STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
E. G. Koch, Director

BULLETIN 45

PROGRESS REPORT ON CLAYS AND SHALES OF MONTANA 1962-1964

by

J. M. Chelini, Montana Bureau of Mines and Geology,
R. I. Smith, Montana School of Mines, and
D. C. Lawson, Montana Bureau of Mines and Geology

MONTANA SCHOOL OF MINES
Butte, Montana
March 1965

CONTENTS

ILLUSTRATIONS

TABLES

PROGRESS REPORT ON CLAYS AND SHALES OF MONTANA 1962-1964

by

J. M. Chelini, R. I. Smith, and D. C. Lawson

ABSTRACT

This report, fourth in a series of progress reports on a survey designed to catalog the clay and shale deposits of the state and to determine possible uses, if any, of the raw materials sampled, contains a description of 72 samples. The clays are tested for use as ceramic raw materials, as possible sources of expanded shale (lightweight aggregate for concrete), and as possible sources of alumina for the production of metallic aluminum.

INTRODUCTION

This bulletin is the fourth progress report on the survey of Montana's clay and shale resources, and is supplementary to the first three (Sahinen, U. M., Smith, R. I., and Lawson, D. C., 1958, 1960, and 1962). The purpose of the project is to catalog the clay and shale deposits of the state. It is intended to sample likely clay and shale deposits and to determine possible uses, if any, of the material sampled. The clays are tested for possible use as ceramic raw materials or as possible sources of expanded shale (lightweight concrete aggregate), and analyzed 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. The project was temporarily suspended during the 1961-63 biennium because of the drastic cuts in Bureau appropriations by the economy-minded 1961 Legislature. 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 withholding the results until the entire survey is completed.

ACKNOWLEDGMENTS

The geological examination of the site and the collection of samples of Glacial Lake Missoula clays (Samples 388-409) were done by J. M. Chelini. Other clay samples were supplied either by private individuals or by members (or former members) of the Bureau staff. Chemical analyses for substances other than sodium and potassium were made by Frank Jones, Montana Laboratories, and Goodall Brothers, assayers. Sodium and potassium determinations were made with a flamephotometer by Don C. Lawson, who also performed the bloating tests. X-ray analyses and ceramic tests were made by Ralph I. Smith.

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 each of these is acknowledged in the description.

CLAY AND SHALE FOR CERAMIC USE

GENERAL STATEMENT

Field trips are conducted each summer to gather samples and to get sufficient geologic data to determine whether 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 whether they are suitable for the manufacture of expanded shale (lightweight aggregate for concrete).

All 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 to indicate the plasticity. 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 after the cut. This is the upper limit of plasticity. The amount of water used is expressed in percent, 1 gram being the weight of 1 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 at temperatures to 2400°F is done in a Hayes Glo-Bar electric furnace equipped with a thermocouple and pyrometer accurate to 5°C (9°F). Firing above 2400°F is done in a Denver Fire Clay cone furnace fired with natural gas.

Test bricks 1 x 1 x 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, the thermocouple pyrometer being used for temperature control. The bricks are removed from the furnace when the predetermined temperature has been reached and then placed in another furnace at 1200°F. When the firing is finished, the furnace is turned off and the test bricks allowed to cool overnight. For specimens requiring temperature greater than 2400°F the Denver Fire Clay furnace is used, and the temperature is 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, the tests permit a good estimate 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 LIGHTWEIGHT AGGREGATE

INTRODUCTION

Expanded clay or shale for use as a lightweight aggregate 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, use of expanded clay and shale for lightweight aggregate increased very slowly. From the start of the war until 1946 there was a tremendous upswing in value of lightweight 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 partly 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 soundproofing qualities when used in ceilings and partitions.

Considerable research on lightweight aggregate material in the last 19 years has led to the following generalized conclusions:

(1) That in order to be classified as a lightweight aggregate, the material must weight 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 not determined 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 conditions necessary to bring about bloating in shales:

(1) When bloating temperature is reached, the general clay mass must be in a semimolten condition.

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

Under these conditions, the developed gases are entrapped in the fusion and cause the bloating.

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 tests should be made. The work done by the Bureau as described in this report is necessarily of a preliminary nature. Many clays and shales are tested in order to establish which ones are most suitable for bloating.

The bloated clay or shale produced by the expanding procedure shows which clays or shales can be treated for use as lightweight aggregate. In general, expanded clay or shale in well-rounded pellets, partly glazed, and of uniform fine cell structure is ideal for lightweight aggregate. The final test, however, is whether a concrete block in which the lightweight aggregate is used will meet all required specifications. Lightweight aggregate must weigh not more than 75 pounds 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.

Non-load-bearing blocks of 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. Weight of the 8 x 8 x 16-inch blocks can range between 24 and 40 pounds.

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 whether they could be used as raw materials for expanded-shale lightweight aggregate for concrete. The material used for bloating is minus 3/4 inch plus 1/2 inch unless the original sample fragments are of a smaller size.

The firing is done in a heavy-duty Glo-Bar electric muffle furnace controlled by a thermostat that allows only a 5°C (9°F) drop in temperature. The samples require preheating. The firing is done at 2000° to 2400°F in steps of 100°F for 20 minutes per run.

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, are 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 100 mesh for x-ray and chemical analyses. The x-ray determinations are made with a Phillips-Norelco diffractometer. Copper radiation is used for all 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 15 minutes and a new trace made. If necessary, further treatments are made such as saturation with glycerin 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. Standard methods are used throughout. Analyses are given in Table 5 of the Appendix. Samples that contain more than 20 percent alumina are reanalyzed for available alumina.

DESCRIPTION OF CLAY SAMPLES AND DEPOSITS

SAMPLE 349

Sample 349 is from an 8-foot section of thin-bedded yellowish-gray (5Y8/1)* lake-bed clays, collected by F. A. Crowley.** The sample was taken about 100 yards west of the underpass on the north side of U. S. Highway 2 at the east end of Kalispell in the NW$\frac{1}{4}$ sec. 8, T. 28 N., R. 21 W.

The material is an illitic calcareous clay of low plasticity and fair working properties. Close control during firing would produce a fair common brick and similar ceramic products. The clay is unsuitable for production of expanded aggregate.

SAMPLE 350

Sample 350 is from a 6-foot section of thin-bedded pinkish-gray (5YR8/1) lake-bed clay, collected by F. A. Crowley. The sample was taken from a road bank about a quarter of a mile south of the underpass and just north of the northeast boundary of Woodland Park in Kalispell, in the SW$\frac{1}{4}$ sec. 8, T. 28 N., R. 21 W.

The material is an illitic calcareous clay of low plasticity and fair working properties. Close control during firing would produce a fair common brick and similar ceramic products. The clay is unsuitable for production of lightweight aggregate.

It is reported that ceramic clubs in Missoula have used this clay for making ceramic ware.

SAMPLE 351

Sample 351 is representative of a 3-foot zone of clay exposed at the base of a bluff composed of 100 feet of silty clay. The sample was taken by F. A. Crowley from the Manuel V. Bauska horse farm in the S$\frac{1}{2}$ sec. 5, T. 28 N., R. 21 W.

The material is a soft pinkish-gray (5YR8/1) illitic calcareous clay of low plasticity and only fair working properties. The firing range is too narrow for the clay to be used in the ceramic industries. It is not suitable as source material for expandable aggregate, as it fuses without bloating.

----

*Color names and designations from "Rock Color Chart" distributed by the Geological Society of America.
**Bureau Economic Geologist, 1958-1962.

SAMPLE 352

Sample 352 is from a 5-foot silty clay and was collected by F. A. Crowley from the material overlying Sample 351. It was taken about a quarter of a mile west of Sample 351 and about 3 feet from the top of the bluff in the SW$\frac{1}{4}$ sec. 5, T. 28 N., R. 21 W.

The material is a soft yellowish-gray (5Y8/1) silty clay of low plasticity and fair working properties. The color of the fired brick is not as pleasing as is generally desired, but if handled with care during firing the material could be used for common brick and similar ceramic products. If blended with a more plastic clay, a better product could be obtained.

SAMPLE 353

Sample 353 is a sample of a 2-foot clay, collected by F. A. Crowley, from a ditch a half mile east of Nita G. Robbin ranch house on the east side of Flathead Lake in the NE$\frac{1}{4}$ sec. 3, T. 27 N., R. 20 W.

The material is a soft yellowish-gray (5Y8/1) illitic calcareous clay of low plasticity and fair working properties. The firing range is too narrow for the clay to be used profitably in the ceramic industries. The material produces a good expanded product at a firing range between 2217° and 2372°F, which is somewhat narrow and high relative to more suitable source materials.

SAMPLE 354

Sample 354 is from a 4-foot section of clay in outcrop along the bank of the North Fork Flathead River. The sample was taken by F. A. Crowley about 100 feet north of the junction of Whale Creek and North Fork Flathead River in the SE$\frac{1}{4}$ sec. 30, T. 36 N., R. 21 W.

The material is soft light-gray (N7) illitic clay of fair plasticity and working properties and good firing characteristics. The fired product is dark green. The clay would perform best if blended with other clays. Expanding tests were negative.

SAMPLE 355

Sample 355 is a 10-foot silty clay, which is underlain by a thick sequence of more sandy material. The sample was collected by F. A. Crowley from the top of a large road cut on the north side of the road, about a half mile north of Polebridge store on North Fork road near the line between sec. 21 and 22, T. 35 N., R. 21 W.

The material is soft yellowish-gray (5Y8/1) illitic clay of fair plasticity and working properties and good firing characteristics. The fired product is dark green. The clay would perform best if blended with other clays. Expanding tests were negative.

SAMPLE 356

Sample 356 is a 10-foot clay in contact with bouldery till. The material was collected by F. A. Crowley from the top of a road cut on the north side of U. S. Highway 2 about 2.6 miles east of the junction with the road to Little Bitterroot Lake, in the W$\frac{1}{2}$ sec. 12, T. 27 N., R. 24 W.

The material is soft pinkish-gray (5YR8/1) illitic clay of fair plasticity and working properties and good firing characteristics. The fired product is dark chocolate red. A fair expanded product was obtained in a firing range of 2200° to 2300°F, which is somewhat narrow, necessitating close control during bloating.

SAMPLE 357

Sample 357 is a 10-foot thin-bedded lake-bed clay collected by F. A. Crowley from the east side of a road cut 3.2 miles northwest of Polson bridge, in the W$\frac{1}{2}$ sec. 29, T. 23 N., R. 20 W.

