregate.

Sample 181

This sample is weathered gumbo-clay soil from the Bearpaw formation 8 miles north of Harlem in Blaine County. The area is a flat rolling upland mostly covered by glacial till and gravel, with but few shale outcrops.

The drying shrinkage is high, and test bricks cracked. Because of the high bentonite content, the clay is not suitable for ceramic use.

When tested for bloating, the clay yielded dark-brown pop-corn-like pellets with uniformly fine cell structure and a fair glaze at all temperatures, 2,000° to 2,200° F. It should make a satisfactory light-weight aggregate.

Sample 182

This sample is a weathered light olive-grey gumbo-clay-shale from an isolated outcrop of the Hell Creek formation (Upper Cretaceous) 18.5 miles north of Harlem in sec. 17, T. 35 N., R. 23 E., in northern Blaine County. The clay is quite bentonitic and forms the crumbly texture in outcrop typical of bentonitic shales. Strata here are flat-lying and mostly covered by glacial drift.

When tested for ceramic properties, the dried bricks cracked badly, so the clay is not suitable for ceramic use.

The clay was not tested for expandability because of its distance from any sizable population center or railroad.

Sample 183

Sample 183 is light olive-grey bentonitic shale from the Hell Creek formation (Upper Cretaceous) exposed in a road cut in sec. 28, T. 36 N., R. 27 E., 4 miles southwest of Chapman, a railroad station on the "Soo line" (Minneapolis, St. Paul, and Sault Ste. Marie Railway) in northern Phillips County.

The tests bricks cracked on drying; the material is not suitable for ceramic use.

The material gave very good results under expansion tests. It bloated into well-rounded pellets, which at 2,000° to 2,200° F. were light brown in color, slightly glazed, and had a very uniform cell structure. At 2,300° the color was dark-brown and the cell structure medium-coarse; and this material had less strength than the pellets fired to lower temperatures. Under a temperature range of 2,000° to 2,200° F., this shale should give a very good, strong light-weight aggregate.

Sample 184

This material is weathered Clagget shale (Upper Cretaceous) exposed along the main road in sec. 13, T. 33 N., R. 30 E., 20 miles north of Malta in northern Phillips County. The shale is quite bentonitic and forms a gumbo soil.

The drying shrinkage is so high that the test bricks cracked. It is of no value as a ceramic material.

Expansion test results were unsatisfactory. The material fused to a porous slag at 2,200° F., and below that temperature, the pellets were very irregular in shape and very brittle.

Sample 185

This material is flood-plain deposit derived from Clagget shale, and the sample was taken along the west bank of Milk River in sec. 19, T. 32 N., R. 30 E.

about 3 miles north of Malta, in Phillips County. The gumbo-clay is sandy, bentonitic, and gypsiferous.

It is unsatisfactory for ceramic use.

The material did not give very good results when tested for expansion. At 2,000° F. there was little expansion. At 2,100° F. it partly expanded into pellets that were brittle and friable. At 2,200° F. the material was overbloated.

Sample 186

This sample is olive-grey shale from the Bearpaw formation taken from a road cut in sec. 19, T. 32 N., R. 40 E., 23 miles north of Glasgow in northern Valley County. It is quite bentonitic, slakes readily in water, and forms a gumbo soil.

The high bentonite content renders it unsuitable for ceramic use.

Expansion tests yielded fair results. The pellets were medium brown in color, but the weathered material yielded a crumbly product. The unweathered shale gave smoother rounded pellets. At 2,200° F. the pellets are well-rounded, but the cell structure is fairly coarse.

Sample 187

Sample 187 is yellowish-grey slightly bentonitic and calcareous shale from above a 6-inch coal seam in the Fort Union formation (Tertiary) taken from an outcrop on the ridge 2½ miles northwest of Richland. The shale is overlain by Flaxville (Tertiary) gravels.

The clay-shale has medium plasticity and low drying and firing shrinkage. The P.C.E. is cone 01, and the firing range, 1,750° to 1,950° F. It could be used for common brick and products of similar grade.

No expansion tests were made on this clay.

Sample 188

This sample is quite similar to sample 187 in color and composition. It is from the Fort Union formation underlying 10 feet of Flaxville gravel in a road cut 4 miles west of Four Buttes, in sec. 5, T. 35 N., R. 45 E., in northern Daniels County.

The ceramic properties are similar to those of sample 187. (See table 2.) It could be used for common brick and like products.

Expansion tests did not give good results. The pellets were glazed, but showed little expansion at the temperatures used, 2,000° F. and 2,100° F.

Sample 189

The material is light-grey bentonitic shale from the Fort Union formation (Tertiary) from a road cut along State Highway 5, 3.1 miles east of Flaxville, in Daniels County.

The drying and firing shrinkages are moderate. The P.C.E. is cone 12 (2,390° F.). The fired colcr is cream or light buff. This is a good ceramic clay which could be used for nany kinds of ceramic products, such as face brick and pottery.

Tests for bloating at the temperatures used (2,000° to 2,300° F.) did not even change the color of the material.

Sample 190

This sample represents 2.5 feet of white clay-shale above a 1-foot coal seam in the Fort Union formation (Tertiary), 4.4 miles east of Redstone along State Highway 5, in Sheridan County. The material is slightly bentonitic and calcareous.

The plasticity is low, as are the drying and firing shrinkages. The firing range is narrow (1,900° to 2,000° F.), but with careful firing the clay could be used fo: common brick and like products.

The clay was not tested for expandability.

Sample 191

This sample represents 3.5 feet of grey shale below the coal seam mentioned under sample 190. It is slightly bentonitic.

The drying and firing shrinkages are moderate. The P.C.E. is cone 9½ (2,290° F.), and the firing range is 2,000° to 2,100° F. As with sample 190, careful firing would be necessary in using this clay for ceramic ware.

No expandability tests were made.

Samples 192 and 193

Sample 192 represents 5 feet of Fort Union clay-shale above a coal bed exposed in a road cut on the road to Outlook from State Highway 5. It was taken in sec. 9, T. 35 N., R. 53 E., 0.7 miles north of Archer, in Sheridan County.

The plasticity is good, and the drying and firing shrinkages are moderate. P.C.E. is cone 4, and the firing range, 2,000° to 2,075° F. It could be used for products similar to common brick.

Sample 193 is light olive-grey shale representing the 1.5 feet below the 1-foot coal seam mentioned above. The clay is slightly bentonitic and contains some plant remains.

The plasticity is low, and the drying and firing shrinkages are moderate. The P.C.E. is cone 2, and the firing range, 1,900° to 2,000° F. It could be used for common brick.

No expansion tests were made on these clays.

Sample 194

This material was taken below a coal bed in the Fort Union formation in sec. 17, T. 35 N., R. 54 E. about 1 mile north of State Highway 5, 3 miles west of Plentywood, in Sheridan County. The clay is yellowish grey, calcareous, slightly bentonitic, and slakes readily in water.

The drying the firing shrinkages are moderate. The P.C.E. is cone 5 (2,156° F.), and the firing range, 2,000° to 2,100° F. In the lower end of the range, the burned material is light red in color. When fired in the upper end of the firing range, the material burns to a buff color. It could be used for common brick, pottery, and a variety of like products. It is a good ceramic clay.

The clay was not tested for bloating.

Samples 195 and 199

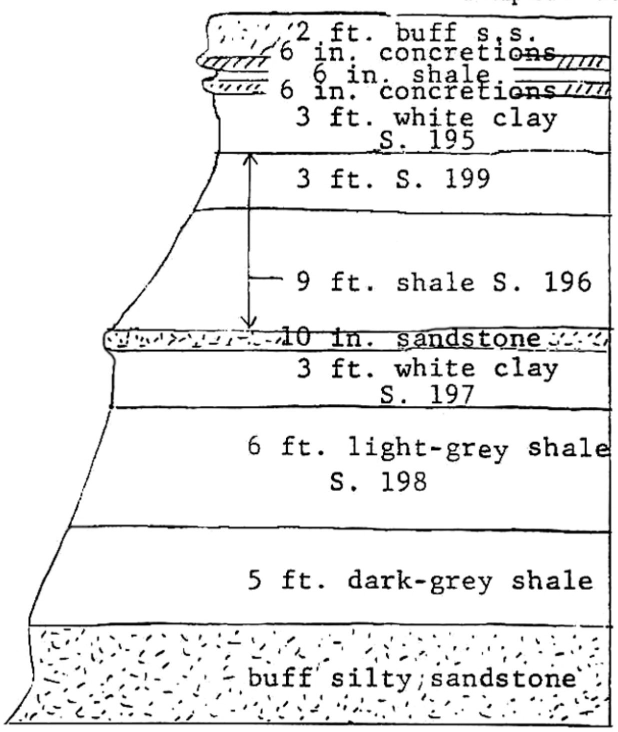

Figure 2.--Showing relationship of samples 195 through 199. Near Plentywood, Sheridan County.

This group of five samples was taken from a bluff exposure north of State Highway 5, in sec. 14, T. 35 N., R. 54 E., about 2.7 miles west of Plentywood, in Sheridan County. The relation of the samples is shown in figure 2. These clays are a kaolin type of clay, but do contain some bentonite. They range in color from very light to light grey.

This group has very similar ceramic properties. They have moderate to good plasticity and moderate drying and firing shrinkages. The P.C.E. ranges from cone 13 in sample 195 to cone 11 in sample 199. Samples show a slight alkali drying scum which results in a glaze at the higher firing temperatures. All can be used for common brick and like products; although material represented by sample 197 may be suitable for better grade products such as pottery.

Sample 200

Sample 200 is light-grey slightly bentonitic shale from the Fort Union (Tertiary) formation in sec. 6, T. 28 N., R. 56 E., 3.9 miles north of Culbertson, in Roosevelt County.

It has moderate plasticity, medium drying shrinkage, and low firing shrinkage. The P.C.E. is cone 1 (2,057° F.), and the firing range is 1,750° to 1,950° F. The fired brick has a slight scum, but the clay could be used for common brick.

Expanding results were not good. The pellets are very irregular in shape, and the bloating range is narrow. (See table 3.)

Samples 201 and 202

These two samples were taken from an exposure of the Fort Union formation just north of the Missouri River bridge at Culbertson. Sample 201 represents 5 feet of shale under the lower coal seam as exposed in the road cut on Highway Montana 16. Samples 202 represents 3 feet of shale above the same coal bed. The clays are yellowish grey, highly calcareous, and bentonitic.

Sample 201 had low plasticity and moderate drying and firing shrinkage. The P.C.E. is cone 6, and the firing range is 2,000° to 2,100° F. It is a good material for common brick. Sample 202 showed considerable scumming, and it is not suitable for ceramic use.

Sample 201 is unsatisfactory for light-weight aggregate. Sample 202 gave a fair medium-brown pop-corn-like product at 2,200° F., but fused completely at 2,300° F.

Sample 203

Sample 203 is from an exposure of Bearpaw shale in a road cut on U. S. Highway 2, just east of Oswego, in Valley County. It is a greenish-grey, noncalcareous, but slightly bentonitic shale which slakes slowly in water.

Because of the bentonite content, the clay had a high drying shrinkage, and the bricks cracked on drying. It is not suitable for a ceramic clay.

When tested for expandability, it showed a slight bloat at 2,000° F., very good bloat at 2,100° F., but was over-bloated at 2,200° F. At 2,100° F., the pellets are well-rounded, slightly glazed, and a pleasing light-brown color.

Sample 204

This sample was taken from a clay bank just north of U. S. Highway 2, at Nashua, in Valley County. It is a light olive-grey bentonitic clay-shale from the Bearpaw formation (Upper Cretaceous).

The test bricks has a heavy alkali scum on drying and cracked on firing. The clay is not a ceramic material.

Tests for expandability gave very good results. At 2,000° and 2,100° F., the pellets were well-rounded and light colored, and had uniform fine cell structure. At 2,200° F., the color was much darker brown and some pellets showed pop-corn-like structure, the the cell structure was still good. All three tests gave a product with a specific gravity less than one (floated on water).

Sample 205

Sample 205 is from a road cut along Highway Montana 19, 5.3 miles southwest of Malta, in Phillips County. It represents 3 feet of yellowish-grey Judith River (Upper Cretaceous) shale below glacial till. It is bentonitic and highly calcareous.

The plasticity is low, and the drying and firing shrinkages, moderate. The P.C.E. is cone 9½ (2,290° F.), and the firing range is 2,000° to 2,150° F. The fired brick has a slight alkali scum. With careful firing, it could be used for common brick.

Because of the high P.C.E., the material is not suitable for light-weight aggregate. It would not bloat at an economic temperature.

Sample 206

This sample was taken between two sandstone beds near the bottom of a coulee a few hundred feet north of sample 205. It is a gritty, calcareous, and slightly bentonitic pale olive-grey shale from the Judith River formation.

It has low plasticity, and the drying and firing shrinkages are moderate. The dried and fired test bricks had a slight alkali scum. The P.C.E. is cone 1 (2,057° F.), and the firing range is 1,750° to 1,950° F. With careful handling it could be used for common brick.

Tests for expandability showed the material unsuitable for light-weight aggregate.

Sample 207

Sample 207 represents 12 feet of shale taken from a large pit in the Bearpaw formation (Upper Cretaceous) west of Highway Montana 19, 14 miles southwest of Malta, in Phillips County. The clay-shale is light-olive grey in color, quite bentonitic in composition, and slakes readily in water.

Because of the high bentonite content, the test bricks cracked on drying, and the material is not satisfactory for ceramic use.

No expandability tests were made because of distance of the deposit from possible markets.

Sample 208

This material is quite similar to sample 207 in color and composition, but is more compact and does not slake in water so readily. It also is Bearpaw shale and was taken from a road cut along Highway Montana 19, 32 miles southwest of Malta, in Phillips County. It represents a 30-foot bank.

It is not a ceramic clay because of its high bentonite content.

No expandability tests were made on the material because of distance from possible markets.

Sample 209

Sample 209 represents 8 feet of yellowish-grey Judith River shale (Upper Cretaceous) taken from a large road cut just west of Fergus, in Fergus County. The shale is weathered, slightly bentonitic and calcareous, and slakes readily in water.

The test bricks cracked on drying. The material is not usable for ceramic products.

Results of the expandability tests were unsatisfactory. (See table 3.)

Sample 210

This sample is of weathered yellowish to olive-grey shale from the Claggett formation (Upper Cretaceous) taken from a shallow road cut along the main highway 9.7 miles east of Hilger, in Fergus County. The clay is somewhat bentonitic and slakes in water.

The test bricks cracked on drying, so the material is not suited to ceramic use.

When tested for bloating, it did not yield a satisfactory product. (See table 3.)

Sample 211

Sample 211 is weathered red Kootenai (Lower Cretaceous) shale taken from a road cut about a mile east of Hanover, in Fergus County. It is a kaolin type of clay, but is highly calcareous and contains much red iron oxide.

The clay has good plasticity, and the drying and firing shrinkage is moderate. The P.C.E. is cone 9 (2,282° F.), and the firing range, 1,950° to 2,175° F. The clay is a good ceramic material for common brick and like products.

The material is not suitable for manufacture of light-weight aggregate.

Sample 212

This sample is from an exposure of weathered shale in the Telegraph Creek formation (uppermost Colorado group; Upper Cretaceous). It is olive grey in color, somewhat bentonitic, and slakes slowly in water.

The plasticity is low; drying shrinkage, medium-high; and firing shrinkage, moderate. The P.C.E. is cone 2 (2,075° F.), and the firing range, 1,800° to 1,950° F. It is a fairly good ceramic material and could be used for common brick.

The material was not tested for expandability.

Sample 213

This sample was taken in a cut along the Running Wolf Creek road, 6 miles southwest of Stanford, in Judith Basin County. It is a red and green, slightly bentonitic, highly calcareous shale from the Kootenai formation (Lower Cretaceous).

It has medium plasticity, and moderate drying and firing shrinkage. The P.C.E. is cone 5, and the firing range, 1,850° to 2,050° F. It is a fairly good material for common brick.

Expandability tests indicate that it is not suitable for light-weight aggregate. (See table 3.)

Sample 214

This sample, like sample 213, is from the Kootenai formation exposed along the Running Wolf Creek road. It was cut 3.5 miles southwest of Stanford. It is similar to sample 213 in color and composition.

Ceramic properties are similar to sample 213. (See table 2.) The material fires to a good red color and could be used for common brick and like products.

The clay is not suitable for manufacture of light-weight aggregate.

Sample 215

Sample 215 represents 10 feet of Kootenai (Lower Cretaceous) shale exposed in a road cut along U. S. Highway 87, 1.5 miles west of Geyser, in Judith Basin County. It is light brownish-grey kaolin-type clay, but is slightly bentonitic.

The plasticity is medium, drying shrinkage moderate, and firing shrinkage moderate in the lower ranges and high in the upper ranges. The P.C.E. is cone 12 (2,390° F.), and the firing range, 2,100° to 2,300° F. With careful firing it is a good material for common brick and like products.

It is unsuited for light-weight aggregate. (See table 3.)

Samples 216 and 217

These two samples were taken from an extensive exposure of the Kootenai formation 1 mile north of Eden, in southern Cascade County. Sample 216 represents 4 feet of purplish-red shale below a 1-foot sandstone bed. Sample 217 represents 6 feet of red shale above the 1-foot sandstone and below a bed of green shale. Both are kaolin-type clays and are somewhate calcareous.

Sample 216 has low plasticity and moderate drying shrinkage. The firing shrinkage is moderate in the lower range and high in the upper firing range. The P.C.E. is cone 6 (2,174° F.), and the firing range, 1,900° to 2,100° F. With careful firing, the clay could be used for common brick.

Sample 217 has low plasticity and moderate drying and firing shrinkage. The P.C.E. is cone 2 (2,075° F.), and the firing range 1,750° to 2,000° F. It is a fair ceramic material for common brick.

Neither clay was tested for expandability.

Sample 218

Sample 218 represents 10 feet of green shale between two sandstone beds exposed just west of Eden, in southern Cascade County. It has been classed ceramically as a kaolin flint clay.

The plasticity is very low, and the drying and firing shrinkages moderate. The P.C.E. is cone 11 (2,075° F.), and the firing range is 1,850° to 2,250° F. The plasticity is too low for use of the material alone, and a bonding clay would be necessary for the production of common brick and products of similar grade.

Sample 219

Sample 219 represents 10 feet of green shale from the Otter formation in the Big Snowy group (Mississippian) taken in sec. 21, T. 15 N., R. 3 E., in southern Cascade County. The shale is slightly calcareous and underlies a limey "paper shale."

The material has no plasticity, and it is not a ceramic material.

Sample 220

Sample 220 is slightly calcareous dark-grey shale from the Heath formation of the Big Snowy group (Mississippian) taken from a road cut in sec. 28, T. 15 N., R. 3 E., about 28.5 miles south of Eden, in southern Cascade County.

The plasticity is extremely low. One test brick was fired to 2,000° F. The fired brick was light and porous and fairly well bonded. It is, however, not a ceramic material.

Sample 221

Sample 221 represents the top 8 feet of a 20-foot exposure of greyish-olive colored shale from the Otter (?) formation in sec. 3, T. 11 N., R. 3 E., in northwestern Meagher County. It has been classified as a hard kaolin flint clay.

The material has no plasticity and would require grinding. It could be used for grog in common brick and like products.

Sample 222

This sample is greyish-red Spokane (?) (Precambrian) shale taken from an exposure in sec. 9, T. 7 N., R. 6 E., in northwestern Meagher County about 24 miles northwest of White Sulphur Springs.

The material is a hard kaolin type of shale and would require grinding before use. The plasticity is extremely low, and the test bricks would not hold a stable shape. The firing characteristics are good, and the material could be used as a grog.

Sample 223

Sample 223 represents Spokane shale (Precambrian, Belt) from an exposure in sec. 9, T. 7 N., R. 6 E., 14.4 miles southwest of White Sulphur Springs in Meagher County. It is light-olive grey in color and very hard.

The material would require grinding before use. The plasticity is very low, and the wet test bricks would not hold their shape. The firing characterisitics are good, and the material could be used as a grog.

Sample 224

Sample 224 represents 5 feet of Greyson shale or argillite (Precambrian) which here strikes N. 10° W. and dips 50° NE. It was taken in a road cut in sec.

22, T. 7 N., R. 5 E., along State Highway 6, 20.6 miles southwest of White Sulphur Springs, in Meagher County. The material is medium-dark grey in color and very hard.

Grinding would be necessary before use. The plasticity is extremely low, but drying and firing characteristics are good. The P.C.E. is cone 9 (2,282° F.), and the firing range, 1,950° to 2,200° F. It could be used as a grog for common brick and similar products.

Sample 225

Sample 225 is a grab sample of Belt argillite (Newland ? formation) taken in a road cut along Montana Highway 6, about 21.5 miles east of Townsend, in eastern Broadwater County. The argillite is medium-dark grey in color and very hard. It is noncalcareous and may be Greyson rather than Newland as shown on the State Geologic Map.

Grinding would be necessary before use. It has extremely low plasticity, but the drying and firing characteristics are good. The P.C.E. is cone 12, and the firing range 2,100° to 2,250° F. It could be used as grog for common brick.

Sample 226

This sample was submitted by R. Ruthmeyer, Hamilton, County Agent-at-Large, Ravalli County. It was taken by Joe Santobena, Corvallis, Montana, from small bench deposits located on the south exposure of a bench cut in the NE¼ sec. 14, T. 6 N., R. 20 W.

The material is a soft white clay high in illite. The plasticity is medium; P.C.E. is cone 11 (2,345° F.); and the drying and firing shrinkages medium. On firing the brick shrank and then expanded appreciably. With careful handling and firing, it could be used for common brick.

The clay was not tested for expandability.

Sample 227

Sample 227 is a partly devitrified pumicite (volcanic dust), slightly bentonitic, from Miocene beds exposed on the Christophsen ranch, 1 mile east of U. S. Highway 10, north of Deer Lodge. The material is from sec. 3, T. 8 N., R. 9 W., in southern Powell County.

The firing characteristics are poor. (See table 2.) It is not a suitable ceramic material.

Expandability tests gave only fair results. At 2,100° F. the pellets averaged 1.7 in specific gravity, but at 2,200° F., the specific gravity of the pellets was less than one, and they had a uniform moderate cell structure. With careful temperature control it probably could be made to yield a satisfactory light-weight aggregate.

Sample 228

Sample 228 is pale yellowish-orange clay from the Pliocene beds west of the Prison Farm near Deer Lodge, in southern Powell County. The clay is noncalcareous and non-bentonitic.

The test bricks cracked when fired. (See table 2.) The clay is not suitable for ceramic material.

It did not give a satisfactory product when tested for bloating.

Sample 229

This sample was taken in sec. 13, T. 9 N., R. 10 W., just west of the Silver Star Inn on U. S. Highway 10, in Powell County. The material is yellowish-grey highly bentonitic clay from Pliocene beds.

The test bricks cracked on drying; it is not a ceramic material.

Tests for expandability showed the material to be unsuited for the manufacture of light-weight aggregate.

Sample 230

Sample 230 is Tertiary clay from sec. 13, T. 9 N., R. 11 W., on the Pioneer road south of Gold Creek Station, in Powell County. The clay is yellowish grey, highly calcareous, and quite bentonitic.

It is not suitable for ceramic use. (See table 2.)

Sample 231

Sample 231 is Tertiary clay from a cut on the new interstate highway 5 miles east of Drummond. The clay is yellowish grey in color and slightly bentonitic. It is partly devitrified pumicite.

Its low plasticity and poor firing characteristics make it unsuitable for ceramic use.

Bloating tests yielded a fair product at 2,000° and 2,100° F. The pellets were well-rounded, well glazed, and had a uniform fine cell structure. The fired color is moderate brown.

Sample 232

This is a sample of Tertiary clay taken on the Manley Ranch in sec. 13, T. 12 N., R. 12 W., 8 miles southwest of Helmville, in Powell County. The clay is yellowish grey and quite bentonitic. The material is a devitrified pumicite (volcanic dust).

The test bricks cracked on drying, and the material is not suitable for ceramic use.

Sample 233

This sample was taken in a cut on the Avon road, 1.5 miles northeast of Helmville, in sec. 13, T. 13 N., R. 11 W., in Powell County. It is a yellowish-grey slightly bentonitic Tertiary clay formed by the devitrification of pumicite and is essentially volcanic glass.

The test bricks cracked on firing. It is not suitable for ceramic use.

No bloating tests were made on the material.

Sample 234

Sample 234 was taken from a clay bank along the Blackfoot River near the bridge at the Erickson Ranch in sec. 32, T. 14 N., R. 11 W., on old Helmville-Ovando road. The clay is greyish-orange pink, very slightly bentonitic and slightly calcareous. The clay contains some hard pebbles which would have to be separated if used.

The plasticity and working qualities of the clay are good, and the firing characteristics are fair. With careful firing, the clay could be used for common brick.

Sample 235

Sample 235 was submitted by J. E. Hildebrant of Thompson Falls and is said to have come from a deposit in sec. 7, T. 21 N., R. 29 W., in Sanders County. It is a yellowish-grey clay that is slightly calcareous and bentonitic.

The ceramic firing characteristics are poor, and it is not suited for ceramic use.

Fair results were obtained on expandability tests. At 2,000° F., the clay yielded moderate-brown pellets with a very fine-grained cell structure. At 2,100° F., the color was light-olive grey and the pellets had a uniform medium cell structure. At 2,000° F., the specific gravity was 1.6, but at 2,100° F., the pellets floated on water. With proper temperature control, this clay should yield a satisfactory light-weight aggregate.

Sample 236

This material was submitted by J. W. Richards, Jr. of Missoula. Location of the deposits from which the sample came is unknown. The clay is yellowish grey and very slightly bentonitic.

The plasticity is medium, and the drying and firing shrinkages moderate. P.C.E. is cone 9 (2,282° F.), and the firing range is 1,950° to 2,150° F. It could be used for common brick and products of similar grades.

Sample 237

This sample was submitted by Don Midboe of Glendive. Location of the deposit is unknown. The clay is grey in color, moderately bentonitic and calcareous.

Its narrow firing range, scummed surface, and poor firing characteristics make it unsuitable for ceramic use.

Samples 238 and 239

These two samples were submitted by E. W. Tenny of Billings. Location of the deposit is unknown. Both clays are highly bentonitic and unsuited for ceramic use.

Sample 240

This sample is white indurated pumicite submitted by George Kanta of Three Forks for expandability tests only. The material is almost pure glassy volcanic dust, firmly compacted.

When tested for expandability, the results were not consistent. Some fragments showed a good bloat, but most of the material merely acquired a glaze without expansion. It is doubtful if this material could be used as a source of light-weight aggregate.