The material is a soft pinkish-gray (5YR8/1) illitic siliceous clay of low plasticity and fair working properties. Because of its narrow firing range it is not suitable for use in the ceramic industries or as source material for expanded aggregate.

SAMPLE 358

Sample 358 is a 12-foot thin-bedded lake-bed clay collected by F. A. Crowley from the east side of a road cut on U. S. Highway 93 in the NW$\frac{1}{4}$ sec. 32, T. 23 N., R. 20 W.

The material is a yellowish-gray (5Y8/1) illitic clay of low plasticity, poor working properties, and narrow firing range. Expandable-aggregate tests were negative.

SAMPLE 359

Sample 359 is a 3-foot thin-bedded lake-bed clay collected by F. A. Crowley from a ditch on the north side of the road south of Pablo reservoir in the SE$\frac{1}{4}$ sec. 34, T. 22 N., R. 20 W.

The material is a yellowish-gray crumbly illitic clay of low plasticity, poor working properties, and narrow firing range. Expanded-aggregate tests were negative.

SAMPLE 360

Sample 360 is a 6-foot thin-bedded lake-bed clay collected by F. A. Crowley from a road cut in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 21, T. 21 N., R. 20 W.

The material is a white (N9) illitic clay of low plasticity, poor working properties, and narrow firing range. Expanded-aggregate tests were negative.

SAMPLE 361

Sample 361 is a 6-foot thin-bedded lake-bed clay collected by F. A. Crowley from a road cut in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 30, T. 21 N., R. 20 W.

The material is a pale-orange (10YR8/2) illitic clay of low plasticity, poor working properties, and narrow firing range. Expanded-aggregate tests were negative.

SAMPLE 362

Sample 362 is a 15-foot thin-bedded lake-bed clay collected by F. A. Crowley from a road cut 1.9 miles east of Round Butte schoolhouse, in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 35, T. 21 N., R. 21 W.

The material is a grayish-orange-pink (5YR7/2) illitic clay of low plasticity, poor working properties, and narrow firing range. Expanded-aggregate tests were negative.

SAMPLE 363

Sample 363 is a 4-foot slightly pebbly clay collected by F. A. Crowley from a road cut 4 miles south and 0.4 mile east of Ronan, in the SE$\frac{1}{4}$ sec. 23, T. 20 N., R. 20 W.

The material is a yellowish-gray (5Y8/1) illitic clay of low plasticity, poor working properties, and narrow firing range. Expanded-aggregate tests were negative.

SAMPLE 364

Sample 364 is a 6-foot silty clay collected by F. A. Crowley from a road cut 10.2 miles south of Yellow Bay State Park along the east shore of Flathead Lake, in the NE$\frac{1}{4}$ sec. 28, T. 23 N., R. 19 W.

The material is a yellowish-gray (5Y8/1) illitic siliceous clay of low plasticity and poor working properties. Firing characteristics are fair, although the firing range is narrow. With careful handling and blending, the clay could be used for manufacture of common brick and similar ceramic products. The clay is not suitable for production of expanded aggregate.

SAMPLE 365

Sample 365 is a 10-foot lake-bed clay collected by F. A. Crowley from a bank 4.3 miles north and 0.6 mile northeast of Arlee, in the W½ sec. 23, T. 17 N., R. 20 W.

The material is a pinkish-gray (5YR8/1) illitic clay of fair plasticity and working properties. The firing range, however, is narrow. With careful handling and blending, the clay could be used for manufacture of common brick and similar ceramic products. The material is unsuitable for manufacture of expanded aggregate.

SAMPLE 366

Sample 366 is a sample of 6 feet of Three Forks Shale collected by Dave Rife* from an exposure near the top of the formation on the east side of a road 0.3 mile south of the Camp Creek road in the S½ sec. 19, T. 2 S., R. 8 W.

The material is a hard greenish-gray (5GY6/1) illitic siliceous clay of low plasticity and fair working and firing properties. It can be used for the manufacture of common brick and similar ceramic products.

The material produces an excellent expanded product at 2372°F and a fair product at 2282°F. These temperatures are high; excellent products are obtained from other, more suitable clays at temperatures of about 2100°F.

SAMPLE 367

Sample 367 is a sample of 6 feet of Three Forks Shale collected by Dave Rife from an exposure near the center of the formation, 0.3 mile south of the Camp Creek road, in the S½ sec. 19, T. 2 S., R. 8 W.

The material is a hard grayish-orange (10YR7/4) illitic siliceous clay of low plasticity and fair working and firing properties. It can be used for the manufacture of common brick and similar ceramic products.

The material produces an excellent well-rounded glazed expanded product over a wide temperature range (2100° to 3350°F). The average specific gravity of the product is 1.9.

*Bureau field assistant, summer 1962.

SAMPLE 368

Sample 368 is a sample of 6 feet of Three Forks Shale collected by Dave Rife* from exposures near the bottom of the formation, in the S$\frac{1}{2}$ sec. 19, T. 2 S., R. 8 W.

The material is a hard pale-yellowish-brown (10YR6/2) illitic siliceous clay of low plasticity and fair working and firing properties. It can be used for the manufacture of common brick and similar ceramic products.

The material produces a good expanded product at 2082°F. Further firing at higher temperature decreased the quality of the product. The average sp. gr. of the material expanded at 2082°F is 1.7.

SAMPLE 369

Sample 369 is a sample of 6 feet of Three Forks Shale collected by Dave Rife from exposures near the middle of the formation, 2.3 miles up Soap Gulch road in the N$\frac{1}{2}$ sec. 12, T. 2 S., R. 9 W.

The material is a grayish-orange (10YR7/4) argillaceous dolomite having no ceramic or expanding properties.

SAMPLE 370

Sample 370 is a sample of 4 feet of argillaceous limestone collected by Dave Rife from the Amsden Formation(?) 6 miles southeast of the Twin Bridges road junction with U. S. Highway 91 in sec. 17, T. 3 S., R. 8 W.

The material is a medium-gray (NG) mottled argillaceous limestone having no ceramic or expanding properties.

SAMPLE 371

Sample 371 is a sample of 15 feet of silty clay, approximately 50 feet thick in outcrop, 1.1 miles east of the Bill Garrison ranch and about 200 yards north of the road on the north side of Big Hole River in T. 4 S., R. 9 W.

The material is a yellowish-gray (5Y8/1) bentonitic clay containing montmorillonite and feldspar. The material is unsuitable for ceramic use. Expanding tests showed minor expansion at 2192°F.

----

*Dave Rife, Bureau field assistant, summer 1962.

SAMPLE 372

Sample 372 was collected by Dave Rife from a dark shale 3.7 miles east of the Bill Garrison ranch on the north side of Big Hole River in T. 4 S., R. 9 W.

The material is a medium-gray (N7) siliceous illitic shale of low plasticity and fair working properties. The material, when fired at 1950°F, produced a pleasing buff-colored product; however, the material alone is unsuitable for the manufacture of ceramic products, but could be used in the industry as a grog or flux with other clays. Expanding tests are negative.

SAMPLE 373

Sample 373 is a sample of 7 feet of varicolored shale, collected by Dave Rife from a road cut 1.3 miles north of U. S. Highway 10 along State Highway 281, in the N$\frac{1}{2}$ sec. 33, T. 2 N., R. 3 W.

The material is a hard light-olive-gray (5Y4/1) illitic siliceous clay of fair plasticity and working properties. The material has good firing characteristics and could be used for manufacture of common brick and similar ceramic products.

SAMPLES 374 and 375

Samples 374 and 375 were sent to the Bureau by Frank G. Ryburn, 16 North Atlantic, Dillon. No location was indicated.

The material contained in sample 374 is an impure limestone having no ceramic properties. Sample 375 is a hard yellowish-gray (5Y8/1) illitic clay containing much feldspar. The plasticity is extremely low and the working properties poor. Firing properties are fair except for a narrow firing range. Best results for product manufacture would be obtained if this material is blended with a more plastic clay.

SAMPLE 376

Sample 376 was collected by E. H. Gilmour* in the SW$\frac{1}{4}$ sec. 18, T. 32 N., R. 23 W.

The material is a very pale orange (10YR8/2) illitic clay of good plasticity and working properties. It would be desirable to use for common brick and similar ceramic products. The clay is not suitable for manufacture of expanded aggregate.

----

*Recipient of Bureau-sponsored geologic mapping fellowship, 1962.

SAMPLE 377

Sample 377 was collected by E. H. Gilmour along Fortine Creek in Lincoln County. No location by township and range was received.

The material is a grayish-yellow (5Y8/4) illitic clay of low plasticity. The clay could be used for manufacture of common brick, but careful handling would be necessary. The clay is unsuitable for use as a source of expanded aggregate.

SAMPLE 378

Sample 378 was collected by W. D. Page* in the NE¼ SW¼ sec. 22, T. 25 N., R. 24 W.

The material is a yellowish-gray (5Y8/1) illitic clay containing a medium amount of kaolinite. It has low drying shrinkage and good firing range and is good material for manufacture of common brick and similar ceramic products. Expanded-aggregate tests were negative.

SAMPLE 379

Sample 379 was collected by W. D. Page in the NE¼ SW¼ sec. 22, T. 25 N., R. 24 W.

The material is a yellowish-gray illitic clay of low plasticity and low drying and firing shrinkage. It could be used for manufacture of common brick but would require careful handling. Expanded-aggregate tests were negative.

SAMPLE 380

Sample 380 was collected by W. D. Page in sec. 18, T. 25 N., R. 24 W.

The material is a yellowish-gray illitic kaolinitic clay having extremely low plasticity. Blended with a more plastic clay, the material would be suitable for grog in manufacture of common brick and similar ceramic products. Expanded-aggregate tests were negative.

SAMPLE 381

Sample 381 was collected by Willis Johns** from the Dalimata ranch in the SW¼ sec. 7, T. 31 N., R. 17 W.

----

*Recipient of Bureau-sponsored geologic mapping fellowship, 1962.
**Bureau economic geologist, head of Kalispell field office from 1958 to 1964.

The material is a yellowishish-gray (5Y8/1) illitic chloritic clay having fair plasticity. Careful handling of the clay during processing and firing could produce a suitable common brick. Expanded-aggregate tests were negative.

SAMPLE 382

Sample 382 was collected by Willis Johns from the Burdick ranch in the SW$\frac{1}{4}$ sec. 18, T. 31 N., R. 22 W.

The material is a grayish-pink chloritic clay of medium plasticity and good working properties. The clay can be used for manufacture of common brick and similar ceramic products. Expanded-aggregate tests were negative.