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Table 1.--Sample locations, Montana clays and shales

Sample No.	Field No.	Location	Sec.	Twp.	Rge.
86	5-1	Kelly, from E. of Whitehall	35	2N	4W
87	5-2	H. Daems, Whitehall, clay from Madison Co.			
88	5-3	Don Albright, Sheridan, from Ruby Mts.			
89	5-4	Greyson shale 8 mi. N. of Helena, Lewis & Clark Co.	5	11N	3W
90	5-5	R. T. Chew (57-124) NP Ry., Intake, Dawson Co.	35	18N	56E
91	5-6	Belt shale NE. Whitehall, Jefferson County	25	2N	4W
92	5-7	Kootenai fm., Hegg coal mine, Broadwater County	12	4N	2E
93	5-8	Kootenai fm., Hegg coal mine, Broadwater County	12	4N	2E
94	5-9	Kootenai shale, 5.8 mi. E. Bozeman, Gallatin Co.	25	2S	6E
95	5-10	Kootenai shale, 5.8 mi. E. Bozeman, Gallatin Co.	25	2S	6E
96	5-11	Hell Crk. fm., 7 mi. E. Reed Pt., Stillwater Co.	6	2S	19E
97	5-12	Hell Crk. fm., 2 mi. W. Columbus, Stillwater Co.	24	2S	19E
98	5-13	Judith River fm., 13 mi. SW. Columbus, Carbon Co.	22	3S	21E
99	5-14	Judith River fm., Billingsley ranch, 4 mi. W. Joliet	18	4S	22E
100	5-15	Ft. Union fm., 6 mi., E. Red Lodge, Carbon Co.	5	8S	21E
101	5-16	Ft. Union fm., 6 mi., E. Red Lodge, Carbon Co.	5	8S	21E
102	5-17	Ft. Union fm., at Bear Creek, Carbon County	4	8S	21E
103	5-18	Cody fm., 14 mi. S. Bridger, Carbon County	16	8S	24E
104	5-19	Cody fm., 14 mi. S. Bridger, Carbon County	16	8S	24E
105	5-20	Frontier fm., 14.7 mi. S. Bridger, Carbon Co.	15	8S	24E
106	5-21	Niobrara fm., Fromberg brick yard, Carbon Co.	18	5S	23E
107	5-22	Judith River fm., 6 mi. N. Billings, Yellowstone Co.	3	1N	26E
108	5-23	Ft. Union fm., 28 mi. N. Billings, Yellowstone Co.	15	5N	26E
109	5-24	Ft. Union fm., 28 mi. N. Billings, Yellowstone Co.	15	5N	26E
110	5-25	Ft. Union fm., 28 mi. N. Billings, Yellowstone Co.	15	5N	26E
111	5-26	Ft. Union fm., 20 mi. S. Roundup, Musselshell	23	6N	26E
112	5-27	Bearpaw fm., 1 mi. E. Melstone, Musselshell, Co.	29	10N	31E
113	5-28	Bearpaw fm., 6 mi. SE. Ingomar, Rosebud County	13	9N	35E
114	5-29	Lebo shale, 10 mi. N. Colstrip, Rosebud County	7	3N	41E
115	5-30	Lebo shale, 11 mi. N. Colstrip, Rosebud County	6	3N	41E
116	5-31	Judith River fm., 10 mi. NW. Forsyth, Rosebud Co.	20	7N	39E
117	5-32	Judith River fm., 9.5 mi. NW. Forsyth, Rosebud Co.	29	7N	39E
118	5-33	Bearpaw fm., 5.3 mi. NW. Forsyth, Rosebud Co.	1	6N	39E
119	5-34	Ft. Union fm., 17 mi. E. Forsyth, Rosebud Co.	22	6N	43E
120	5-35	Ft. Union fm., 1.5 mi. NE. Hathaway, Rosebud	12	6N	44E
121	5-36	Lebo shale, Moon Creek, Custer County	32	7N	46E
122	5-37	Ft. Union fm., 8 mi. E. Miles City, Custer Co.	26	8N	48E
123	5-38	Ft. Union fm., 8.2 mi. E. Miles City, Custer	26	8N	48E
124	5-39	Ft. Union fm., 5.7 mi. W. Baker, Fallon Co.	12	7N	58E
125	5-40	Pierre shale, 2 mi. N. Baker, Fallon Co.	31	8N	60E
126	5-41	Ft. Union fm., 20.5 mi. N. Baker, Fallon Co.	6	10N	60E
127	5-42	Ft. Union fm., 6 mi. E. Glendive, Dawson Co.	36	16N	56E
128	5-43	Ft. Union fm., 6 mi. E. Glendive, Dawson Co.	36	16N	56E
129	5-44	Ft. Union fm., 6 mi. E. Glendive, Dawson Co.	36	16N	56E
130	5-45	Ft. Union fm., 3 mi. SW. Sidney, Richland Co.	12	22N	58E
131	5-46	Ft. Union fm., 3 mi. SW. Sidney, Richland Co.	12	22N	58E
132	5-47	Ft. Union fm., 35 mi. W. Sidney, Richland Co.	4	22N	54E
133	5-48	Ft. Union fm., 35 mi. W. Sidney, Richland Co.	4	22N	54E

Table 1.--Sample locations, Montana clays and shales, cont'd.

Sample No.	Field No.	Location	Sec.	Twp.	Rge.
134	5-49	Ft. Union fm., 35 mi. W. Sidney, Richland Co.	4	22N	54E
135	5-50	Ft. Union fm., 35 mi. W. Sidney, Richland Co.	4	22N	54E
136	5-51	Ft. Union fm., 34 mi. E. Jordan, Garfield Co.	16	18N	43E
137	5-52	Ft. Union fm., 8.8 mi. E. Jordan, Garfield Co.	9	18N	39E
138	5-53	Ft. Union fm., 8.8 mi. E. Jordan, Garfield Co.	9	18N	39E
139	5-54	Ft. Union fm., McDonald Ranch, Garfield Co.	18	18N	37E
140	5-55	Ft. Union fm., McDonald Ranch, Garfield Co.	18	18N	37E
141	5-56	Colorado fm., 1 mi. E. Mosby, Garfield Co.	11	14N	30E
142	5-57	Colorado fm., 1 mi. E. Mosby, Garfield Co.	11	14N	30E
143	5-58	Claggett(?) fm., 1.7 mi. W. Lavina, Golden Valley	33	7N	22E
144	5-59	Judith River fm., 4.9 mi. W. Harlowton, Wheatland	13	8N	14E
145	5-60	Eagle fm., 9.8 mi. W. Harlowton, Wheatland	19	8N	14E
146	5-61	Belt shale, 33.2 mi. W. Harlowton, Meagher Co.	9	9N	10E
147	5-62	Belt shale, 33.2 mi. W. Harlowton, Meagher Co.	9	9N	10E
148	5-63	Belt shale, 18.4 mi. E. White Sulphur Sprs., Meagher	34	10N	9E
149	5-64	Brooke Taylor, clay near Mildred, Prairie Co.	29	11N	54E
150	5-65	Pleistocene glacial lake clay, 1 mi. N. Polson, Lake	31	23N	20W
151	5-66	R.E. Logan, Deer Lodge, clay from Bearmouth	14	11N	14W
152	5-67	Roger Craig, Darby, Ravalli County			
153	5-68	C.V. Brady, Butte, location unknown			
154	5-69	N.E. Bartram, Columbus, Dawson County		16N	55E
155	5-70	Colorado shale near Vaughn, Montana	2	21N	1E
156	6-1	J.T. Abbey, Hamilton, near Grantsdale, Ravalli	17	5N	20W
157	6-2	J.T. Abbey, Hamilton, near Grantsdale, Ravalli	17	5N	20W
158	6-3	J.T. Abbey, Hamilton, near Grantsdale, Ravalli	17	5N	20W
159	6-4	J.T. Abbey, Hamilton, near Grantsdale, Ravalli	17	5N	20W
160	6-5	R.T. Chew, 3 mi. NW. Plains, Sanders County	9	20N	26W
161	6-6	R.T. Chew, Lake Missoula beds, Sanders County	4	18N	21W
162	6-7	R.T. Chew, 2 mi. NE. Drummond, Granite County	21	11N	12W
163	6-8	R.T. Chew, Tertiary, Madison County	16	9S	2W
164	6-9	Glacial lake clay, 9 mi. NW Troy, Lincoln Co.	5	32N	34W
165	6-10	Tomlin, Ft. Benton, Chouteau County		24N	8E
166	6-11	Kay Smith, Georgetown Lake, Granite County	12	5N	14W
167	6-12	Kay Smith, across river from Townsend, Broadwater	36	7N	1E
168	6-13	Pleistocene, 9 mi. NW. Troy, Lincoln County	5	32N	34W
169	6-14	Pleistocene glacial clay, Garrison ranch, Yaak, Lincoln	5	35N	32W
170	6-86	R. Ruthmeyer, Hamilton, Ravalli County	23	8N	20W
171	6-16	Du Pois Ranch, (Mrs. Gus Du Pois)			
172	6-17	Adolph Beckstrom No. 1 Colorado(?)	9	13N	25E
173	6-18	Adolph Beckstrom No. 2	9	13N	25E
174	6-19	Colorado shale, 2 mi. SE. Garrison, Powell Co.	19	9N	9W
175	6-20	Nita Robbins ranch near Creston, Flathead Co.	26	27N	20W
176	6-21	Volcanic ash, Tertiary, W of Craig, L & C Co.	4	15N	3W
177	6-22	Colorado shale, Cascade School, Cascade Co.	35	18N	1W
178	6-23	Judith River fm., 5.5 mi. S. Havre, Hill Co.	32	32N	16E
179	6-24	Colorado shale, 27 mi. S. Havre, Hill County	19	29N	17E
180	6-25	Bearpaw shale, 1.9 mi. N. Harlem, Blaine Co.	4	32N	23E
181	6-26	Bearpaw shale, 8 mi. N. Harlem, Blaine County	6	33N	23E

Table 1.--Sample locations, Montana clays and shales, cont'd.

Sample No.	Field No.	Location	Sec.	Twp.	Rge.
182	6-27	Hell Crk. fm., 18.5 mi. N. Harlem, Blain Co.	17	35N	23E
183	6-28	Hell Crk. fm., 4 mi. SW. Chapman, Phillips Co.	28	36N	27E
184	6-29	Claggett fm., 20 mi. N. Malta, Phillips Co.	13	33N	30E
185	6-30	Claggett fm(?), 13 mi. N. Malta, Phillips Co.	19	32N	30E
186	6-31	Bearpaw fm., 23 mi. N. Glasgow, Valley Co.	19	32N	40E
187	6-32	Ft. Union fm., ridge 2½ mi. N. Richland, Daniels	23	36N	43E
188	6-33	Ft. Union fm., 12 mi. W. Four Buttes, Daniels	5	35N	45E
189	6-34	Ft. Union fm., 3.1 mi. E. Flaxville, Daniels	12	35N	50E
190	6-35	Ft. Union fm., 4.4 mi. E. Redstone, Sheridan	12	35N	52E
191	6-36	Ft. Union fm., 4.4 mi. E. Redstone, Sheridan	11	35N	52E
192	6-37	Ft. Union fm., 0.7 mi. N. Archer, Sheridan Co.	9	35N	53E
193	6-38	Ft. Union fm., 0.7 mi. N. Archer, Sheridan Co.	9	35N	53E
194	6-39	Ft. Union fm., 1 mi. N. St. Hwy. 5, 3 mi. W. Plentywood	17	35N	54E
195	6-40	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
196	6-41	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
197	6-42	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
198	6-43	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
199	6-44	Ft. Union fm., 2.7 mi. W. Plentywood, Sheridan	14	35N	54E
200	6-45	Ft. Union fm., 3.9 mi. N. Culbertson, Roosevelt	6	28N	56E
201	6-46	Ft. Union fm., 3.4 mi. S. Culbertson, Roosevelt	34	28N	56E
202	6-47	Ft. Union fm., 3.4 mi. S. Culbertson, Roosevelt	34	28N	56E
203	6-48	Bearpaw fm. at Oswego, Valley County	27	27N	45E
204	6-49	Bearpaw fm. at Nashua, Valley County	31	28N	42E
205	6-50	Judith River fm., 5.3 mi. SW. Malta, Phillips	3	29N	29E
206	6-51	Judith River fm., 5.3 mi. SW. Malta, Phillips	3	29N	29E
207	6-52	Bearpaw fm., 14 mi. SW. Malta, Phillips Co.	12	28N	28E
208	6-53	Bearpaw fm., 32 mi. SW. Malta, Phillips Co.	29	26N	27E
209	6-54	Judith River fm., road cut W. Fergus, Fergus Co.	17	18N	21E
210	6-55	Claggett shale, 9.7 mi. E. Hilger, Fergus Co.	20	18N	20E
211	6-56	Kootenai fm., 1 mi. E. Hanover, Fergus Co.	26	16N	17E
212	6-57	Telegraph Crk. fm., 1 mi. W. Windham, Ju. Basin	1	15N	12E
213	6-58	Kootenai fm., 6 mi. SW. Stanford, Judith Basin	2	15N	11E
214	6-59	Kootenai fm., 3½ mi. SW. Stanford, Judith Basin	26	16N	11E
215	6-60	Kootenai fm., 1½ mi. W. Geyser, Judith Basin	12	17N	9E
216	6-61	Kootenai fm., 1 mi. N. Eden, Cascade County	32	18N	4E
217	6-62	Kootenai fm., 1 mi. N. Eden, Cascade County	32	18N	4E
218	6-63	Kootenai fm., .02 mi. W. Eden, Cascade County	31	18N	4E
219	6-64	Otter fm., 26.5 mi. S. Eden, Cascade County	21	18N	3E
220	6-65	Heath fm., 28.5 mi. S. Eden, Cascade County	28	15N	3E
221	6-66	Otter fm., 30 mi. NW. White Sulphur Sprs., Meagher	3	11N	3E
222	6-67	Spokane shale, 24 mi. NW Wht. Sul. Sprs., Meagher	29	11N	4E
223	6-68	Spokane shale, 14.4 mi. SW. Wht. Sul. Sprs. Meagher	9	7N	6E
224	6-69	Greyson shale, 20.6 mi. SW. Wht. Sul. Sprs. Meagher	22	7N	5E
225	6-70	Newland(?) fm., 21.5 mi. E. Townsend, Broadwater	20	7N	5E
226	6-88	R. Ruthmeyer, Hamilton, Ravalli County	14	6N	20W
227	6-72	Miocene, Christophsen ranch, N. Deer Lodge	3	8N	9W
228	6-73	Pliocene, W. prison farm, Deer Lodge, Powell	4	8N	9W
229	6-74	Pliocene, W. Silver Star, near Garrison, Powell	13	9N	10W

Table 1.--Sample locations, Montana clays and shales, cont'd.

Sample No.	Field No.	Locations	Sec.	Twp.	Rge.
230	6-75	Tertiary(?), S. Gold Crek. on Pioneer Rd.,Powell	13	9N	11W
231	6-76	Tertiary, 5 mi. E. Drummond, Granite County	13	10N	12W
232	6-77	Tertiary, 8 mi. SW. Helmville, Powell County	13	12N	12W
233	6-78	Tertiary, 1½ mi. N. Helmville, Powell County	13	13N	11W
234	6-79	Tertiary, N. bank Blackfoot R. bridge, Powell Co.	32	14N	11W
235	6-80	J.E. Hildebrant, Thompson Falls, Sanders County	7	21N	29W
236	6-81	J.W. Richards, Jr., Missoula, Montana			
237	6-82	Don Midboe, Glendive, Montana			
238	6-83	E.W. Tenny, Billings, Montana			
239	6-84	E.W. Tenny, Billings, Montana			
240	6-85	George Kanta, Three Forks, Montana			

Table 2.--Ceramic properties of Montana clays and shales

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F	Firing Temperature °F	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
a	b	c	d	e	f	g	h	i	
86	L 36 H 40	1.4	1	none	1,550 1,750 1,950	3 1.4 3.5	lt. red lt. red orange	SS SS SS	Not suitable
87	---	---	--	---	----	---	----	--	Not suitable
88	L 37 H 45	2.9	2	plus or minus 2,000	1,500 1,750 1,950 2,050	1.3 3.0 5.8 20.0	pink pink pink brown	SS SS SS HS	Not suitable
89	L 24 H 38	5.4	2	2,000 to 2,075	1,550 1,750 1,950 2,050	0.0 0.6 1.3 4.3	lt. red lt. red lt. red red	SS SS S S	Common brick, with careful firing
90	L 26 H 38	6.0	2	1,950 to 2,050	1,550 1,750 1,950 2,050	0.0 0.0 0..0 0.0	lt. red lt. red lt. red cream	SS SS S S	Common brick, with careful handling and firing

a. See table 1
b. L = Lower limit; H = Upper limit
c. Drying shrinkage is lineal.
d. P.C.E. in Std. Seger cones
e. Degrees Fahrenheit
f. Degrees Fahrenheit
g. Firing shrinkage is lineal.
h. Lt. = light; Dk. = dark
i. S = steel hard; HS = harder than steel; SS = softer than steel

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
91	L 24 H 31	4.7	11	2,050 to 2,200	1,900 2,100 2,250	0.3 2.6 6.2	lt. red red brown	SS S HS	Common brick, alkali scum
92	L 18 H 22	4.0	10	2,000 to 2,200	1,800 2,000 2,200	0.0 0.0 0.2	lt. red lt. red lt. red	SS S HS	Common brick, some drying alkali scum
93	L 22 H 29	4.2	over 12	2,000 to 2,300	1,900 2,100 2,250 2,300	0.9 1.8 1.8 1.9	lt. red lt. red grey grey	S HS HS HS	Common brick
94	L 20 H 25	4.0	8	1,950 to 2,150	1,950 2,050 2,200	0.0 1.4 fused	lt. red lt. red brown	S S HS	Common brick
95	L 24 H 38	7.4	11	1,900 to 2,200	1,900 2,100 2,250	3.7 2.4 10.0	orange red dk. red	HS HS HS	Common brick
96	L 26 H 34	6.5	1	none	1,550 1,750 1,950	0.0 1.1 1.6	lt. red lt. red lt. red	SS SS SS	Not suitable, poor firing characteristics
97	L 26 H 38	8.7	4	none	1,650 1,850 2,050	0.0 cracked cracked	lt. red lt. red red	SS SS S	Not suitable, bricks cracked on firing
98	L 29 H 39	8.0	9	none	1,800 2,000 2,200	1.2 cracked cracked	lt. red lt. red dk. red	SS SS HS	Not suitable, bricks cracked on firing
99	L 30 H 67	8.6	4	none	1,650 1,850 2,050	cracked cracked cracked	lt. red red dk. red	SS S HS	Not suitable, bricks cracked on firing
100	L 35 H 71	9.4	10	1,800 to 2,100	1,800 2,000 2,200	0.6 2.5 swelled	lt. red lt. red chocolate	HS HS HS	Not suitable, scum and poor firing characteristics
101	L 28 H 68	7.7	8	1,950 to 2,050	1,950 2,050 2,200	0.8 3.2 swelled	lt. red lt. red brown	S HS HS	Common brick with careful firing

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
102	L 29 H 56	6.9	11	1,900 to 2,000	1,900 2,100 2,200	1.2 swelled swelled	lt. red lt. red dk. red	S HS HS	Not suitable, poor firing characteristics
103	L 32 H 56	8.3	11	1,900 to 2,100	1,900 2,100 2,200	2.2 5.8 swelled	lt. red lt. red brown	S HS HS	Common brick
104	L 27 H 52	Not fired							Alkali content too high
105	L 30 H 40	5.8	10	2,100 to 2,200	1,800 2,000 2,200	0.0 1.5 5.0	orange lt. red dk. red	SS SS HS	Common brick
106	L 28 H 43	5.7	5	2,100 to 2,150	1,650 1,850 2,050 2,150	0.0 0.0 0.3 2.0	tan brown brown brown	SS SS SS S	Not suitable, scum & narrow firing range
107	L 22 H 50	6.8	3	2,025 to 2,075	1,650 1,850 2,000 2,100	0.0 0.0 0.4 2.2	tan lt. red lt. red lt. red	SS SS SS S	Not suitable, narrow firing range & scum
108	L 26 H 39	3.5	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.0 0.0 0.6 1.4	lt. red lt. red lt. red dk. red	SS SS SS S	Not suitable, scum & poor firing characteristics
109	L 24 H 26	6.8	11	2,050 to 2,175	1,900 2,100 2,250	1.3 4.3 6.4	lt. red red dk. red	SS S HS	Common brick
110	L 23 H 34	5.6	5	2,100 to 2,150	1,650 1,850 2,050 2,150	0.9 0.7 0.3 3.1	lt. red lt. red lt. red brown	SS SS SS HS	Not suitable, narrow firing range & scum
111	L 33 H 48	4.9	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.8 0.5 0.6 3.0	lt. red lt. red lt. red lt. red	SS SS SS HS	Not suitable, narrow firing range & scum

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
112	L 34 H 72	9.3	9	1,900 to 2,150	1,800 2,000 2,200	1.3 5.6 4.7	lt. red red dk. red	SS S HS	Common brick
113	L 36 H 53	8.1	9	none	1,800 2,000 2,200	1.9 cracked cracked	lt. red red dk. red	HS HS HS	Not suitable bricks cracked & swelled on firing
114	L 32 H 88	Not fired, bricks cracked on drying							Not suitable
115	L 36 H 76	Not fired, bricks cracked on drying							Not suitable
116	L 28 H 68	Not fired, bricks cracked on drying							Not suitable
117	L 24 H 59	8.0	4	2,050 to 2,100	1,650 1,850 2,050	0.0 0.3 0.9	lt. red lt. red lt. red	SS HS HS	Not suitable, narrow firing range & scum
118	L 36 H 56	10.3	5	none	1,650 1,850 2,050	cracked cracked cracked	lt. red red dk. red	S HS HS	Not suitable, bricks cracked on firing
119	L 24 H 45	5.4	9	2,000 to 2,200	1,800 2,000 2,200	0.0 0.3 3.8	lt. red lt. red dk. red	SS S HS	Not suitable, scum
120	L 26 H 54	Not fired, bricks cracked on drying							Not suitable
121	L 36 H 78	Not fired, bricks cracked on drying							Not suitable
122	L 34 H 86	Not fired, bricks cracked on drying							Not suitable
123	L 36 H 93	Not fired, bricks cracked on drying							Not suitable
124	L 36 H 68	Not fired, bricks cracked on drying							Not suitable

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
125	L 30 H 70	Not fired, bricks cracked on drying							Not suitable
126	L 24 H 40	5.7	11	2,050 to 2,200	1,800 2,000 2,200	0.9 0.9 1.5	lt. red lt. red lt. red	SS S HS	Not suitable, scum
127	L 34 H 74	Not fired, bricks cracked on drying							Not suitable
128	L 36 H 74	Not fired, bricks cracked on drying							Not suitable
129	Naturally burned material, no plasticity								Might be used for grog
130	L 29 H 35	4.5	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.8 0.0 0.8 2.6	lt. red lt. red lt. red lt. red	SS SS SS S	Not suitable, scum
131	L 30 H 38	4.8	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.0 0.0 0.3 2.4	lt. red lt. red lt. red lt. red	SS S S S	Not suitable, scum
132	L 30 H 44	6.5	2	1,950 to 2,050	1,550 1,750 1,950 2,050	0.0 0.6 1.0 1.0	lt. red lt. red lt. red lt. red	SS SS S HS	Common brick, altho brick fired at low temp. has a slight scum
133	L 29 H 45	5.0	2	1,900 to 2,050	1,550 1,750 1,950 2,050	0.0 0.6 1.4 1.9	lt. red lt. red lt. red lt. red	SS SS S HS	Not suitable, scum
134	L 31 H 44	4.0	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.0 0.0 0.0 0.3	cream cream cream cream	SS SS SS S	Common brick

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
135	L 32 H 54	6.5	4	2,000 to 2,100	1,650 1,850 2,050 2,150	0.0 1.6 1.7 8.0	tan tan tan green	SS SS S HS	Not suitable, scum
136	Naturally burned material, non-plastic								Might be used for grog
137	L 36 H 96	Not fired, bricks cracked on drying							Not suitable
138	L 28 H 62	8.2	12	2,100 to 2,250	1,900 2,100 2,250	0.0 0.9 3.5	orange red dk. red	SS S HS	Common brick
139	L 34 H 95	Not fired, bricks cracked on drying							Not suitable
140	L 28 H 50	7.1	3	1,850 to 2,050	1,650 1,850 2,050	0.0 1.5 3.1	orange red dk. red	SS S HS	Not suitable, scum
141	L 26 H 46	Not fired, brick had excessive scum on drying							Not suitable
142	L 28 H 74	Not fired, brick had excessive scum on drying							Not suitable
143	L 22 H 40	Not fired, brick had excessive scum on drying							Not suitable
144	L 25 H 34	5.7	3	2,050	1,650 1,850 2,050	0.0 0.0 1.5	lt. red lt. red lt. red	SS SS S	Not suitable, scum
145	L 23 H 26	4.1	2	2,000 to 2,050	1,550 1,750 1,950 2,050	0.6 0.0 0.0 0.0	tan tan tan tan	SS SS SS S	Common brick
146	L 24 H 30	4.8	above 12	2,100 to 2,250	1,900 2,100 2,250	2.3 4.6 3.5	lt. red lt. red dk. red	S HS HS	Common brick with careful firing

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
147	L 16 H 22	No plasticity, not fired							Not suitable
148	L 22 H 28	6.1	6	2,050 to 2,150	1,700 1,900 2,100 2,200	0.0 1.5 2.0 5.6	orange lt. red lt. red dk. red	SS S S HS	Common brick if handled & fired carefully or blended w/ more plastic material
149	L 25 H 36	6.0	5	1,850 to 2,050	1,650 1,850 2,050	0.5 0.0 1.1	tan tan tan	SS S HS	Common brick
150	L 28 H 34	Not fired, not enough plasticity to hold shape							Not suitable
151	Not tested, too much lime to be a ceramic material								Not suitable
152	Not tested, no plasticity								Not suitable
153	L none H 40	3.0	6	2,000 to 2,100	1,700 1,900 2,100	2.4 2.5 14.0	cream orange dk. red	SS SS HS	Not suitable, plasticity too low & excess firing shrinkage
154	L 25 H 64	Not fired, brick cracked on drying							Not suitable
155	L 40 H 100	Not fired, brick cracked on drying							Not suitable
156	L 40 H 56	11.0	11	none	1,600 1,750 1,950	0.0	tan lt. red red	SS SS SS	Not suitable
157	L 40 H 70	no test	1	Dried brick cracked					Not suitable
158	L 24 H 34	5.2	8	2,150 to 2,200	1,750 1,950 2,150	0.6 0.0 3.5	tan red red	SS SS SS	Not suitable, poor ceramic bond