SAMPLE 383

Sample 383 was collected by Willis Johns in the SE$\frac{1}{4}$ sec. 23, T. 20 N., R. 20 W.

The material is a yellowish-gray illitic kaolinitic clay of very low plasticity, poor working properties, and narrow firing range. Blended with a more plastic clay it could be used to make common brick and similar ceramic products. Expanded-aggregate tests were negative.

SAMPLE 384

Sample 384 was received by the Bureau from Mrs. L. Dustin, 2704 Sixth Avenue South, Great Falls, Montana. It is reported to have been collected in T. 32 N., R. 23 W.

The material is yellowish-gray (5Y8/1) impure kaolin clay of low plasticity and good working properties. The clay can be used for manufacture of common brick and similar ceramic products. It is not suitable for the manufacture of expanded aggregate.

SAMPLE 385

Sample 385 was received by the Bureau from H. B. Syverud Dagmar, Montana. It is reported to have been collected in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 13, T. 34 N., R. 57 E.

The material is a yellow impure kaolin clay of good plasticity and working properties. The clay can be used for manufacture of common brick and similar ceramic products. It was not tested for expandability.

SAMPLES 386 A and B

Samples 386 A and B were received by the Bureau from Judge Leonard DeKalb of Lewistown. It was collected in sec. 26, T. 18 N., R. 15 E.

The material of Sample 386 A is almost pure kaolin and was collected from the Whiteware clay deposit in the South Moccasin Mountains. This clay also has been reported as Sample 74 in Montana Bureau of Mines and Geology Information Circular 23, Progress Report on Clays of Montana, but was reported erroneously as dickite. The material is a flint clay of low plasticity. It burns white. Blended with a white-firing plastic clay, the material could be used for many high-standard ceramic products.

Sample 386 B is composed of about 15 percent kaolin and 85 percent potassium-rich feldspar, quartz, and mica. The plasticity is extremely low, as is the wet strength. When fired to 2300°F the product becomes well bonded with glass and has a slight pink tinge. Blended with a more plastic material it would produce a good ceramic product. The material itself would possibly be best used as a blending material in a plastic clay, thus utilizing the feldspar content. Expandable-aggregate tests were not performed on this sample.

SAMPLE 387

Sample 387 was collected by U. M. Sahinen, associate director of the Bureau, from beds mapped by Rector (1963) as Woolsey Shale. Similar rocks in northwestern Montana were correlated with the Gordon Shale by Howell and others (1944). The sample was taken from the southwest corner of SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 26, T. 24 N., R. 28 W.

The material is a fairly pure kaolinite of low plasticity but good working and firing properties. It will make good brick and similar ceramic products. The material was not tested for expandability.

SAMPLES 388 to 409

Location

Samples 388 to 409 were collected by the author and Don C. Lawson in the summer of 1962 from Glacial Lake Missoula clay, of Pleistocene age. Samples 388 to 392 were collected from a small knoll on the east end (above the abandoned stock-car racetrack) of East Missoula in the SE$\frac{1}{4}$ sec. 13, T. 13 N., R. 19 W. (Fig. 1). Samples 393 to 409 were collected from a larger area (Fig. 2) just west of Missoula and south of the Missoula County airport in T. 13 N., R. 20 W.

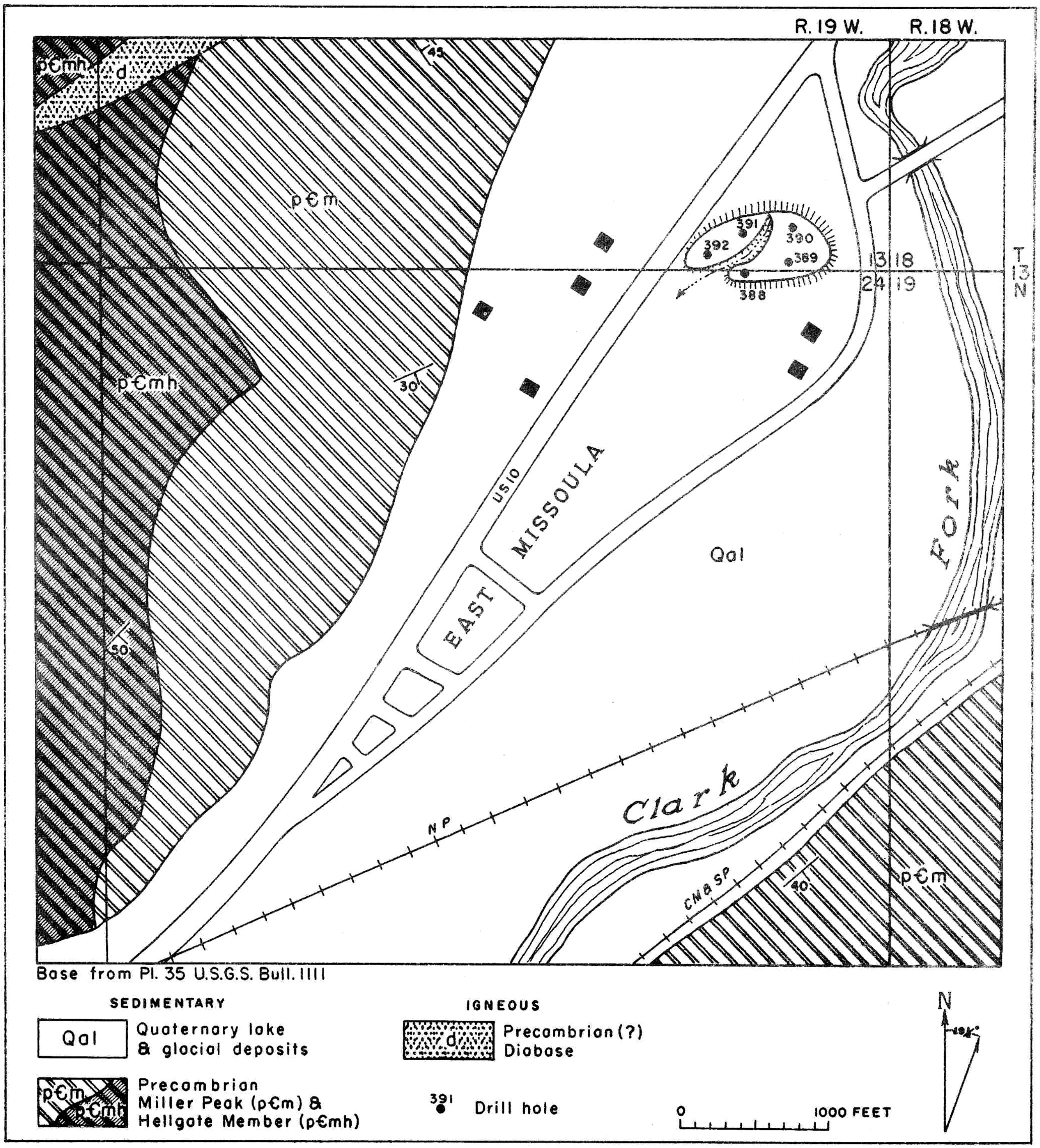


Figure 1.--Sketch map of East Missoula area showing geology and location of drill holes in Glacial Lake Missoula clay in the SE$\frac{1}{4}$ sec. 13, T. 13 N., R. 19 W., Missoula County.

Sampling Procedure

Holes at both localities were drilled to a depth of 9 feet with a McCulla power two-man (back-breaking) auger. The total cuttings from each hole were mixed on a sample cloth and quartered. In the laboratory, each sample was further mixed and cut to about 5-pound samples. All tests were performed on these fractions.

In the area west of Missoula, the holes were spaced every half mile; the five holes in the area east of Missoula were spaced for convenience of drilling.

Geology

Glacial Lake Missoula was formed when ice from the Cordilleran ice sheet in British Columbia moved southward down the Purcell Trench of northern Idaho and dammed the Clark Fork River near the Montana-Idaho line. This damming created a lake that reached a maximum altitude of about 4,200 feet above sea level. Its maximum depth near the ice dam was 2,000 feet and its area is estimated as 2,900 to 3,100 square miles. Water backed up about 200 miles; it extended into the Bitterroot Valley more than 60 miles south of Missoula, and into the Blackfoot Valley 25 miles east of Missoula. Interconnected valleys south and west of Polson also were flooded (Perry, 1962).

In the quiet central parts of the lake, somewhat distant from the feeder streams, varved clay of considerable total thickness was formed. Even today, after much erosion, total thickness of the remaining clay beds exceeds 100 feet. At the DeSmet school, about 5 miles west of Missoula (Fig. 2), water-well logs show the clay to be 80 feet thick; at the Forest Service Fire Research Center the clay has been logged to a depth of 85 feet; at the airport, 111 feet; and at the cemetery south of the airport, 115 feet. A Northern Pacific Railway Co. cut about 1 mile in length and 40 feet in depth, in sec. 30, T. 14 N., R. 20 W., exposes Glacial Lake Missoula clay throughout.

After Glacial Lake Missoula was drained, much of the lacustrine sediment was removed by erosion. The clay within the Missoula Valley and elsewhere was reworked or washed away by the Clark Fork and its tributaries. Today three distinct lithologies can be mapped (Fig. 2): (1) The Recent alluvium (Qfa) is composed mainly of poorly sorted, unconsolidated silt, sand, and gravel, and is found on the flood plains of Ninemile Creek, Clark Fork and Bitterroot Rivers, and in the slope, gully, and stream wash associated with their tributaries; (2) Subrecent alluvium (Qta), which is mainly a thin mantle of reworked Lake Missoula silty clay and poorly sorted, unconsolidated sand and gravel found on low terraces marginal to the flood plains of the Clark Fork and Bitterroot Rivers and their tributaries; and (3) Pleistocene glaciolacustrine deposits, which are semiconsolidated varved clay and silt underlying the high terraces (McMurtrey, Konizeski, and Brietkrietz, in press).