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
159	L 32 H 36	6.0	8	2,150 to 2,200	1,750 1,950 2,150	0.0 1.9 6.9	tan orange dk. red	SS SS SS	Not suitable, poor ceramic bond
160	L 22 H 31	5.8		2,100 to 2,400	2,000 2,200 2,400	0.9 3.7 5.7	tan lt. red dk. red	SS S HS	Good ceramic material, common brick, pottery, etc.
161	L 28 H 38	6.2	3	1,900 to 2,000	1,600 1,800 2,000	0.0 0.6 4.5	tan tan lt. red	SS S HS	Common brick
162	L 24 H 32	6.1		none	2,000 2,200 2,300	1.4 5.7 7.4	lt. red dk. red dk. red	S HS HS	Not suitable, fired brick cracked
163	L 80 H 116	Not fired for ceramic data							Not suitable
164	Not fired for ceramic data								
165	L 40 H 82	Dried brick cracked							Not suitable
166	L 20 H 27	4.6	10	2,100 to 2,200	1,800 2,000 2,200	0.3 1.5 2.0	orange lt. red dk. red	SS SS HS	Common brick
167	L 27 H 34	6.7	12	2,000 to 2,300	1,900 2,100 2,300	1.2 7.6 3.6	orange dk. red dk. red	S HS HS	Common brick, pottery, etc.
168	L 26 H 30	1.8	8	none	1,750 1,950 2,150	0.0 0.2 6.3	tan tan red	SS SS SS	Not suitable
169	L 32 H 54	6.3	4	1,950 to 2,050	1,650 1,850 2,050	0.0 2.4 11.0	tan red chocolate	SS S HS	Not suitable, high firing shrinkage
170	L 22 H 28	3.3	9	2,050 to 2,100	1,750 1,950 2,150	0.0 0.0 9.5	tan tan mottled	SS SS HS	Common brick & like products; grog w/ a more plastic clay

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
171	L 24 H 30	5.1	8	none	1,750 1,950 2,150	0.0 0.3 9.3	tan tan green	SS SS HS	Not suitable, poor firing characteristics
172	L 28 H 32	2.9	33	2,600 up	not fired	--	white white white	--	Excellent, fire-brick, whiteware, etc.
173	L 29 H 36	3.0	33	2,600 up	not fired	--	white	--	Excellent, fire-brick, whiteware, etc.
174	L 20 H 23	4.4	5	none	1,600 to 2,100	3.3ex* to 0.1	tan tan tan	SS to S	Not suitable, poor firing characteristics & ceramic bond
175	L 28 H 58	7.5	5	1,950 to 2,050	1,650 1,850 2,050	0.0 1.2 9.8	tan orange red	SS S HS	Possible common brick w/careful firing
176	L 24 H 37	4.8	7	2,000 to 2,100	1,700 1,900 2,100	0.0 0.6 9.3	tan tan brown	SS SS S	Not suitable, poor firing characteristics
177	L 24 H 48	6.1	2	1,750 to 1,950	1,600 1,750 1,950	0.0 0.9 3.2	tan tan lt. red	SS S HS	Not suitable, alkali scum
178	L 25 H 56	10.6	1	none	1,600 1,750 1,950	none	tan red red	SS S HS	Not suitable, fired bricks were cracked
179	L 20 H 22	4.6	4	2,050 to 2,100	1,650 1,850 2,050	1.06 0.60 0.58	tan orange red	SS SS SS	Not suitable, poor firing characteristics
180	L 30 H 64	Dried	bricks	were	cracked				Not suitable
181	L 26 H 52	Dried	bricks	were	cracked				Not suitable
182	L 34 H 72	Dried	bricks	were	cracked				Not suitable

*ex = expansion

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
183	L 34 H 54	Dried	bricks	were	cracked				Not suitable
184	L 32 H 76	Dried	bricks	were	cracked				Not suitable
185	L 20 H 62	Fired	bricks	were	cracked				Not suitable
186	L 34 H 74	Fired	bricks	were	cracked				Not suitable
187	L 28 H 58	6.4	1	1,750 to 1,950	1,600 1,750 1,950	0.6ex 0.0 0.3	tan tan lt. red	SS S HS	Common brick, some alkali scum
188	L 29 H 49	7.1	1	1,750 to 1,950	1,600 1,750 1,950	0.67ex	tan tan red	SS S HS	Common brick
189	L 20 H 38	5.4	?	1,950 to 2,400	1,950 2,150 2,300	0.0 1.8 2.7	buff buff buff	S HS HS	Common brick, face brick, etc. good ceramic clay
190	L 20 H 36	5.2	1	1,950 to 2,000	1,650 1,850 2,050	0.3ex 0.3 0.60	tan lt. red lt. red	SS SS SS	Common brick w/ careful handl-ing & firing
191	L 30 H 54	7.4	9½	2,000 to 2,100	1,800 2,000 2,200	0.0 4.3 --	tan dk. red green	SS S HS	Common brick, w/ careful firing
192	L 24 H 44	6.9	4	2,000 to 2,075	1,650 1,850 2,050	0.0 0.0 0.6	tan tan red	SS SS S	Common brick, with careful firing
193	L 28 H 43	6.5	2	1,900 to 2,000	1,600 1,750 1,950	0.3ex 0.0 1.2	tan lt. red lt. red	SS SS S	Common brick
194	L 25 H 36	6.3	5	2,000 to 2,100	1,650 1,850 2,050	0.9ex 0.0 0.3	lt. red lt. red buff	SS SS S	Good ceramic clay, common brick, pottery

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
195	L 24 H 60	7.7	13	1,950 to 2,200	1,950 2,150 2,300	3.8 5.8 4.1	tan dk. red grey	S HS HS	Common brick, minor alkali scum, careful firing necessary
196	L 28 H 56	7.9	12+	1,950 to 2,200	1,950 2,150 2,300	2.9 5.0 0.6	red tan green	S HS HS	Common brick, minor alkali scum, careful firing necessary
197	L 25 H 30	6.4	12	2,000 to 2,300	1,900 2,100 2,300	1.4 2.7 6.0	white grey grey	SS HS HS	Good ceramic clay, common brick, pottery, etc. w/ careful firing
198	L 24 H 52	7.5	11	1,850 to 2,150	1,850 2,050 2,250	1.6 4.8 6.3	lt. red tan grey	S HS HS	Common brick, minor alkali scum
199	L 22 H 46	6.0	11	2,050 to 2,200	1,850 2,050 2,250	0.9 4.4 4.7	lt. red dk. red green	S HS HS	Common brick, some alkali scum
200	L 28 H 60	7.9	1	1,750 to 1,950	1,600 1,750 1,950	0.0 0.9 1.6	tan tan tan	SS S HS	Common brick, some alkali scum
201	L 27 H 38	6.4	6	2,000 to 2,100	1,700 1,900 2,100	0.9 1.0 1.6	tan tan white	SS SS S	Common brick
202	L 28 H 50	5.4	5	1,850 to 2,050	1,650 1,850 2,050	0.0 0.7 2.1	tan orange lt. red	SS S HS	Not suitable, alkali scum
203	L 36 H 86	Dried bricks were cracked							Not suitable
204	L 34 H 64	11.3	9½	none	1,800 2,000 2,200	0.3 7.7 7.5ex	lt. red dk. red dk. red	S HS HS	Not suitable, fired bricks were cracked

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
205	L 22	7.2	9½	2,000 to 2,150	1,800 2,000 2,200	0.6 3.4 4.3	tan red chocolate	S S HS	Common brick, minor alkali scum
206	L 22 H 47	6.4	1	1,750 to 1,950	1,600 1,750 1,950	0.6ex 0.6ex 0.6	tan tan lt. red	SS S HS	Common brick, some alkali scum
207	L 36 H 75	Dried brick cracked							Not suitable
208	L 34 H 68	Dried brick cracked							Not suitable
209	Bricks cracked on drying								Not suitable
210	L 28 H 66	Dried brick cracked							Not suitable
211	L 21 H 26	6.6	9	1,950 to 2,150	1,750 1,950 2,150	0.0 1.5 4.8	lt. red lt. red dk. red	SS S HS	Common brick
212	L 24 H 42	8.1	2	1,800 to 1,950	1,600 1,750 1,950	1.0ex 0.0 3.4	tan tan tan	SS S HS	Common brick, fairly good material
213	L 21 H 34	5.4	5	1,850 to 2,050	1,650 1,850 2,050	0.9ex 0.3 1.3	tan tan red	SS S HS	Common brick, fairly good material
214	L 20 H 28	5.5	5	1,850 to 2,050	1,650 1,850 2,050	1.0ex 0.9 4.3	lt. red lt. red dk. red	SS S HS	Common brick
215	L 21 H 34	5.9	12	2,100 to 2,300	1,900 2,100 2,300	0.9 4.7 6.2	tan dk. red chocolate	SS S HS	Common brick, with careful firing
216	L 22 H 28	4.7	6	1,900 to 2,100	1,700 1,900 2,100	0.0 3.0 6.2	lt. red lt. red dk. red	SS S HS	Common brick, with careful firing

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
217	L 20 H 26	4.1	2	1,750 to 2,000	1,600 1,750 1,950	0.3ex 0.3ex 0.6	lt. red lt. red lt. red	SS SS S	Fair ceramic material for common brick
218	L 19 H 23	5.3	11	1,850 to 2,250	1,850 2,050 2,250	1.7 4.5 4.5	tan brown chocolate	S HS HS	Grog for common brick
219	L 24 H 25	--	--	--	--	--	--	--	Unsuitable
220	L 24 H 30	--	--	--	--	--	--	--	Unsuitable
221	L 20 H 22	--	--	--	--	--	--	--	Grog for common brick
222	L 20 H 22	2.4	1	1,800 to 2,000	1,600 1,750 1,950	0.5 0.5 0.5	lt. red lt. red lt. red	SS S HS	Grog for common brick
223	L 21 H 23	2.8	6	1,900 to 2,100	1,700 1,900 2,100	0.0 0.0 0.3	lt. red tan dk. red	SS S HS	Grog for common brick
224	L 20 H 23	2.8	9	1,950 to 2,150	1,750 1,950 2,150	0.0 1.3 3.0	tan tan red	SS S HS	Grog for common brick
225	L 16 H 17	0.8	12	2,100 to 2,250	1,900 2,100 2,300	0.0 0.0 0.0	tan grey green	S S HS	Grog for common brick
226	L 37 H 44	6.3	11	1,950 to 2,150	1,850 2,050 2,250	4.0 12.0 7.5	tan dk. red brown	SS HS HS	Common brick and products of similar grade
227	L 50 H 86	9.0	1	none	1,600 1,750 1,950	1.3 5.5 16.2	tan tan red	SS SS S	Not suitable, poor firing characteristics

Table 2.--Ceramic properties of Montana clays and shales, cont'd.

Sample No.	Water of Plasticity Percent	Drying Shrinkage Percent	P.C.E.	Firing Range °F.	Firing Temperature °F.	Firing Shrinkage Percent	Fired Color	Hardness	Remarks
228	L 32 H 62	9.2	8	none	1,750 1,950 2,150	--	--	--	Not suitable, fired bricks were cracked
229	L 42 H 72	Dried bricks were cracked							Not suitable
230	L 58 H 70	9.3	2	none	1,600 1,750 1,950	0.3 8.0 9.0	tan tan tan	SS SS S	Not suitable, poor firing characteristics
231	L 52 H 62	6.7	1	1,900 to 1,950	1,600 1,750 1,950	1.5 4.5 17.1	tan tan dk. red	SS SS S	Not suitable, poor firing characteristics
232	L 62 H 82	9.1	8	none	1,750 1,950 2,150	--	--	--	Unsuitable, poor firing characteristics
233	L 40 H 44	6.4	1	1,900 to 1,950	1,600 1,750 1,950	0.9 4.8 14.1	tan tan red	SS SS S	Not suitable, poor firing characteristics
234	L 34 H 56	8.9	3	1,800 to 2,000	1,600 1,800 2,000	-0.6 2.9 9.1	lt. red orange dk. red	SS S HS	Common brick, with careful firing
235	L 36 H 50	7.6	5	1,800 to 2,000	1,650 1,850 2,050	0.0 3.3 10.3	tan orange dk. red	SS S HS	Not suitable, poor firing characteristics
236	L 26 H 32	5.4	9	1,950 to 2,150	1,750 1,950 2,150	0.0 2.4 5.8	tan red chocolate	SS S HS	Common brick
237	L 27 H 46	7.8	8	2,050 to 2,150	1,750 1,950 2,150	0.0 0.0 8.5	tan tan green	SS SS HS	Unsuitable, poor firing characteristics
238	L 54 H 130	High grade bentonite							Unsuitable
239	L 53 H 132	High alkali bentonite							Unsuitable

Table 3.--Expandability of Montana clays and shales

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
88	Tertiary Ruby Mts.	--	--	poor	fused @ 2,192°F.	Not suitable
89	Grayson Helena	2,012	1.53	poor	glazed @ 2,282°F.	Not suitable
94	Kootenai Bozeman	--	--	poor	slightly fused @ 2,372°F.	Not suitable
95	Kootenai Bozeman	2,012 to 2,102	1.3	poor	spalled & glazed @ 2,192°F.	Partially expanded, very light product
96	Hell Cr. Reed Point	2,070 to 2,192	-1.0	very good	well-bloated glazed pellets	Good product with wide range
97	Hell Cr. Columbus	2,192	-1.0	very good	well-bloated fused @ 2,192°F.	Good product, but narrow range
98	Judith Riv. Columbus	2,192	-1.0	very good	glazed @ all temp.	Good product below 2,192°F.
99	Judith Riv. Joliet	2,192	-1.0	fair	mixed material 50% bloat	Variable aggregate
100	Ft. Union Washoe	--	--	poor	spalled badly	Not suitable
101	Ft. Union Washoe	2,192 to 2,282	-1.0	fair	fused @ 2,282°F.	Fair product w/ wide range, coarse cell structure
102	Ft. Union Bear Cr.	2,192 to 2,282	-1.0	good	fused @ 2,282°F.	Good product, but brittle; narrow range
104	Cody Warren	2,012 to 2,192	1.0	fair	fused @ 2,192°F.	Might be suitable