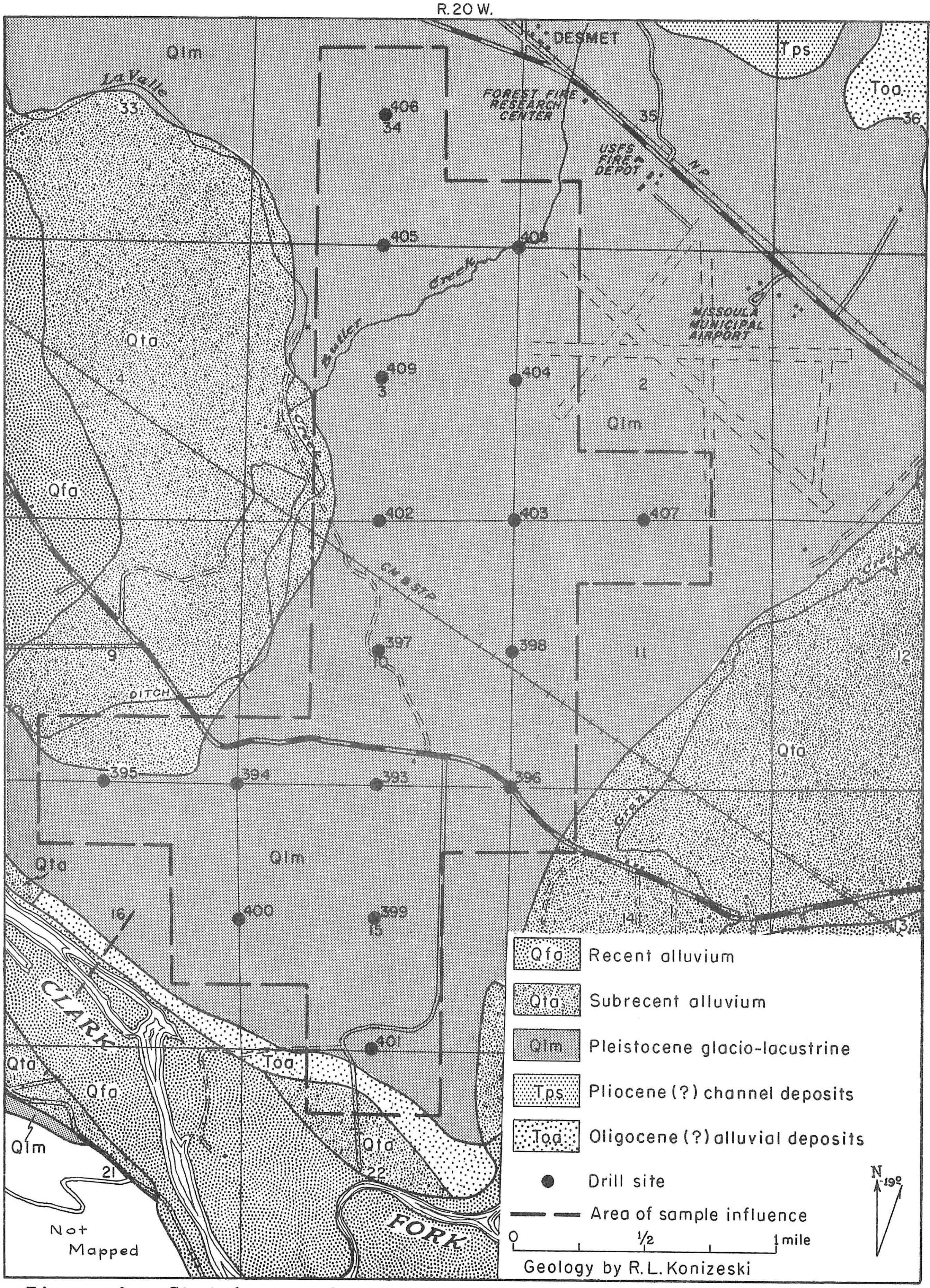


Figure 2.--Sketch map of area west of Missoula showing geology and location of drill holes in Glacial Lake Missoula clay.

These three units could be mapped on the basis of color or, during the growing season, by quantity of vegetation as well as by lithology. The Recent alluvium is dark and supports a good growth; the Subrecent alluvium is lighter in color and supports only fair growth; the virgin clay (Qlm) is pink and supports virtually no growth.

Preglacial deposits in the valley are Pliocene(?) channel deposits of unconsolidated sand and gravel, and Oligocene(?) alluvial deposits of semi- to well-consolidated conglomerate interstratified with incompetent beds of lignitic shale.

Description and Use of Clay

Both areas that were sampled and described herein are underlain by the pink (5R8/2) varved illitic siliceous clay (Qlm) containing various amounts of kaolinite, bentonite, and calcite. They have an average P.C.E. of 2 and an average firing range of 1900° to 2000°F. Water of plasticity is about 32 percent (low) to 43 percent (high); range is 27-39 percent (low) to 39-54 percent (high).

The only sample deviating from the above description is Sample 406, which was collected from reworked clay. It is a gray montmorillonite clay of good plasticity. Upon firing, however, the brick swelled and cracked; therefore, the material represented by this one sample is not suitable for manufacture of common brick, but all the other samples described in this section are suitable. After firing, the bricks are tan to red. No expanded-aggregate tests were performed on these samples.

Several brick plants have utilized the virgin clay for manufacture of common brick. Remnants of one plant are still visible at East Missoula. The brick produced was usable, but after several years exposure to the elements it began to peel or split. This undesirable feature can be eliminated by thorough mixing of the clay before molding and firing. The splitting was due to the lamination (varves) of the clay.

Reserves

Reserves are for all practical purposes unlimited. In the area sampled west of Missoula (Fig. 2), calculation on the area sampled (13,164,800 sq. yd.) times the depth to which sampled (3 yd.) times 1.4 (1 cu. yd. of natural bed clay weighs about 1.4 tons) gives a reserve of 55 million tons of usable clay. Other areas in the Missoula Valley contain virgin clay, and there is no reason to believe that its mineralogy or ceramic properties would differ to any great extent.

SAMPLE 410

Sample 410 was received by the Bureau from Ray Ward, Clyde Park, Montana. Specific location of the sample is unknown.

The material is a light-red montmorillonite clay of good plasticity, but upon firing at high temperature, blowholes developed and the brick began to swell. The material is therefore unsuitable for ceramic use. The sample was not tested for expandability.

SAMPLE 411

Sample 411 was collected by Donald Freestone* from a locality in the Centennial Valley in sec. 5, T. 14 S., R. 4 W.

The material is a dark-gray (N3) impure illitic clay containing large percentages of quartz and calcite. The firing characteristics are poor. The material is unsuitable for ceramic use. The sample was not tested for expandability.

SAMPLES 412 and 413

Samples 412 and 413 were received by the Bureau from Otto Haglund, Seely Lake.

The material of both samples is an impure metahalloysite clay. Although the clay is refractory, it lacks plasticity, and the firing shrinkage is excessive. Alone it is unsuitable for ceramic use, but it could be used as a grog mixed with plastic clays. The samples were not tested for expandability.

SAMPLE 414

Sample 414 was received by the Bureau from Ruth Olmstead, P. O. Box 655, Glendive. The clay was reportedly collected in sec. 22, 23, and 26, T. 20 N., R. 57 E.

The material is an impure illitic kaolinitic clay of fair plasticity and poor firing characteristics. The sample when fired at the highest temperature softened and swelled. It is not suitable for ceramic use. The sample was not tested for expandability.

SAMPLE 415

Sample 415 was collected by Ralph Smith** from a road cut in sec. 26, T. 1 S., R. 2 W.

The material is a very pale orange (10YR8/2) montmorillonite clay. Upon firing the brick cracked. Its use in the ceramic industry would be limited. The sample was not tested for expandability

----

*Bureau field assistant, 1962.
**Professor of Metallurgy, Montana School of Mines.

SAMPLE 416

Sample 416 was collected by Ralph Smith from a road cut in sec. 16, T. 1 S., R. 2 W.

The material is a grayish-orange (10YR7/4) montmorillonite clay. Upon firing, the brick cracked. Use of this clay in the ceramic industry would be limited. The sample was not tested for expandability.

SAMPLE 417

Sample 417 was collected by Ralph Smith from a road cut in sec. 36, T. 1 N., R. 3 W.

The material is a light-gray (N7) illitic clay having no properties advantageous to the ceramic industry. Expanded-aggregate tests were not made.

SAMPLE 418

Sample 418 was collected by Ralph Smith from the south end of a road cut in sec. 36, T. 1 N., R. 3 W.

The material is a grayish-red (5R5/4) mixture of quartz and feldspar bonded with a small amount of illite and kaolinite. The plasticity is understandably low. Use of this clay in the ceramic industry is limited. The sample was not tested for expandability.

SAMPLE 419

Sample 419 was collected by Ralph Smith from a road cut in sec. 38, T. 2 N., R. 3 W.

The material is a bluish-white (5B9/1) shale, which would require grinding before processing. The plasticity is low, working properties fair, and firing properties good. The material is suitable for manufacture of common brick and similar ceramic products.

SAMPLE 420

Sample 420 was collected by Dr. S. L. Groff* from altered Precambrian(?) shale in sec. 22, T. 12 N., R. 4 E.

----

*Chief of Ground-Water and Fuels Division, Bureau of Mines and Geology.

The material is a grayish-orange (10YR7/4) limy montmorillonite clay not suitable for use in the ceramic industry. The clay was not tested for expandability.

SAMPLE 421

Sample 421 was collected by Dr. S. L. Groff from altered Precambrian(?) shale in sec. 22, T. 12 N., R. 4 E., Meagher County.

The material is a grayish-yellow (5Y8/4) very siliceous illitic clay of low plasticity and poor working properties. The firing characteristics are fair. The material burns white, which makes it desirable as a blending material for production of whiteware products. The clay was not tested for expandability.

R E F E R E N C E S

Brindley, G. W., X-ray identification and crystal structure of clay minerals, Mineralogical Society of London.

Conley, J. E., Wilson, Hewitt, Kleinfelter, T. A., and others, 1948, Production of lightweight concrete aggregates from clays, shales, slates, and other materials: U. S. Bur. Mines Rept. Inv. 4401, 121 p.

Howell, B. F., and others, 1944, Correlation of the Cambrian Formations of North America: Geol. Soc. America Bull., v. 55, p. 993-1003.

Kinneson, C. S., 1915, A study of the Atterberg plasticity method: U. S. Bur. Mines Tech. Paper 46.

McMurtrey, R. G., Konizeski, R. L., and Brietkrietz, Alex, (in press), Geology and ground-water resources of the Missoula Basin, Montana: Montana Bur. Mines and Geol. Bull. 47.

Perry, E. S., 1962, Montana in the geologic past: Montana Bur. Mines and Geol. Bull. 26.

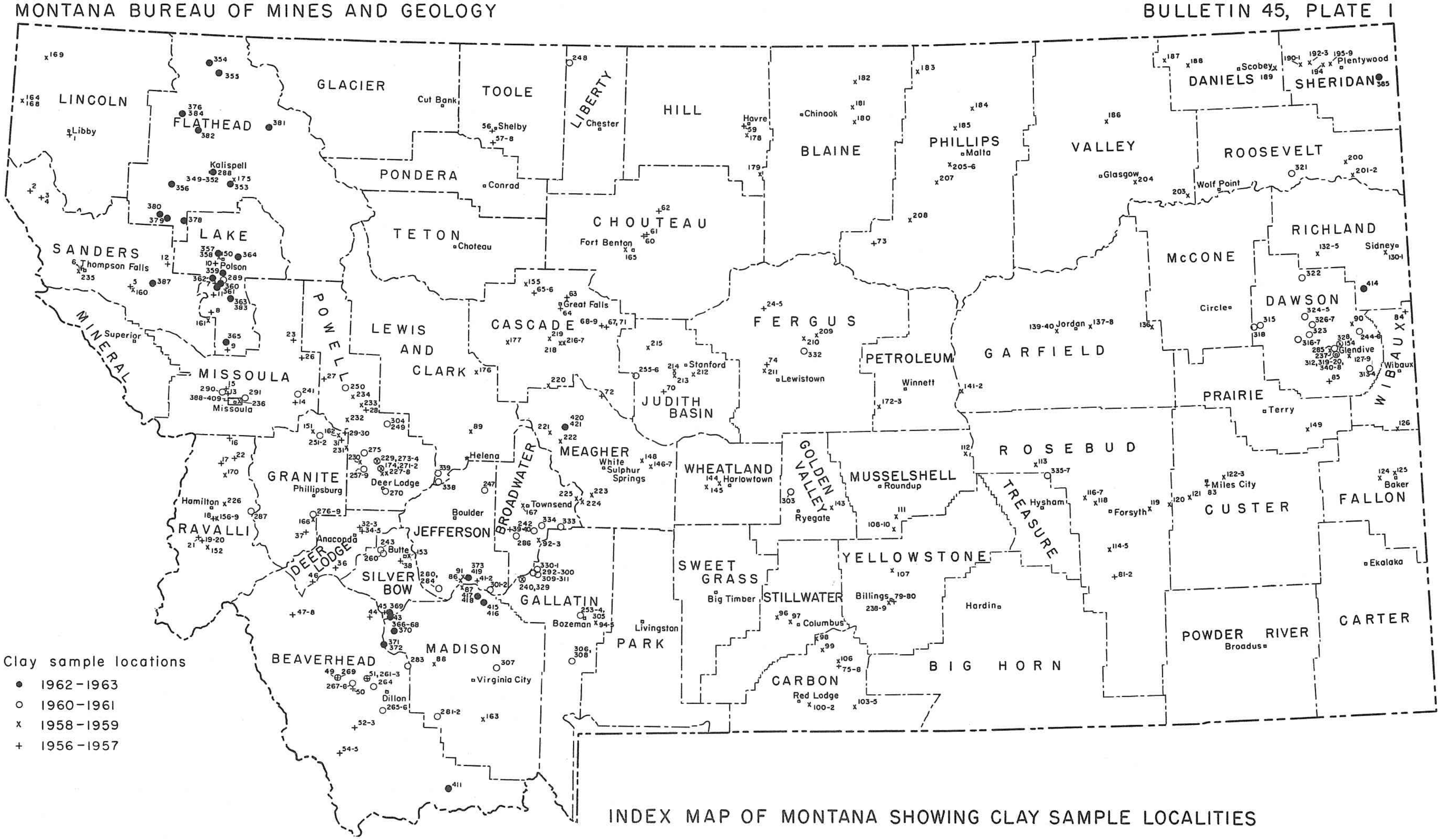
Rector, R. J., 1963, Geologic appraisal of the Fishtrap Creek building-stone belt, Sanders County, Montana: Geol. Div., Northern Pacific Railway Co.

Sahinen, U. M., Smith, R. I., and Lawson, D. C., 1958, Progress report on clays of Montana, 1956-1957: Montana Bur. Mines and Geol. Inf. Circ. 23, 41 p.

__________ 1960, Progress report on clays and shales of Montana, 1958-1959: Montana Bur. Mines and Geol. Bull. 13, 83 p.

__________ 1962, Progress report on clays and shales of Montana, 1960-1961: Montana Bur. Mines and Geol. Bull. 27, 61 p.

Skinner, K. G., and Kelly, H. G., 1949, Preliminary ceramic tests of clays from seven Pacific Northwest deposits: U. S. Bur. Mines Rept. Inv. 4449, 59 p.



INDEX MAP OF MONTANA SHOWING CLAY SAMPLE LOCALITIES

TABLE 1.--Sample locations, Montana clay and shale.

Sample no.	Field no.	Formation	Location, collector	County	Location	Sec.	T.	R.
349	62-1	Unknown	East of Kalispell, F. Crowley	Flathead	NW$\frac{1}{4}$	8	28N	21W
350	62-2	---do---	Kalispell, F. Crowley	---do---	SW$\frac{1}{4}$	8	28N	21W
351	62-3	---do---	Bauska Horse Farm, F. Crowley	---do---	S$\frac{1}{2}$	5	28N	21W
352	62-4	---do---	-----do-----	---do---	SW$\frac{1}{4}$	5	28N	21W
353	62-5	---do---	5 mi. south Creston, F. Crowley	---do---	NE$\frac{1}{4}$	3	27N	20W
354	62-6	---do---	Whale Creek, F. Crowley	---do---	SE$\frac{1}{4}$	30	36N	21W
355	62-7	---do---	Flathead River road, F. Crowley	---do---	---	21, 22	35N	21W
356	62-8	---do---	Road cut, U. S. 2, F. Crowley	---do---	W$\frac{1}{2}$	12	27N	24W
357	62-9	---do---	Polson, F. Crowley	Lake	W$\frac{1}{2}$	29	23N	20W
358	62-10	---do---	Road cut, U. S. 93, F. Crowley	---do---	NW$\frac{1}{4}$	32	23N	20W
359	62-11	---do---	South of Pablo res., F. Crowley	---do---	SE$\frac{1}{4}$	34	22N	20W
360	62-12	---do---	-----do-----	---do---	NW$\frac{1}{4}$ NW$\frac{1}{4}$	21	21N	20W
361	62-13	---do---	-----do-----	---do---	NE$\frac{1}{4}$ NE$\frac{1}{4}$	30	21N	20W
362	62-14	---do---	Round Butte School, F. Crowley	---do---	SE$\frac{1}{4}$ SE$\frac{1}{4}$	35	21N	21W
363	62-15	---do---	Ronan, F. Crowley	---do---	SE$\frac{1}{4}$	23	20N	20W
364	62-16	---do---	Road cut, State 35, F. Crowley	---do---	NE$\frac{1}{4}$	28	23N	19W
365	62-17	---do---	NE of Arlee, F. Crowley	---do---	W$\frac{1}{2}$	23	17N	20W
366	62-18	Three Forks	Camp Creek, D. Rife	Silver Bow	S$\frac{1}{2}$	19	2S	8W
367	62-19	---do---	-----do-----	---do---	S$\frac{1}{2}$	19	2S	8W
368	62-20	---do---	-----do-----	---do---	S$\frac{1}{2}$	19	2S	8W
369	62-21	---do---	Soap Gulch, D. Rife	---do---	N$\frac{1}{2}$	12	2S	9W
370	62-22	Amsden(?)	6 mi. SE of Melrose, D. Rife	Madison	---	17	3S	8W
371	62-23	Unknown	Garrison Ranch, D. Rife	---do---	---	---	4S	9W
372	62-24	---do---	-----do-----	---do---	---	---	4S	9W
373	62-25	---do---	Road cut, State 281, D. Rife	Jefferson	N$\frac{1}{2}$	33	2N	3W
374	62-26	---do---	Dillon, F. Ryburn, 16 N Atlantic	(?)	(Location not received)			
375	62-27	---do---	-----do-----	(?)	(Location not received)			
376	62-28	---do---	E. H. Gilmour	Flathead	SW$\frac{1}{4}$	18	32N	23W
377	62-29	---do---	Fortine Creek, E. Gilmour	Lincoln	(Location not received)			
378	62-30	---do---	W. D. Page	Flathead	SW$\frac{1}{4}$	26	25N	23W

379	62-31	---do---	-----do-----	---do---	$NE\frac{1}{4}$ $SW\frac{1}{4}$	22	25N	24W
380	62-32	---do---	-----do-----	---do---	---	18	25N	24W
381	62-33	---do---	Dalimata Ranch, W. Johns	---do---	$SW\frac{1}{4}$	7	31N	17W
382	62-34	---do---	Burdick Ranch, W. Johns	---do---	$SW\frac{1}{4}$	18	31N	22W
383	62-35	---do---	South of Kalispell, W. Johns	Lake	$SE\frac{1}{4}$	23	20N	20W
384	62-36	---do---	Mrs. L. Dustin (M. Id. 10,464) 2704 - 6 Ave. S., Great Falls	Flathead	---	---	32N	23W
385	63-1	---do---	H. B. Syverud, Dagmar	Sheridan	$NW\frac{1}{4}$ $SE\frac{1}{4}$	13	34N	57E
386	63-2a,b	---do---	L. DeKalb, Lewistown	Fergus	Not recd.	26	18N	15E
387	63-3	Woolsey	U. M. Sahinen	Sanders	$SW\frac{1}{4}SE\frac{1}{4}NE\frac{1}{4}$	26	24N	28W
*388	63-4	Glacial Lake Missoula	East Missoula	Missoula	$SE\frac{1}{4}$	13	13N	19W
*389	63-5	---do---	-----do-----	---do---	$SE\frac{1}{4}$	13	13N	19W
*390	63-6	---do---	-----do-----	---do---	$SE\frac{1}{4}$	13	13N	19W
*391	63-7	---do---	-----do-----	---do---	$SE\frac{1}{4}$	13	13N	19W
*392	63-8	---do---	-----do-----	---do---	$SE\frac{1}{4}$	13	13N	19W
**393	63-9	---do---	West of Missoula	---do---	$S\frac{1}{4}$ corner	10	13N	20W
**394	63-10	---do---	-----do-----	---do---	SW corner	10	13N	20W
**395	63-11	---do---	-----do-----	---do---	$S\frac{1}{4}$ corner	9	13N	20W
**396	63-12	---do---	-----do-----	---do---	SE corner	10	13N	20W
**397	63-13	---do---	-----do-----	---do---	Center	10	13N	20W
**398	63-14	---do---	-----do-----	---do---	$E\frac{1}{4}$ corner	10	13N	20W
**399	63-15	---do---	-----do-----	---do---	Center	15	13N	20W
**400	63-16	---do---	-----do-----	---do---	$E\frac{1}{4}$ corner	16	13N	20W
**401	63-17	---do---	-----do-----	---do---	$S\frac{1}{4}$ corner	15	13N	20W
**402	63-18	---do---	-----do-----	---do---	$S\frac{1}{4}$ corner	3	13N	20W
**403	63-19	---do---	-----do-----	---do---	SE corner	3	13N	20W
**404	63-20	---do---	-----do-----	---do---	$E\frac{1}{4}$ corner	3	13N	20W
**405	63-21	---do---	-----do-----	---do---	$S\frac{1}{4}$ corner	34	13N	20W
**406	63-22	---do---	-----do-----	---do---	Center	34	14N	20W
**407	63-23	---do---	-----do-----	---do---	$S\frac{1}{4}$ corner	2	13N	20W
**408	63-24	---do---	-----do-----	---do---	SE corner	34	13N	20W
**409	63-25	---do---	-----do-----	---do---	Center	3	13N	20W

----

*See Fig. 1.
**See Fig. 2.