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
106	Niobrara Fromberg	--	--	poor	sandy, no change	Not suitable
107	Judith Riv. Billings	2,102 to 2,192	-1.0	very good	glass @ 2,282°F.	Very good bloat, @ narrow, low temp. range
108	Ft. Union Roundup	2,102	-1.0	very good	glass @ 2,102°F.	Very good bloat, @ narrow, low temp. range
110	Ft. Union Roundup	2,192 to 2,282	1.65	fair	glass @ 2,282°F.	Possibly suitable
111	Ft. Union Roundup	2,192	1.2	poor	fused @ 2,192°F.	Poor product, narrow range, poor bloat
113	Bearpaw Melstone	2,192 to 2,282	-1.0	poor	fused & spalled @ 2,282°F.	Poor product, narrow range, bad spalling
114	Lebo Forsyth	2,372	-1.0	good	sticky glaze @ 2,372°F.	Good at maximum economic temp.
115	Lebo Forsyth	2,102 to 2,192	-1.0	poor	spotty material 50% bloat	Variable, bloating characteristics
116	Judith Riv. Forsyth	2,192 to 2,282	-1.0	good	fused @ 2,282°F.	Good product, narrow, high range
117	Judith Riv. Forsyth	2,102 to 2,192	-1.0	good	fused @ 2,192	Good product, narrow range
118	Bearpaw Forsyth	2,192	-1.0	very good	porous fused fragments @ 2,192°F.	Good product, large pores

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
120	Ft. Union Forsyth	2,102 to 2,192	1.1	very good	glazed @ 2,102°F. fused @ 2,192°F.	Good product, narrow range
121	Lebo Moon Crk.	2,012 to 2,372	-1.0	very good	fused @ 2,372°F.	Good product, with wide range
122	Ft. Union Miles City	2,012 to 2,192	-1.0	very good	fused @ 2,192°F.	Good product, with wide range
123	Ft. Union Miles City	2,012 to 2,192	1.4	very good	spalled & fused @ 2,192°F.	Good product, with wide range
124	Ft. Union Baker	2,012 to 2,192	-1.0	very good	minor spalling & fused @ 2,192°F.	Good product, with wide range
125	Pierre Baker	2,012 to 2,192	-1.0	very good	glazed @ 2,192°F.	Good product, with wide range
127	Ft. Union Glendive	2,012 to 2,192	1.2	very good	fused @ 2,192°F.	Good product below 2,192°F.
128	Ft. Union Glendive	2,192	1.4	poor	bloated & fused @ 2,192°F.	Fair product, but spotty & narrow range
129	Ft. Union Glendive	--	--	--	no change	Not suitable
130	Ft. Union Sidney	2,102 to 2,282	-1.0	good	bloated & fused @ 2,282°F.	Best product @ 2,192°F.
131	Ft. Union Sidney	--	--	--	fused @ 2,282°F.	Not suitable

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
137	Ft. Union Jordan	--	--	--	glaze @ 2,192°F.	Not suitable
139	Ft. Union Jordan	2,282 to 2,372	1.2	fair	fused @ 2,372°F.	Fair product, narrow range
140	Ft. Union Jordan	2,192	1.1	poor	fused @ 2,192°F.	Marginal material, narrow range
141	Colorado Mosby	2,012 to 2,102	1.1	very good	glaze @ 2,102°F.	Good product, low, narrow range
142	Colorado Mosby	2,102	-1.0	good	fused @ 2,102°F.	Good product, low, narrow range
143	Claggett Lavina	2,012 to 2,102	-1.0	good	fused @ 2,102°F.	Good product, narrow, low range
144	Judith Riv. Harlowton	2,102 to 2,192	-1.0	very good	fused @ 2,192°F.	Good product below 2,192°F.
145	Eagle Harlowton	2,102	-1.0	fair	badly fused @ 2,102°F.	Might yield good product below 2,102°F.
147	Belt (?) White Sulphur Springs	2,012 to 2,192	1.3	fair	fused @ 2,192°F.	Fair product
151	Alluvium Bearmouth	2,012	1.3	fair	fusion & decreased bloat @ 2,102°F.	Fair bloat, narrow, low range
154	Ft. Union Glendive	2,012 to 2,282	1.1	excellent	fused @ 2,282°F.	Good product below 2,282°F.

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
156	Tertiary Hamilton	--	--	--	fused @ 2,282°F.	Not suitable
157	Tertiary Hamilton	2,192	1.25	fair	fused @ 2,192°F.	Fair product, narrow range
158	Tertiary Hamilton	--	--	--	fused @ 2,282°F.	Not suitable
159	Tertiary Hamilton	--	--	--	fused @ 2,282°F.	Not suitable
160	Belt Plains	--	--	--	no change	Not suitable
161	Pleistocene Moiese	2,102 to 2,192	-1.0	fair	fused @ 2,192°F.	Fair product, narrow range
162	Jurassic (?) Drummond	2,012 to 2,192	-1.0	poor	fused @ 2,282°F.	Marginal, spalls badly, brittle
163	Tertiary Virginia City	--	--	--	fused @ 2,282°F.	Not suitable
164	Pleistocene Troy	--	-1.0	good	bloated & fused @ 2,282°F.	Good product, narrow high range
165	Unknown Ft. Benton	--	-1.0	fair	spalled @ all temp.	Fair product, spalls badly
168	Pleistocene Troy	--	--	poor	darkened in color	Not suitable
169	Pleistocene Yaak	slight change	--	poor	poor	Not suitable
174	Colorado Garrison	--	--	poor	poor	Not suitable
175	Alluvium Creston	--	--	poor	poor	Not suitable

Table 3.-- Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
177	Colorado Cascade	2,000 to 2,200	-1.0	very good	well-bloated glazed pellets	Very good product, wide range
178	Judith Riv. Havre	2,100	-1.0	fair	well-bloated angular pellets	Good product, narrow range
180	Bearpaw Harlem	2,100 to 2,200	-1.0	fair	varied bloating good cell structure	Fair product, narrow range
181	Bearpaw Harlem	2,000 to 2,200	--	good	popcorn-like fine celled glazed	Good product, wide range
183	Hell Cr. Chapman	2,000 to 2,200	-1.0	very good	well-rounded glazed pellets	Very good product, wide range
184	Claggett Malta	--	--	poor	irregular expansion & fusion	Not suitable
185	Claggett Malta	2,000 to 2,200	--	poor	brittle & friable	Not suitable
186	Bearpaw Glasgow	2,200	1.0	fair	rounded, coarse-celled	Fair product, narrow range
188	Ft. Union Four Buttes	--	--	poor	glazed, very minor expansion	Not suitable
189	Ft. Union Flaxville	--	--	poor	no change	Not suitable
200	Ft. Union Culbertson	2,000	1.0	fair	irregular glazed	Not suitable
201	Ft. Union Culbertson	--	--	poor	fused @ 2,102°F. no bloating	Not suitable

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
202	Ft. Union Culbertson	2,200	1.2	fair	popcorn-like bloat @ 2,192°F.	Fair product, very narrow range
203	Bearpaw Oswego	±2,100	-1.0	good	very good bloat @ 2,100°F.	Very good product, narrow range
204	Bearpaw Nashua	2,000 to 2,200	-1.0	very good	glazed, rounded pellets	Very good product, wide range
205	Judith Riv. Malta	--	--	poor	glazed @ 2,300°F.	Not suitable
206	Judith Riv. Malta	--	--	poor	glazed @ 2,100°F.	Not suitable
209	Judith Riv. Fergus	--	--	poor	fused @ 2,100°F.	Not suitable
210	Claggett Hilger	--	--	poor	fused @ 2,200°F.	Not suitable
211	Kootenai Hanover	--	--	poor	fused @ 2,100°F.	Not suitable
213	Kootenai Stanford	--	--	poor	fused @ 2,200°F.	Not suitable
214	Kootenai Stanford	--	--	poor	fused @ 2,200°F.	Not suitable
215	Kootenai Geyser	--	--	poor	slight glaze @ 2,300°F.	Not suitable
227	Miocene Deer Lodge	2,100 to 2,200	1.7	fair	over-bloat @ 2,200°F.	Fair product, very narrow range
228	Pliocene Deer Lodge	--	--	poor	fused @ 2,100°F.	Not suitable

Table 3.--Expandability of Montana clays and shales, cont'd.

Sample No.	Geologic Formation	Expansion Range °F.	Sp. Gr. after Firing	Grade of Product	Firing Behavior	Remarks
229	Pliocene Silver Star	none	--	poor	fused @ 2,100°F.	Not suitable
231	Tertiary Drummond	2,000 to 2,100	1.0	fair	fused @ 2,100°F.	Fair product
235	Unknown Thompson Falls	2,000 to 2,100	1.0	fair	fused @ 2,100°F.	Fair product, narrow range
240	Pumicite Three Forks	2,100	--	poor	fused @ 2,100°F.	Not suitable

Table 4.--X-ray diffraction data on Montana clays and shales

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
86	-	Min*	Maj*	Maj	Min (M)	-	
87	Tra*	Tra	Maj	-	Tra	Maj	
88	-	Maj	Min	-	-	Min	Pumicite
89	-	Med*	Maj	Min	Med (M)	Tra	Gypsum
90	Min	-	Maj	Min	Med (M)	-	Dolomite
91	Med	-	Maj	-	Med (I)	-	
92	Med	-	Maj	-	Min (M)	-	Tobermorite
93	Maj	-	Maj	-	Med	-	Tobermorite
94	Maj	-	Maj	-	Med (I)	Med	Mica
95	Tra	-	Maj	-	Med (I)	-	Hydrobiotite
96	-	Maj	Maj	Maj	-	-	
97	Tra	Med	Maj	Med	-	-	Min. hydrobiotite & amphibole

*Maj = Major; Med - Medium; Min = Minimum; Tra = Trace

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
98	-	Maj	Maj	Maj	-	-	
99	-	-	Maj	Maj	Min (I)	-	Gypsum, hydrobiotite
100	Med	Maj	Maj	-	-	Tra	Gypsum
101	Min	Med	Maj	Min	-	-	Maj. gypsum
102	Tra	Med	Maj	Tra	Min (I)	-	Gypsum, hydrobiotite
103	Tra	Med	Maj	Tra	Med (I)	-	Med. gypsum
104	Tra	Med	Maj	Tra	Med (I)	Tra	Min. gypsum
105	Min	Min	Maj	Tra	-	-	Min. gypsum
106	Tra	Med	Maj	Maj	Min (M)	Med	Min. gypsum
107	Tra	Min	Maj	Tra	Min (M)	Med	Med. gypsum
108	Med	-	Maj	Med	Med (M)	Med	Min. gypsum
109	Min	Med	Maj	Min	Min (I)	-	Min. gypsum
110	Min	Min	Maj	Min	Min (M)	Maj	Dolomite
111	Med	-	Maj	Min	Med (I)	Med	
112	Min	Maj	Maj	Min	Min (I)	Min	Min. gypsum
113	-	Med	Maj	Min	-	Min	Med. gypsum, dolomite
114	Tra	Maj	Maj	Min	Min	Tra	Dolomite
115	-	Maj	Maj	-	Min (M)	-	Gypsum, chlorite
116	-	Maj	Maj	Med	Min	Min	
117	Tra	Maj	Maj	Med	Min (I)		Gypsum, dolomite
118	Tra	Maj	Maj	Min	Min (I)	Min	Chlorite, dolomite
119	-	Maj	Maj	Med	Med (I)	Tra	Chlorite
120	-	Maj	Maj	Min	Min	-	Dolomite
121	Tra	Maj	Maj	Min	Min (I)	Min	Chlorite
122	-	Maj	Maj	Min	-	Min	Gypsum

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
123	Tra	Maj	Maj	Min	-	Tra	
124	Tra	Maj	Maj	Med	-	-	Gypsum
125	-	Maj	Maj	Min	Min (I)	-	
126	Tra	Maj	Maj	Min	Maj (I)	Tra	Amphibole (?)
127	Min	Maj	Maj	Min	Min (I)	-	Hydrobiotite
128	Min	Maj	Maj	Min	Min (I)	-	Hydrobiotite
129	-	-	Maj	Min	Maj (I)	-	Gypsum
130	Min	Min	Maj	Min	Maj (I)	Min	Mica, dolomite
131	Min	Maj	Maj	Min	Maj (I)	Min	
132	-	Med	Maj	Min	Tra (I)	Maj	
133	Min	Med	Maj	Min	Maj (M)	Min	Maj. dolomite
134	Tra	Maj	Maj	Min	Maj (I)	Min	Maj. dolomite
135	Min	-	Maj	Tra	Maj (I)	Maj	Maj. dolomite
136	Tra	-	Maj	Min	Maj (I)	Maj	Maj. dolomite
137	-	Maj	Maj	Tra	Min (I)	-	Chlorite
138	Tra	Min	Maj	Min	Tra	Tra	Chlorite
139	-	Maj	Maj	Min	-	-	Gypsum
140	Tra	Med	Maj	Min	-	-	
141	Tra	Tra	Maj	Min	Med (I)	Maj	Maj. hydrobiotite
142	Tra	Med	Maj	Tra	Tra (I)	Med	Gypsum, dolomite
143	-	-	Maj	Min	Maj (I)	Med	Dolomite
144	-	Med	Maj	Med	Med (I)	Tra	Dolomite
145	Min	Med	Maj	Tra	Med (I)	Maj	Mica, dolomite
146	Maj	-	Maj	-	Maj (I)	Tra	
147	Tra	-	Maj	Min	Med (I)	-	Tra. gypsum