TABLE 1.--Sample locations, Montana clay and shale, contd.

Sample no.	Field no.	Formation	Location, collector	County	Location	Sec.	T.	R.
410	63-26	Unknown	Ray Ward, Clyde Park	(?)	(Location not received)			
411	63-27	---do---	Centennial Valley, D. Freestone	Beaverhead	---	5	14S	4W
412	63-28	---do---	10 mi. N Seeley Lake, O. Haglund	Missoula	(Location not received)			
413	63-29	---do---	-----do-----	---do---	(Location not received)			
414	63-30	---do---	R. Olmstead, Glendive	Richland	---	22,23,26	20N	57E
415	63-31	---do---	Road cut, R. Smith	Madison	---	26	1S	2W
416	63-32	---do---	-----do-----	---do---	---	16	1S	2W
417	63-33	---do---	-----do-----	---do---	---	36	1N	3W
418	63-34	---do---	-----do-----	---do---	---	36	1N	3W
419	63-35	---do---	-----do-----	Jefferson	---	33	2N	3W
420	63-36	Pre-cambrian(?) shale	Smith River, S. L. Groff	Meagher	---	22	12N	4E
421	63-37	---do---	-----do-----	---do---	---	22	12N	4E

TABLE 2.--Ceramic properties of clay and shale samples.

Sample no. a/	Water of plasticity % b/	Drying shrinkage % c/	P.C.E. d/	Firing range °F	Firing temperature °F	Firing shrinkage % e/	Fired color f/	Hardness g/	Remarks
349	L 23 H 36	3.6	4	2000 to 2100	1650 1850 2050	0.5 1.9 11.0	pink tan brown	SS SS HS	Fair common brick material with careful handling
350	L 25 H 36	5.0	4	2000 to 2100	1650 1850 2050	0.0 2.5 5.5	pink tan brown	SS SS HS	Fair common brick material with careful handling
351	L 22 H 30	3.5	4	2075 to 2100	1650 1850 2050	0.5 0.8 0.8	pink tan brown	SS SS S	Not suitable, narrow firing range
352	L 23 H 28	4.0	4	1900 to 2050	1650 1850 2050	0.0 0.0 8.8	pink tan green	SS S HS	Fair common brick material
353	L 30 H 42	5.7	2	2000 to 2050	1600 1800 2000	0.0 2.2 7.4	pink lt. red lt. red	SS SS SS	Not suitable, narrow firing range
354	L 24 H 32	4.3	8	1900 to 2150	1750 1950 2150	1.2 5.0 7.7	pink green green	SS HS HS	Fair common brick material
355	L 22 H 38	5.3	8	1950 to 2150	1750 1950 2150	3.2 2.5 2.6	pink green green	S HS HS	Fair common brick material
356	L 33 H 40	4.9	8	1900 to 2150	1750 1950 2150	1.1 5.1 11.4	tan dk. red dk. red	SS HS HS	Fair common brick material
357	L 30 H 34	4.2	2	2025 to 2050	1600 1800 2000	0.5 0.6 3.5	tan tan tan	SS SS SS	Not suitable, narrow firing range
358	L 32 H 40	3.7	2	2025 to 2050	1600 1800 2000	0.0 0.0 0.0	tan tan tan	SS SS SS	Not suitable, narro firing range; fired brick cracked

a/See Table 1.
b/L, lower limit; H, upper limit.
c/Drying shrinkage is lineal.
d/Pyrometric cone equivalent in standard Seger cones.
e/Firing shrinkage is lineal; OF, over fired.
f/lt, light; dk, dark.
g/S, steel hard; HS, harder tha steel; SS, softer than steel.

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
359	L 27	4.0	2	2025	1600	0.0	tan	SS	Not suitable, narrow
	H 34			to	1800	0.5	tan	SS	firing range, fired
				2050	2000	0.5	tan	SS	brick cracked
360	L 32	3.6	3	1900	1600	1.0	tan	SS	Not suitable, narrow
	H 37			to	1800	4.0	tan	SS	firing range, poor
				1950	2000	13.5	green	SS	working characteristics
361	L 30	4.5	2	1900	1600	0.0	tan	SS	Not suitable, narrow
	H 36			to	1800	1.9	tan	SS	firing range, poor
				1950	2000	8.1	choc.	HS	working characteristics
362	L 32	3.3	2	2025	1600	0.0	tan	SS	Not suitable, narrow
	H 37			to	1800	0.3	tan	SS	firing range, fired
				2050	2000	0.3	tan	SS	brick cracked
363	L 21	5.4	2	1950	1600	0.0	tan	SS	Not suitable, narrow
	H 34			to	1800	4.6	tan	SS	firing range
				2000	2000	5.4	choc.	S	
364	L 28	2.6	3	1900	1600	0.0	tan	SS	Poor common brick
	H 34			to	1800	0.0	tan	SS	material
				2000	2000	8.8	choc.	HS	
365	L 29	5.1	2	2000	1600	0.8	tan	SS	Poor common brick
	H 35			to	1800	0.8	tan	SS	material
				2050	2000	1.0	tan	S	
366	L 21	3.4	4	1950	1650	0.8	tan	SS	Fair common brick
	H 28			to	1850	5.4	red	S	material
				2050	2050	6.3	dk. red	HS	
367	L 20	3.3	4	1950	1650	0.0	tan	SS	Fair common brick
	H 25			to	1850	6.0	lt. red	S	material
				2050	2050	5.8	red	HS	
368	L 22	2.6	2	1900	1600	0.5	tan	SS	Fair common brick
	H 30			to	1800	3.9	lt. red	S	material
				2000	2000	6.6	red	HS	
369	Impure dolomite, not fired								
370	Impure limestone, not fired								
371	L 33	3.6	1	1800	1550	4.7	tan	SS	Not suitable, narrow
	H 37				1750	10.0	red	SS	firing range, fired
					1850	OF	dk. red	HS	brick cracked

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
372	L 20 H 25	3.5	1	2000	1650 1750 1950	0.0 0.0 0.6	lt. red tan buff	SS SS SS	Not suitable, narrow firing range
373	L 26 H 36	4.3	over 12	2000 to 2300	1900 2100 2300	6.8 7.2 6.3	tan red red	HS HS HS	Fair common brick material
374	Impure calcite or limestone, not fired								
375	L 36 H 42	3.7	1	2000	1550 1750 1950	1.7 5.7 4.9	tan red red	SS SS SS	Very poor common brick material
376	L 29 H 40	6.3	3	1900 to 2000	1650 1850 2050	0.5 0.9 9.4	lt. red lt. red dk. red	SS SS HS	Common brick
377	L 29 H 37	4.0	6	1950 to 2050	1750 1950 2150	0.0 2.7 12.4	lt. red red brown	SS S HS	Common brick
378	L 42 H 56	6.0	12	2100 to 2300	1900 2100 2300	3.1 12.2 11.0	tan red green	SS HS HS	Common brick
379	L 26 H 32	3.0	5	2000 to 2100	1700 1900 2100	0.0 0.4 5.3	tan tan red	SS SS HS	Common brick
380	L 30 H 35	3.5	12	2100 to 2300	1900 2100 2300	0.0 5.1 10.6	tan red dk. red	SS S HS	Lacks plasticity, good grog
381	L 25 H 36	4.3	6	1950 to 2050	1750 1950 2150	0.0 2.5 13.0	tan lt. red	SS S HS	Common brick; sample fired at 2150 was over fired
382	L 26 H 44	7.9	10	2000 to 2250	1850 2050 2250	0.3 7.8 8.6	tan red dk. red	SS HS HS	Common brick
383	L 20 H 24	2.4	7	2000 to 2050	1750 1950 2150	0.0 0.0 2.5	tan tan green	SS SS HS	Very low plasticity, good for grog; sample fired at 2150 was over fired

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
384	L 44 H 70	9.9	over 12	1900 to 2200	1900 2100 2300	6.2 11.5 12.2	tan lt. brown brown	SS HS HS	Good common brick; brick fired at 2300 cracked
385	L 27 H 38	4.1	6	2000 to 2050	1750 1950 2150	0.6 0.0 10.2	buff lt. red green	SS SS HS	Unsuitable, firing range too narrow
386A	L 48 H 64	6.0	over 12	Not tested	1900 2100 2300	3.1 5.2 7.8	white white white	SS SS SS	A high-grade ceramic material; needs a binder, as all bricks cracked on firing
386B	L 17 H 26	2.7	12	2250 to 2350	1900 2100 2300	0.0 1.2 6.3	pink pink pink	SS SS HS	A fair ceramic material
387	L 23 H 31	4.5	12	1900 to 2200	1900 2100 2300	3.4 7.6 1.0	red dk. red dk. red	S HS HS	A good material for common brick and similar products
388	L 30 H 40	4.7	2	1900 to 2000	1650 1850 2050	0.0 0.3 9.1	lt. red lt. red dk. red	SS SS HS	Common brick
389	L 32 H 45	4.3	2	1900 to 2000	1650 1850 2050	0.0 0.4 7.8	lt. red tan dk. red	SS SS HS	Common brick
390	L 31 H 43	5.9	3	1900 to 2000	1650 1850 2050	0.0 0.0 12.5	tan tan dk. red	SS SS HS	Common brick
391	L 30 H 43	6.2	5	2000 to 2050	1750 1950 2150	0.7 0.0 0.8	lt. red lt. red brown	SS SS	Common brick, sample fired at 2150 was overfired
392	L 31 H 39	4.1	5	2000 to 2050	1750 1950 2150	0.0 1.0 6.8	lt. red lt. red lt. red	SS SS HS	Common brick
393	L 36 H 54	7.5	2	1900 to 2000	1650 1850 2050	0.0 9.3 11.5	tan tan dk. red	SS SS HS	Common brick
394	L 37 H 54	7.3	2	1850 to 2000	1650 1850 2050	0.0 0.9 11.2	tan red dk. red	SS S HS	Common brick

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
395	L 32 H 40	5.7	2	1900 to 2000	1650 1850 2050	0.6 0.6 5.8	tan tan red	SS SS S	Common brick
396	L 36 H 54	7.6	2	1900 to 2000	1650 1850 2050	0.0 0.9 7.7	tan tan red	SS SS HS	Common brick
397	L 39 H 53	7.3	2	1900 to 2000	1650 1850 2050	0.0 0.7 9.7	tan tan red	SS S HS	Common brick
398	L 31 H 44	6.5	2	1900 to 2050	1650 1850 2050	0.0 0.6 7.7	tan tan red	SS S HS	Common brick
399	L 36 H 50	6.8	2	1850 to 2050	1650 1850 2050	0.0 0.0 10.1	tan tan red	SS S HS	Common brick
400	L 36 H 52	8.2	2	1900 to 2000	1650 1850 2050	0.0 0.0 10.6	tan tan red	SS S HS	Common brick
401	L 32 H 42	7.8	2	1850 to 2050	1650 1850 2050	0.0 0.0 12.0	tan tan red	SS S HS	Common brick
402	L 35 H 46	7.1	2	1900 to 2000	1650 1850 2050	0.0 1.1 9.4	tan tan red	SS SS HS	Common brick
403	L 30 H 44	5.7	3	1900 to 2000	1650 1850 2050	0.0 0.6 8.3	lt. red lt. red red	SS S HS	Common brick
404	L 32 H 42	5.9	3	1900 to 2050	1650 1850 2050	0.0 0.6 9.8	tan tan red	SS S HS	Common brick
405	L 30 H 44	5.7	2	1900 to 2050	1650 1850 2050	0.0 1.0 10.0	tan tan red	SS SS HS	Common brick
406	L 27	9.3	10	none	1850 2050 2100	--- --- ---	tan red red	S HS HS	Not suitable, brick swelled and cracked

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
407	L 31 H 40	4.4	2	1900 to 2050	1650 1850 2050	0.0 0.7 10.8	tan tan red	SS S HS	Common brick
408	L 29 H 44	7.9	2	1800 to 2050	1650 1850 2050	0.0 0.8 8.1	tan tan red	SS S HS	Common brick
409	L 37 H 52	7.5	2	1900 to 2000	1650 1850 2050	0.0 6.3 12.0	tan tan red	SS S HS	Common brick
410	L 37 H 59	7.9	2	none	1650 1850 2050	0.0 3.2 9.6	tan tan red	SS S HS	Unsuitable, brick fired at 2050 had gas blowholes, and had swelled
411	L 31 H 56	10.5	2	1650 to 1800	1650 1850 2050	0.0 1.0 1.0	lt. red lt. red lt. red	HS HS HS	Not suitable, poor firing character-istics
412	L 37 H 48	6.0	over 14	2100 to 2500	1900 2100 2300	2.1 8.8 14.9	white tan tan	S HS HS	Not suitable, low plasticity and poor firing characteristics
413	L 44 H 56	6.0	over 14	2100 to 2500	1900 2100 2300	4.4 10.5 14.4	white white tan	S HS HS	Not suitable, poor firing character-istics
414	L 30 H 46	6.0	9	1950 to 2100	1850 2050 2250	4.1 8.8 -6.0 OF	tan red green	SS HS HS	Not suitable, poor firing characteristics
415	L 41 H 56	5.0	3	none	1650 1850 2050	0.6 5.2 14.5	tan orange dk. red	SS SS HS	Unsuitable, brick cracked on firing
416	L 24 H 29	2.0	3	none	1650 1850 2050	0.8 2.9 5.0	tan orange red	SS SS HS	Unsuitable, extremely low plasticity, and brick cracked on firing

TABLE 2.--Ceramic properties of clay and shale samples, contd.

Sample no.	Water of plasticity %	Drying shrinkage %	P.C.E.	Firing range °F	Firing temperature °F	Firing shrinkage %	Fired color	Hardness	Remarks
417	L 35 H 57	12.6	4	none	1650 1850 2050	0.9 2.9 3.5	tan tan red	SS HS HS	Unsuitable, brick cracked on drying
418	L 27 H 44	10.5	4	none	1650 1850 2050	0.0 1.2 3.7	red red dk. red	SS SS HS	Unsuitable, brick cracked on firing
419	L 22 H 29	1.8	12	2000 to 2300	1900 2100 2300	0.5 3.2 9.3	pink red dk. red	SS HS HS	Good ceramic material
420	L 45 H 62	0.0	11	none	1900 2100 2300	21.0 23.0 19.0	red red red	SS S HS	Not suitable, brick cracked on drying and firing
421	L 31 H 40	5.7	12	2000 to 2200	1900 2100 2300	2.2 3.2 -7.0	cream white white	SS S HS	Fair material for common brick

TABLE 3.--Results of expandability tests made on some samples of clay and shale described in this report.

Sample no.	Location	Expansion range °F	Sp. gr. after firing	Firing behavior	Remarks
349	Flathead County			Fused at 2372°F	Not suitable
350	-----do-----			Fused at 2282°F	Not suitable
351	-----do-----			Fused at 2192°F	Not suitable
352	-----do-----			Fused at 2282°F	Not suitable
353	-----do-----	-2372	1.2	Rounded fused at 2372°F	Good product, narrow range
354	-----do-----			Minor fusion	Not suitable
355	-----do-----			Minor	Not suitable
356	-----do-----	-2282		Expanded with fusion at 2282°F	Fair product, narrow high range
357	Lake County	-2192	1.6	Expanded with fusion at 2192°F	Fair product, narrow range
358	Flathead County			Fused at 2192°F	Not suitable
359	Lake County			Fused at 2282°F	Not suitable
360	-----do-----			Fused at 2372°F	Not suitable
361	-----do-----			Fused at 2192°F	Not suitable
362	-----do-----			Fused at 2372°F	Not suitable
363	-----do-----	-2282	2.3	Expanded with fusion at 2282°F	Fair product, narrow high range
364	-----do-----			Fused at 2282°F	Not suitable
365	-----do-----			Fused at 2282°F	Not suitable
366	Silver Bow County	2282 to 2372	1.5	Fused at 2372°F	Good product, high range
367	-----do-----	2102 to 2372	1.9	Fused at 2372°F	Excellent product, wide range

368	-----do-----	2012 to 2372	1.7	Fused at 2372°F	Poor product, wide range
369	-----do-----			No reaction	Not suitable
370	Madison County			No reaction	Not suitable
371	-----do-----			Minor expansion with fusion at 2192°F	Not suitable
372	-----do-----			Fused at 2282°F	Not suitable
373	Jefferson County	2282 to 2372	1.45	Minor fusion at 2372°F	Excellent, rounded glazed product
374	Unknown			No change	Not suitable
375	-----do-----			Fused at 2282°F	Not suitable
376	Flathead County			Fused at 2282°F	Not suitable
377	Lincoln County			No change	Not suitable
378	Flathead County			No change	Not suitable
379	-----do-----			Glaze at 2372°F	Not suitable
380	-----do-----			No change	Not suitable
381	-----do-----			Minor bloat with fusion at 2372°F	Not suitable
382	-----do-----			Fused at 2372°F	Not suitable
383	Lake County			Fused at 2192°F	Not suitable
384	Flathead County			Minor fusion at 2372°F	Not suitable
409	Pleistocene Missoula County	2282	-1.0	Fused at 2372°F	Not suitable

TABLE 4.--X-ray diffraction data on Montana clay and shale.

Sample no.	Kaolin	Montmor-illonite	Quartz	Feldspar	Illite	Calcite	Other
349	min	min	maj	min	maj	maj	Dolomite
350	med	min	maj	min	maj	maj	Dolomite
351	min	med	maj	min	maj	maj	Dolomite, trace of cristobalite
352	med	---	maj	min	maj	maj	Dolomite, trace of cristobalite
353	med	min	maj	min	maj	---	Trace of cristobalite
354	med	---	maj	min	maj	---	Minor chlorite, cristobalite, and complex silicates
355	med	---	maj	min	med	---	Chlorite, trace of cristobalite
356	med	---	maj	min	maj	tr	Trace of dolomite
357	min	---	maj	min	maj	med	Trace of dolomite
358	min	---	maj	min	maj	med	Minor dolomite and vermiculite
359	min	---	maj	min	maj	med	Trace of cristobalite
360	tr	---	maj	min	maj	maj	---
361	min	min	maj	min	maj	med	Chlorite
362	min	---	maj	med	maj	med	Chlorite, minimum dolomite
363	med	---	maj	min	maj	med	---
364	min	---	maj	min	med	med	Trace of cristobalite
365	min	---	maj	min	maj	min	Chlorite, minimum dolomite
366	med	tr	maj	---	maj	min	Trace of chlorite
367	med	tr	maj	---	maj	med	Trace of chlorite
368	med	---	maj	---	maj	min	Minor chlorite
369	---	---	min	---	min	---	Impure dolomite
370	---	---	min	---	---	maj	Minimum dolomite, impure limestone
371	---	maj	---	med	---	---	---

TABLE 4.--X-ray diffraction data on Montana clay and shale, cont.