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
148	Tra	Med	Maj	-	Med (I)	Med	
149	Med	-	Maj	Tra	Med (M)	Tra	Dolomite
150	Tra	Tra	Maj	Med	Med (M)	Tra	Tra. gypsum
151	-	Med	Min	Min	-	Maj	Tra. gypsum
152a	-	Tra	Maj	Maj	-	-	Nephelite
152b	Med	Tra	Maj	Min	Med (I)	Tra	Antigorite
153	Tra	Tra	Maj	Min	-	-	
154	Tra	-	Maj	Med	Med (I)	Min	Tra. gypsum
155	-	Min	Med	Med	Maj (I)	-	
156	-	-	Maj	Min	-	Min	Maj. chlorite, min. hornblende
157	-	Maj	Maj	Maj	Min	-	
158	-	Maj	Maj	Maj	Maj	-	Min. dolomite & talc
159	Min	-	Maj	Maj	Maj	-	min. chlorite & talc
160	Maj	Tra	Maj	Min	Maj	-	Min. hydromica & hydrated iron oxide
161	Maj	-	Maj	Min	Maj	Min	Min. chlorite & dolomite
162	Maj	-	Maj	-	Min	-	Min. chamosite
163	-	Maj	Min	Min	-	-	Min. apatite
164							
165	-	Maj	Min	Min	Tra	-	
166	Min	-	Maj	Min	Min	Min	Min. dolomite & hydra-mica; kaolin mineral is metahalloysite
167	Maj	-	Maj	-	Maj	-	Maj. metahalloysite, min. hydrobiotite & hydrous iron oxide

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
168	-	-	Maj	Maj	Maj	Min	Min. chlorite & dolomite
169	Min	Min	Maj	Maj	Maj	Min	Min. chlorite & dolomite
170	-	Tra	Maj	Min	Min	Maj	Min. chlorite, halloysite, hydromica, and complex silicates
171	Med	Tra	Maj	Maj	Maj	Maj	Tra. chlorite
172	Maj	-	Maj	-	Min	-	
173	Maj	Tra	Maj	-	-	-	Tra. hydromica
174	Med	Tra	Maj	Tra	Med	Maj	Tra. chlorite
175	Med	Tra	Maj	Min	Med	Tra	Min. vermiculite
176	Min	Min	Maj	Maj	Min	Med	Min. chlorite & dolomite
177	-	Tra	Maj	Med	Med	-	Min. chlorite, hydromica & gypsum
178	-	Maj	Maj	Min	Maj	-	Chlorite, chamosite, min. talc & dolomite
179	Med	-	Maj	Min	Maj	Min	Complex silicates
180	-	Med	Maj	Min	Maj	-	Gypsum & complex silicates
181	-	Maj	Maj	Maj	Med	-	Gypsum & dolomite
182	-	Maj	Maj	Min	Med	-	
183	-	Min	Maj	Min	Maj	-	Possibly bayerite
184	-	Maj	Maj	Min	Maj	-	Min. chlorite & iron oxides
185	-	Maj	Maj	Min	Med	Tra	Min. chlorite, complex silicates & gypsum
186	-	Tra	Maj	Min	Maj	-	
187	Min	Maj	Maj	Min	Maj	-	Dolomite & min chlorite

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
188	-	Med	Maj	Tra	Maj	-	Chlorite, chamosite, min. goethite & boehmite
189	Maj	-	Med	Tra	Min	-	Tra. complex silicates, & iron oxide
190	-	-	Maj	Min	Maj	Tra	Maj. dolomite, med chamosite, min hydro-mica
191	Min	Min	Maj	Med	Med	-	Chamosite
192	Maj	Min	Maj	Med	Maj	-	Chlorite, maj. dolo-mite
193	-	Min	Maj	Min	Maj	-	Maj. chlorite, min gypsum
194	Min	-	Maj	Min	Med	Tra	Maj. dolomite, med chlorite
195	Med	Min	Maj	Min	Maj	Tra	Min. chlorite
196	Maj	-	Maj	Tra	Med	-	Min. chamosite
197	Maj	Tra	Maj	Tra	Maj	-	Halloysite & min. dolomite
198	Med	-	Maj	Tra	Maj	-	Med. gypsum, tra. hydro-mica & chlorite
199	Min	-	Maj	Tra	Maj	-	Min. dolomite, mica is illite
200	Tra	Tra	Maj	Tra	Maj	Tra	Med. dolomite, mica is illite
201	Med	Tra	Maj	-	Maj	Med	Maj. dolomite, tra chlorite & hydromica
202	Min	Med	Maj	-	Maj	Min	Maj. dolomite, gypsum, min chlorite, chamo-site & hydromica
203	-	Maj	Maj	Min	Med	-	Gypsum
204	Min	Maj	Maj	Tra	Maj	Tra	Tra. complex silicates

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
205	Tra	Med	Maj	Med	Min	Tra	Min. gypsum, chlorite, & dolomite
206	Min	Tra	Maj	Min	Maj	-	Chlorite, dolomite
207	Min	Maj	Maj	Min	Maj	Tra	Chlorite, dolomite, gypsum & complex silicates
208	Tra	Maj	Maj	Med	Maj	-	Chamosite, min. dolo-mite, & iron oxides
209	Tra	Maj	Maj	Min	Med	-	Min. complex sili-cates & chlorite
210	Min	Maj	Maj	Min	Maj	Tra	Min. chlorite
211	Maj	-	Maj	Tra	Maj	Min	Med. dolomite, min. iron oxides & com-plex silicates
212	Med	Med	Maj	Min	Min	-	Min. chlorite & dolomite
213	Min	Min	Maj	Maj	Maj	Maj	Min. hydromica
214	Med	Tra	Maj	Tra	Med	Med	Tra. chlorite
215	Maj	Med	Maj	Tra	Min	-	Med. dolomite, min complex silicates
216	Min	-	Maj	Min	Med	Med	Min. chlorite, & hydromica, med. dolomite, iron oxides
217	Maj	-	Maj	Tra	Med	Med	Med. dolomite, min. chlorite, hydro-mica, iron oxides & complex silicates
218	Maj	Min	Maj	Min	Med	-	Min. hydromica & complex silicates
219	-	-	Min	Tra	Med	Maj	Maj. analcite, med dolomite, min com-plex silicates, tra chlorite

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
220	-	-	Min	Tra	Maj	-	Maj. analcite & dolomite, min chlorite
221	Maj	-	Maj	Med	Maj	-	Chlorite, min. dolomite & complex silicates
222	Med	Tra	Maj	Med	Maj	Maj	Min. hydromica & hematite
223	-	-	Maj	Maj	Maj	-	Med. chlorite, min. apatite
224	Maj	-	Maj	Med	Maj	-	Chlorite, min. talc & hydromica
225	Min	-	Maj	Med	Maj	-	Med. chlorite, chamosite & apatite
226	-	Tra	Maj	Med	Maj	-	Min. chlorite, hydromica, dolomite, metahalloysite, and lepidocrosite
227	-	Maj	Med	Med	Med	-	Maj. chlorite
228	Med	-	Maj	Min	Maj	-	Med. chlorite
229	-	Maj	Min	Med	Min	-	Maj. chlorite
230	Tra	Maj	Med	Med	Min	Maj	Maj. chlorite, min. complex silicates or phosphates
231	-	Med	Min	Med	-	-	Maj. chlorite, min. complex silicates
232	Tra	Maj	Min	Med	-	-	Med. dolomite, min. complex silicates
233	-	Min	Maj	Maj	Maj	-	Min. chlorite & complex silicates
234	Med	Maj	Maj	Min	Maj	Tra	Med. chlorite
235	Min	Med	Maj	Min	Maj	Min	Med. chlorite
236	Min	Min	Maj	Min	Maj	Min	Med. chlorite, min. dolomite
237	-	Min	Maj	Min	Maj	-	Maj. chamosite & dolomite

Table 4.--X-ray diffraction data on Montana clays and shales, cont'd.

Sample No.	Kaolin	Montmor-illonite	Quartz	Feld-spar	Mica or Illite	Calcite	Other
238	Tra	Maj	Maj	Maj	-	Tra	Maj. chlorite, med hydromica
239	Min	Min	Med	Med	Maj	Tra	Med. hydromica & chlorite

Table 5.--Chemical analyses of Montana clays and shales

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
86	64.0	14.4	3.2	3.5	1.2	4.6	2.1	0.40
87								
88	69.8	14.1	1.2	1.3	0.7	2.3	2.7	0.45
89	67.6	16.0	3.2	8.0	4.8	1.7	2.3	0.75
90	54.8	12.0	2.5	0.7	2.5	2.1	2.2	0.50
91	60.0	17.2	8.2	0.4	0.6	0.4	1.9	0.04
92	68.0	23.4	1.8	0.4	0.2	2.2	1.4	0.30
93	73.3	16.1	1.4	0.3	0.2	2.4	1.4	0.75
94	60.6	19.1	3.6	4.3	0.2	0.8	1.3	0.50
95	57.8	24.2	3.9	1.2	0.2	0.9	2.3	0.50
96	60.7	17.3	3.6	2.0	0.2	2.9	2.1	0.60
97	59.7	19.7	4.4	1.2	0.2	2.3	2.0	0.60
98	59.3	20.0	3.7	2.3	0.2	1.2	1.5	0.60
99	66.1	16.1	3.2	1.7	0.2	2.4	1.8	0.60
100	54.5	19.2	4.1	2.0	0.2	0.5	1.8	0.50
101*	56.3	21.5	3.9	1.1	0.2	0.5	1.6	0.50

*P_2O_5 = 0.10

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
102	58.1	19.8	2.8	4.5	0.4	0.5	1.5	0.65
103	62.3	15.5	3.8	2.0	0.2	0.5	2.1	0.70
104	61.0	17.0	5.0	2.0	1.5	0.1	3.6	0.70
105	63.4	14.7	3.2	1.8	0.7	1.0	2.1	0.50
106	63.0	14.1	3.1	4.0	2.8	1.3	1.8	0.30
107	56.6	15.2	2.8	4.8	2.6	2.0	0.9	0.40
108	66.2	17.5	3.2	0.6	3.1	1.3	3.0	0.30
109	59.1	16.1	3.0	4.2	1.1	0.6	1.9	0.50
110	52.6	13.3	4.4	5.0	3.3	0.7	2.2	0.50
111	54.0	19.0	4.5	4.1	3.5	1.7	0.8	0.60
112	57.7	19.1	4.2	2.2	4.0	2.0	1.4	0.60
113	55.4	18.7	4.3	1.8	2.0	2.1	0.8	0.70
114	60.5	16.5	2.7	1.1	1.3	1.6	1.2	0.70
115	59.6	20.0	2.2	1.0	0.4	2.1	0.9	0.30
116	59.7	15.9	2.5	3.0	2.0	1.8	1.7	0.40
117	57.4	15.0	2.8	4.0	2.1	1.1	1.8	0.30
118	58.6	19.5	4.0	1.0	0.7	0.5	1.3	0.30
119	70.0	15.3	2.7	1.0	1.4	0.9	1.7	0.60
120	55.1	16.8	3.4	1.2	3.2	1.7	1.1	0.70
121	60.1	17.7	3.0	1.0	1.2	1.9	0.3	0.60
122	56.3	19.6	4.0	1.6	1.8	1.6	1.1	0.50
123	59.0	20.0	3.6	3.7	1.3	1.5	0.8	0.60
124	57.2	18.6	4.7	1.4	1.7	1.5	0.8	0.70
125	55.0	16.8	3.5	1.9	1.5	0.9	0.8	0.60
126	72.0	17.1	1.9	1.4	1.8	1.1	1.2	0.50

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	Cao	MgO	Na_2O	K_2O	TiO_2
127	56.2	15.8	3.0	1.0	1.2	1.4	1.0	0.60
128	61.2	17.7	3.7	0.8	1.5	0.8	1.0	0.70
129	63.1	18.3	3.5	0.5	0.9	2.1	2.9	0.6
130	53.4	16.3	3.0	6.4	4.0	1.1	2.5	0.40
131	57.3	15.4	2.7	6.3	3.3	1.3	2.1	0.40
132	50.8	15.5	2.9	6.7	5.1	1.2	1.8	0.50
133	50.9	16.4	3.1	5.5	3.6	1.0	2.5	0.20
134	51.0	15.5	2.7	8.0	4.9	1.5	2.0	0.40
135	47.4	15.5	2.8	10.2	3.8	1.5	2.5	0.45
136	63.4	16.5	2.8	2.2	0.1	1.4	2.3	0.50
137	61.6	20.0	3.3	0.8	0.8	2.0	0.8	0.60
138	57.7	19.0	4.3	1.8	1.7	1.1	2.5	0.60
139	63.5	17.4	4.2	1.1	1.1	1.2	0.6	0.60
140	61.1	16.5	3.3	2.2	2.0	1.6	1.5	0.50
141	59.0	14.8	2.8	4.0	2.8	1.6	1.6	0.40
142	51.0	15.1	3.2	6.6	2.2	1.6	1.3	0.40
143	57.4	15.0	3.3	4.7	2.6	2.0	1.4	0.30
144	60.7	14.5	3.0	3.3	2.1	2.2	1.6	0.30
145	54.8	14.0	3.5	7.0	3.3	2.0	1.5	0.30
146	49.7	27.0	5.7	1.7	2.0	1.4	2.1	0.85
147	67.5	16.7	3.2	1.2	1.8	1.2	2.7	0.40
148	59.3	15.5	3.2	6.5	2.5	1.7	1.8	0.50
149	53.0	17.7	3.0	5.4	4.3	1.0	1.6	0.40
150								
151	49.3	14.5	2.2	11.0	0.2	--	--	--

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
152								
153	66.2	16.5	2.0	1.7	0.7	1.6	1.1	0.30
154	57.8	20.6	4.3	2.0	0.2	1.5	0.9	0.80
155								
156	63.4	16.8	3.1	3.5	2.0	2.3	1.2	0.5
157	64.6	15.4	3.7	1.8	2.1	2.4	1.2	0.5
158	74.8	13.0	2.5	2.0	1.1	1.4	0.6	0.5
159	64.4	18.3	3.0	2.2	1.0	1.0	1.3	0.5
160	74.6	14.4	2.6	0.7	0.6	1.1	1.5	0.5
161	57.0	20.6	3.8	3.6	3.1	1.8	3.2	0.4
162	52.4	25.4	5.8	1.1	1.2	1.2	1.1	0.5
163	53.2	21.4	2.3	3.0	3.0	0.9	0.2	0.3
164								
165	64.4	15.8	3.5	0.9	1.8	1.4	2.3	0.3
166	69.8	14.7	3.1	1.5	0.7	2.4	2.0	0.4
167	65.2	16.9	4.0	1.6	1.1	1.5	2.0	0.5
168	69.2	15.6	3.2	2.4	1.1	1.4	1.5	0.5
169	56.2	24.1	5.0	1.1	2.9	0.7	4.9	0.5
170	49.4	14.7	1.1	13.6	1.3	2.5	2.4	
171	67.9	14.9	1.2	6.2	2.1	1.0	2.2	0.2
172	69.9	21.9	0.9	0.5	Nil	0.4	Nil	Nil
173	69.0	23.8	0.6	0.2	Nil	0.4	Nil	Nil
174	55.2	16.6	3.8	8.5	3.2	0.6	1.2	0.1
175	64.5	16.9	3.4	1.5	2.6	0.6	2.7	0.1
176	71.5	14.0	3.3	0.7	0.9	1.4	2.1	0.5

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
177	62.3	16.6	3.0	2.2	1.4	0.7	2.4	0.6
178	61.7	17.2	3.5	1.9	1.7	1.3	1.9	0.6
179	62.5	18.6	4.1	0.9	0.9	1.4	2.0	0.6
180	56.5	19.2	4.5	1.1	0.9	1.4	0.4	0.5
181	60.2	15.8	4.5	2.8	0.8	1.1	2.7	0.5
182	59.8	17.4	4.8	0.8	1.2	1.1	2.7	0.5
183	52.3	17.6	3.5	5.3	1.8	0.3	0.6	0.5
184	58.5	12.6	3.6	6.4	1.0	2.0	2.3	0.5
185	61.4	14.5	2.8	2.2	1.0	1.5	1.8	0.6
186	58.3	15.9	3.6	4.1	1.8	2.7	2.1	0.5
187	60.0	13.5	3.8	4.0	1.8	1.8	1.2	0.4
188	58.4	16.9	4.8	4.1	1.8	1.5	1.1	0.4
189	74.3	15.7	1.3	1.0	0.4	1.0	1.6	0.5
190	59.1	16.4	2.8	4.1	2.5	1.1	1.3	0.5
191	61.3	20.0	3.0	4.0	1.0	1.7	1.3	0.6
192	53.7	15.7	3.0	6.2	2.4	1.8	2.0	0.6
193	66.2	15.6	2.8	1.2	0.9	1.6	2.8	0.6
194	45.7	17.5	2.6	9.8	3.3	1.4	2.7	0.5
195	60.5	22.2	2.2	0.8	0.9	1.1	2.1	0.5
196	63.3	21.1	2.2	0.6	0.4	0.9	1.8	0.5
197	67.6	19.1	2.0	0.4	0.8	1.1	2.1	0.6
198	64.4	18.7	1.5	1.0	0.9	1.4	2.1	0.6
199	63.1	18.3	3.5	0.5	0.9	2.1	2.9	0.6
200	54.1	17.0	3.1	5.3	3.1	0.2	2.6	0.6
201	47.7	16.0	3.0	9.6	3.1	0.7	2.7	0.6

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
202	49.5	17.0	3.2	8.8	4.7	0.6	2.8	0.6
203	55.0	18.8	4.8	1.5	1.4	1.3	2.5	0.6
204	60.1	18.3	4.0	0.8	1.3	1.4	2.6	0.6
205	68.3	16.5	2.2	1.0	0.9	0.8	2.4	0.6
206	63.4	16.5	2.8	2.2	0.1	1.5	3.2	0.5
207	59.4	18.5	4.1	1.2	1.4	1.4	2.3	0.5
208	57.7	19.0	4.3	1.8	1.7	1.1	2.5	0.5
209	58.0	16.8	3.6	2.7	2.6	0.9	2.5	0.6
210	57.6	18.9	4.1	1.5	1.7	1.6	2.5	0.6
211	47.7	17.4	3.2	9.6	1.4	0.3	2.1	0.5
212	59.0	16.1	2.9	3.2	1.2	0.7	2.6	0.5
213	57.7	17.2	2.5	5.5	1.0	0.2	3.2	0.6
214	62.0	16.3	3.8	2.8	0.8	1.1	2.1	0.6
215	61.0	21.6	4.0	1.0	0.7	0.4	2.4	0.6
216	57.2	18.6	4.3	3.5	1.1	0.1	2.6	0.6
217	54.4	15.0	3.6	8.9	1.3	0.3	2.0	0.6
218	63.5	19.5	2.5	1.0	1.1	0.7	2.8	0.6
219	42.3	18.2	4.6	9.6	2.0	2.5	3.5	0.6
220	49.0	19.5	4.0	2.8	3.5	5.1	3.0	0.6
221	62.1	19.5	4.2	0.9	1.9	0.9	3.8	0.6
222	55.3	19.6	4.1	6.5	1.4	2.4	3.4	0.5
223	67.3	16.6	3.5	0.6	1.5	1.1	3.4	0.5
224	62.5	19.6	4.3	0.6	1.7	1.3	2.9	0.4
225	71.4	15.6	2.0	0.6	3.2	0.9	3.6	0.1
226	58.9	20.4	2.2	1.9	0.7	1.9	2.0	

Table 5.--Chemical analyses of Montana clays and shales, cont'd.

Sample No.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
227	60.3	16.2	3.5	2.2	1.1	1.4	2.7	0.5
228	53.4	16.2	4.6	4.1	2.7	0.3	0.7	0.4
229	60.1	16.7	3.5	2.6	3.0	1.7	1.2	0.2
230	59.4	17.8	4.5	1.5	1.8	1.0	1.9	0.4
231	58.7	17.0	3.5	2.7	1.6	0.6	1.1	0.4
232	48.1	15.1	3.2	10.5	2.9	0.6	1.1	0.4
233	57.3	17.3	4.2	3.1	1.3	1.0	1.9	0.5
234	56.1	19.3	4.0	3.0	3.6	1.7	3.2	0.5
235	54.8	20.4	4.3	2.8	3.4	0.8	1.3	0.4
236	65.6	17.8	2.0	1.2	2.2	1.1	2.0	0.6
237	53.5	15.3	2.4	5.8	4.2	1.7	3.2	0.5
238	59.6	17.4	2.2	1.7	1.0	0.3	0.6	0.1
239	55.8	23.0	2.5	1.6	1.0	0.7	1.2	0.1

Table 6.--Acid-soluble alumina in high-aluminum clays and shales

Sample No.	Total Al_2O_3	Soluble Al_2O_3	Soluble Fe_2O_3	Soluble Silica	Remarks
2	20.7	6.4	2.9	2.4	Glacial lake clay, Sanders County
14	27.2	12.4	8.9	2.0	Tertiary bentonitic clay, Missoula Co.
16	20.1	3.2	4.3	1.8	Tertiary bentonitic clay, Florence
17	23.4	8.8	2.6	1.8	Tertiary benontitic clay, Stevensville
31	25.3	6.2	8.0	2.9	Colorado shale, near Drummond
37	24.2	15.1	6.6	1.3	Kay Smith

Table 6.--Acid-soluble alumina in high-aluminum clays and shales, cont'd.

Sample No.	Total Al_2O_3	Soluble Al_2O_3	Soluble Fe_2O_3	Soluble Silica	Remarks
40	20.8	0.9	2.9	1.0	Hydrothermally altered diorite
42	20.3	5.2	12.2	1.4	Belt shale, near Whitehall
43	20.3	3.6	6.0	1.5	Three Forks shale, near Melrose
49	25.6	2.3	7.1	1.6	Kootenai(?) shale, Beaverhead County
51	21.1	14.5	3.4	1.6	Bentonitic shale, near Argenta
52	24.1	12.0	4.1	1.4	Bentonitic shale, near Armstead
53	24.7	11.6	4.0	1.4	Bentonitic shale, near Armstead
54	22.5	5.3	5.7	0.6	Tertiary shale, near Medicine Lodge
56	20.7	3.8	3.9	0.6	Colorado shale at Shelby
62	28.0	12.4	4.0	0.7	Claggett shale near Loma
63	20.6	8.4	6.6	0.7)	Glacial clay derived from Colorado shale in the Great Falls area, Cascade County
64	22.0	8.6	5.9	0.4)	
65	22.3	12.7	5.7	0.7)	
68	26.9	3.8	0.9	0.8	Kootenai shale at Belt
70	30.4	22.8	0.4	0.5	Footwall clay, Running Wolf Fe dep.
71	27.0	5.5	0.9	0.8	Kootenai shale at Armington
72	28.2	4.8	3.4	0.5	Hydrothermally altered rock, Iron Mt.
*73	27.4	1.5	1.1	1.4	Kaolin(?) near Zortman
92	23.4	8.4	--	--	Kootenai shale from Hegg coal mine
95	24.2	11.7	--	--	Kootenai shale near Bozeman
101	21.5	11.4	--	--	Ft. Union fm. near Red Lodge
129	18.3	10.3	3.7	1.3	Ft. Union fm. near Glendive
136	16.5	10.4	3.6	0.8	Ft. Union fm., Garfield County
138	19.0	5.2	1.6	0.7	Ft. Union fm. near Jordan

*For other data, see Nos. 2 through 73, Information Circular 23.

Table 6.--Acid-soluble alumina in high-aluminum clays and shales, cont'd.

Sample No.	Total Al_2O_3	Soluble Al_2O_3	Soluble Fe_2O_3	Soluble Silica	Remarks
146	27.0	13.8	--	--	Belt shale in Meagher County
159	18.3	8.1	--	--	Bentonitic shale near Hamilton
161	20.6	10.2	--	--	Glacial lake shale near Moiese
162	25.4	15.3	--	--	Composite of 60' shale near Drummond
163	21.4	5.6	--	--	Tertiary pumicite, Madison County
169	24.1	9.6	--	--	Glacial clay near Yaak
172	21.9	21.0	--	--)	Material sent in by Adolph Beckstrom of Silesia, from sec. 9, T.13N.,R. 25E., Petroleum County
173	23.8	23.1	--	--)	
191	20.0	11.7	--	--	Shale below Ft. Union coal
195	22.2	15.6	--	--	Ft. Union clay West of Plentywood
196	21.1	16.1	--	--	Clay below sample 195
197	19.1	13.4	--	--	Clay below sample 196
215	21.6	12.5	--	--	Kootenai clay west of Geyser
235	20.4	12.7	--	--	Old Thompson Falls brickyard
239	23.0	7.0	--	--	Material from E. W. Tenney, Billings

Table 7.--Fusing points of Seger cones

Cone Number	When fired slowly 20° C. per hour		When fired rapidly 150° C. per hour	
	°Cent.	°Fahr.	°Cent.	°Fahr.
022	585	1,085	605	1,121
021	595	1,103	615	1,139
020	625	1,157	650	1,202
019	630	1,166	660	1,220
018	670	1,238	720	1,328
017	720	1,328	770	1,418
016	735	1,355	795	1,463
015	770	1,418	805	1,481
014	795	1,463	830	1,526
013	825	1,517	860	1,580
012	840	1,544	875	1,607
011	875	1,607	905	1,661
010	890	1,634	895	1,643
09	930	1,706	930	1,706
08	945	1,733	950	1,742
07	974	1,787	990	1,814
06	1,005	1,841	1,015	1,859
05	1,030	1,886	1,040	1,904
04	1,050	1,922	1,060	1,940
03	1,080	1,976	1,115	2,039
02	1,095	2,003	1,125	2,037
01	1,110	2,030	1,145	2,093
1	1,125	2,057	1,160	2,120
2	1,135	2,075	1,165	2,129
3	1,145	2,093	1,170	2,138
4	1,165	2,129	1,190	2,174
5	1,180	2,156	1,205	2,201
6	1,190	2,174	1,230	2,246
7	1,210	2,210	1,250	2,282
8	1,225	2,237	1,260	2,300
9	1,250	2,282	1,285	2,345
10	1,260	2,300	1,305	2,381
11	1,285	2,345	1,325	2,417
12	1,310	2,390	1,335	2,435
13	1,350	2,462	1,350	2,462
14	1,390	2,534	1,400	2,552
15	1,410	2,570	1,435	2,615
16	1,450	2,642	1,465	2,669

Table 7.--Fusing points of Seger cones, cont'd.

Cone Number	When fired slowly 20° C. per hour		When fired rapidly 150° C. per hour	
	°Cent.	°Fahr.	°Cent.	°Fahr.
17	1,465	2,669	1,475	2,687
18	1,485	2,705	1,490	2,714
19	1,515	2,759	1,520	2,768
20	1,520	2,768	1,530	2,786
23			1,580	2,876
26			1,595	2,903
27			1,605	2,921
28			1,615	2,939
29			1,640	2,984
30			1,650	3,002
31			1,680	3,056
32			1,700	3,092
33			1,745	3,173