Sample no.	Kaolin	Montmor-illonite	Quartz	Feldspar	Illite	Calcite	Other
372	min	min	maj	---	med	---	Major dolomite, trace of gypsum
373	min	---	maj	---	maj	---	Trace of goethite
374	---	---	---	---	---	maj	Minimum complex silicates, impure limestone
375	---	---	maj	maj	maj	---	Minimum complex silicates
376	med	---	maj	min	maj	maj	---
377	min	tr	maj	min	maj	---	Hydromica
378	med	---	maj	min	---	---	---
379	tr	---	maj	med	maj	min	Minor cristobalite and complex silicates
380	med	---	maj	min	med	---	---
381	---	---	maj	min	med	---	Medium chlorite
382	---	---	maj	min	med	---	Minimum chlorite, palygorsk-ite, and metahalloysite
383	med	---	maj	med	med	maj	Chlorite, cristobalite, and dolomite
384	maj	---	maj	---	med	---	Hydromica
385	med	---	maj	min	med	maj	Major dolomite, trace of chlorite
386a	all	---	---	---	---	---	---
386b	maj	---	min	med	tr	---	Feldspar is orthoclase
387	med	---	med	---	maj	---	---
388	min	---	maj	min	med	---	Minimum dolomite
389	min	---	maj	min	med	min	Minimum dolomite and chlorite
390	min	---	maj	min	med	min	Minimum dolomite, chlorite, and complex silicate
391	min	---	maj	min	med	min	Minimum dolomite, chlorite, and sepiolite
392	min	tr	maj	min	med	min	Minimum dolomite
393	med	---	maj	min	med	min	Minimum dolomite and chlorite
394	min	---	maj	min	med	min	Minimum dolomite and chlorite

TABLE 4.--X-ray diffraction data on Montana clay and shale, contd.

Sample no.	Kaolin	Montmor-illonite	Quartz	Feldspar	Illite	Calcite	Other
395	min	min	maj	min	med	med	Minimum dolomite
396	min	---	maj	min	med	med	Minimum dolomite
397	med	tr	maj	min	maj	min	Trace of dolomite, minimum chlorite
398	min	tr	maj	min	maj	min	Trace of dolomite
399	med	---	maj	min	maj	min	Trace of dolomite, minimum chlorite
400	min	---	maj	min	maj	min	Minimum dolomite and chlorite
401	med	---	maj	min	med	min	Minimum dolomite, chlorite, and cristobalite
402	med	---	maj	min	maj	min	Minimum dolomite and chlorite
403	min	tr	maj	min	maj	min	Minimum dolomite and chlorite
404	min	---	maj	min	maj	min	Minimum dolomite and chlorite
405	min	tr	maj	min	maj	min	Minimum dolomite and chlorite
406	min	maj	maj	min	med	---	---
407	min	---	maj	min	maj	min	Minimum chlorite and hydromica
408	med	---	maj	med	maj	min	Minimum dolomite and chlorite
409	med	---	maj	min	med	min	Minimum dolomite and chlorite
410	min	med	maj	min	med	min	Minimum dolomite and chlorite
411	min	min	maj	min	med	maj	Minor dolomite and metahalloysite
412	---	---	maj	tr	min	---	Major metahalloysite, trace amesite
413	---	---	maj	tr	min	---	Major metahalloysite
414	maj	---	maj	min	maj	tr	Minimum chlorite, trace dolomite
415	---	maj	min	min	---	tr	---
416	---	maj	min	med	---	med	Hydromica
417	---	min	tr	med	maj	min	Hydromica and complex silicate
418	tr	---	maj	maj	min	tr	Trace of dolomite
419	med	tr	maj	tr	maj	---	---
420	---	maj	min	tr	min	maj	Minor iron oxide
421	---	---	maj	tr	med	--	Medium metahalloysite

TABLE 5.--Partial chemical analyses of high-alumina clay samples giving available alumina for those exceeding 20 percent total alumina.

Sample no.	SiO_2	Al_2O_3	CaO	Fe	Na_2O	K_2O	Sol. SiO_2	Available Al_2O_3	Sol. Fe_2O_3	Loss on ignition
349	54.60	14.32	10.4	2.8	6.47	2.16				
350	54.40	14.34	8.9	2.6	1.41	3.17				
351	55.96	14.42	9.0	2.4	1.21	2.26				
352	58.64	12.96	9.2	2.0	0.38	1.33				
353	67.40	15.84	1.2	2.8	2.36	3.01				
354	68.76	16.98	0.0	2.1	2.80	4.40				
355	67.84	15.70	1.2	2.6	1.34	2.71				
356	60.00	22.78	1.4	2.8	1.62	3.01	1.32	13.42	3.72	4.58
357	62.66	14.62	4.9	2.6	1.48	2.93				
358	64.40	14.18	5.2	2.6	1.95	5.30				
359	68.16	13.34	4.6	2.4	2.70	3.25				
360	70.16	12.80	5.4	2.2	1.82	2.17				
361	66.00	14.50	4.6	2.6	2.26	4.52				
362	59.50	17.40	4.2	2.4	0.81	4.73				
363	64.62	14.30	4.4	2.6	2.00	3.29				
364	70.96	12.22	5.0	2.1	1.21	1.51				
365	58.32	16.96	4.0	2.3	1.15	3.85				
366	55.92	24.10	4.3	4.3	0.66	5.12	1.14	17.99	7.15	4.48
367	56.08	24.14	3.6	4.3	1.08	5.30	1.14	18.21	6.57	5.60
368	54.72	23.70	3.2	4.5	0.88	5.04	1.28	19.15	7.15	5.24
369	12.24	6.70	26.4	1.3	0.54	0.16				
370	14.44	2.32	45.8	1.3	1.55	0.90				
371	55.80	19.40	4.2	4.5	0.74	0.72				
372	46.08	19.74	9.4	3.8	2.36	4.22				
373	54.48	22.74	1.1	7.9	1.25	2.26	1.26	17.56	8.86	7.50
374	26.00	2.90	40.0	0.7	1.55	2.20				
375	62.48	18.12	1.0	2.6	1.55	3.13				
376	58.04	14.42	8.1	3.1	0.94	2.86				
377	71.04	10.46	0.9	2.6	1.39	3.19				
378	65.78	19.04	0.29	0.35	1.01	1.69	1.26	13.59	1.71	8.80
379	68.22	14.05	2.5	1.52	1.45	2.65				
380	73.08	16.03	0.12	1.16	1.74	2.65				
381	70.72	14.84	1.1	2.5	1.59	2.65				
382	68.00	16.04	1.5	3.0	0.94	1.61				
383	71.80	9.88	5.2	1.9	1.28	1.08				
384	64.40	21.56	0.8	2.6	0.74	2.05	0.96	18.84	2.00	8.12
385	52.50	11.98		2.05	1.21	2.59				
386a	46.04	38.13		0.2	0.85	0.18	1.26	38.00	0.28	13.46
386b	77.34	14.33		1.0	2.36	2.17				

TABLE 5.--Partial chemical analyses of high-alumina clay samples giving available alumina for those exceeding 20 percent total alumina, contd.

Sample no.	SiO_2	Al_2O_3	CaO	Fe	Na_2O	K_2O	Sol. SiO_2	Available Al_2O_3	Sol. Fe_2O_3	Loss on ignition
387	51.88	23.21	---	5.10	1.19	4.52	1.38	22.38	7.00	8.14
388	67.20	13.80	---	1.85	1.35	2.46				
389	65.00	13.37	---	1.95	1.48	2.89				
390	62.62	14.16	---	1.90	1.39	2.63				
391	61.46	13.46	---	1.95	1.55	2.71				
392	61.10	13.48	---	1.95	1.52	2.23				
393	57.08	16.43	---	2.30	1.75	3.67				
394	55.04	16.58	---	2.30	1.35	3.19				
395	55.32	14.97	---	2.15	1.36	3.40				
396	59.66	15.91	---	2.35	1.12	3.92				
397	59.10	16.74	---	2.35	1.39	4.13				
398	60.04	15.79	---	2.29	1.16	3.47				
399	57.60	16.41	---	2.45	1.42	3.37				
400	57.64	17.61	---	2.35	1.35	3.90				
401	58.90	15.27	---	2.30	1.35	3.61				
402	57.50	16.66	---	2.35	1.62	3.31				
403	57.98	17.02	---	2.20	1.39	3.59				
404	57.16	16.20	---	2.45	1.21	3.73				
405	58.38	16.77	---	2.45	1.28	3.98				
406	60.04	17.77	---	2.15	1.15	2.77				
407	59.76	17.53	---	2.35	1.21	3.67				
408	61.60	17.03	---	2.20	1.28	3.61				
409	57.18	17.80	---	2.55	1.21	4.04				
410	55.70	19.35	---	2.65	0.67	1.02				
411	52.88	14.44	---	2.00	0.78	1.57				
412	56.86	21.46	---	0.95	1.21	4.43	1.18	25.56	0.86	11.72
413	54.42	27.64	---	0.60	0.85	1.51	0.94	26.85	0.57	11.84
414	62.66	18.75	---	1.75	1.08	4.10				
415	61.20	15.40	---	1.85	1.75	1.94				
416	65.54	15.79	---	2.20	4.29	3.01				
417	52.42	18.12	---	4.20	1.82	1.21				
418	47.48	20.11	---	4.35	1.09	5.76	0.64	12.47	5.43	11.16
419	58.78	21.08	---	7.25	1.09	3.25	0.86	14.82	10.00	4.58
420	33.64	23.82	---	7.40	1.28	2.11	0.90	23.42	10.27	23.14
421	77.04	12.98	---	0.30	0.78	2.59				

TABLE 6.--Fusing points of Seger cones.

Cone no.	When fired slowly 20°C per hr. °C	°F	When fired rapidly 150°C per hr. °C	°F
022	585	1085	605	1121
021	595	1103	615	1139
020	625	1157	650	1202
019	630	1166	660	1220
018	670	1238	720	1328
017	720	1328	770	1418
016	735	1355	795	1463
015	770	1418	805	1481
014	795	1463	830	1526
013	825	1517	860	1580
012	840	1544	875	1607
011	875	1607	895	1643
010	890	1634	905	1661
09	930	1706	930	1706
08	945	1733	950	1742
07	974	1787	990	1814
06	1005	1841	1015	1859
05	1030	1886	1040	1904
04	1050	1922	1060	1940
03	1080	1976	1115	2039
02	1095	2003	1125	2037
01	1110	2030	1145	2093
1	1125	2057	1160	2120
2	1135	2075	1165	2129
3	1145	2093	1170	2138
4	1165	2129	1190	2174
5	1180	2156	1205	2201
6	1190	2174	1230	2246
7	1210	2210	1250	2282
8	1225	2237	1260	2300
9	1250	2282	1285	2345
10	1260	2300	1305	2381
11	1285	2345	1325	2417
12	1310	2390	1335	2435
13	1350	2462	1350	2462
14	1390	2534	1400	2552
15	1410	2570	1435	2615
16	1450	2642	1465	2669
17	1465	2669	1475	2687
18	1485	2705	1490	2714
19	1515	2759	1520	2768
20	1520	2768	1530	2786
23			1580	2876
26			1595	2903
27			1605	2921
28			1615	2939
29			1640	2984
30			1650	3002
31			1680	3056
32			1700	3092
33			1745	3173