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Clays of Eastern Colorado

BY

G. MONTAGUE BUTLER

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The Clays of Eastern Colorado

AND DATA CONCERNING THOSE NEAR SOME CENTERS OF POPULATION ELSEWHERE IN THE STATE

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LETTER OF TRANSMITTAL

STATE GEOLOGICAL SURVEY,
UNIVERSITY OF COLORADO, October 27, 1914.

Governor Elias M. Ammons, Chairman, and Members of the Advisory Board of the State Geological Survey.

GENTLEMEN: I have the honor to transmit herewith Bulletin 8 of the Colorado Geological Survey.

Very respectfully,

R. D. GEORGE,
State Geologist.

PREFACE

This report was prepared for the purpose of spreading information concerning the great undeveloped, or partially developed, clay resources of Colorado. It is not intended to be a manual for those engaged in clay-mining, or for the brick-man or potter; so it is not cumbered with descriptions of appliances or processes used by practical ceramists. All such will find their needs fully satisfied by books already on the market. Neither is this work supposed to be merely a text-book for those interested purely in the theoretical aspects of ceramics. In fact, a determined effort has been made to subordinate theory to practice. There is no doubt but that the report will be of most value to the unscientific citizen, and his needs have been the ones principally considered in its preparation.

A serious attempt to obtain data on Colorado clays was first made by the author in the summer of 1909. During the summer of 1910 three parties were placed in the field, whose duties included the examination of possible clay-bearing horizons and the collection of samples. One of these consisted of Professor Frank F. Grout, of the University of Minnesota, and Arnold W. Lauer, a student in the University of Colorado. Most of their work was done north and east of Golden. A second party comprised C. D. Heaton, assistant in geology in the Colorado School of Mines, and R. G. Bowman, a student in that institution. Their investigations were carried on south and southeast of Golden. The author and A. T. Mertes, a student in the School of Mines, made up the third party, which visited a number of widely separated areas.

The entire summers of the years 1911 and 1912, and the winter of 1912-13, were consumed in testing the clay samples previously collected. This work was carried on, under the author's direction, by G. W. Voelzel and T. H. M. Crampton, both students in the School of Mines. The latter was assisted for some time by his brother, F. A. Crampton. All the chemical analyses were made by Dr. H. A. Tremaine, of Bennett, Colorado.

The author is greatly indebted to all of these gentlemen for their whole-hearted interest and endeavors in his behalf. The thanks of the Survey are also due to scores of people all over the

state who aided the investigation in one way or another. Unfortunately, some of the names of these people have been lost, and it has been thought best to publish none rather than an incomplete list.

Professor Grout made many suggestions relative to the report that were found useful; and Mr. Crampton devised the furnace, without which it would have been difficult to secure satisfactory results. He also evidenced great interest in the work in many other ways.

Free use has been made of Dr. Heinrich Ries's work on "Clays: Their Occurrence, Properties, and Uses." Whole paragraphs have been transcribed almost verbatim in some places, without other acknowledgment than is contained in this statement.

The delay in the publication of this report is due to a number of causes. In the first place, the testing and classification of such a large number of samples—many more than most state surveys examine—required an amount of time and labor that is inconceivable to one unfamiliar with such work. Secondly, the Survey has often been handicapped by a lack of funds when the author was at leisure to work on the report; and the author was fully occupied with other duties at several periods when the Survey's financial condition was more satisfactory. This has been especially true of the past winter (1913-14), when the author occupied a new position in a new school, and was compelled to give every moment of his time to the work of that institution.

The report has been divided into five parts, which may be thus summarized:

Part I is introductory in character and includes brief discussions of the composition, properties, and classification of clays, together with a detailed account of the methods employed in this investigation.

Part II comprises a brief description of the sedimentary formations of those parts of the state covered by this report. When these are clay-bearing, the nature of the clays found therein is discussed in some detail.

Part III consists of statements concerning the location, occurrence, field characteristics, and economic value of each specimen collected. As the samples from each county are usually grouped together, it should be easy to ascertain the general nature of the clays in any given area by consulting the proper portion of this part of the report.

Part IV contains a tabulation in which are indicated the geological horizon of each sample and the products for the manufacture of which it is best adapted. This table makes it possible to locate the beds that offer the best promise for any given purpose.

Part V is a tabulation of the results of the laboratory tests made on each sample. Most of Parts II, III, and IV has been compiled from the data given in Part V, supplemented by a visual examination of the bricklets.

CORVALLIS, OREGON,
September 30, 1914.

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PART I

CHAPTER I

The Nature, Composition, and Origin of Clays

A CLAY DEFINED

There are two definitions of clay in common use; the first might be called the ceramists' or the clay-users', and the second the geologists' definition. They are as follows:

1. A clay is a naturally occurring material which is more or less plastic when wet, and which, when heated to redness or above, becomes permanently hard.

2. A clay is a sedimentary or aeolian deposit composed largely of kaolin, in which the bedding planes or laminations are not well developed. When the substance is decidedly laminated, a geologist calls it a shale.

The former definition includes both clays and shales as defined from a geological standpoint. This is not illogical, since the physical properties (outside of lamination) and the products of both may be identical. The ceramists' definition is applicable to some substances, such as those high-grade clays formed by the alteration of igneous rocks, which a geologist would never consider clays or shales.

It is, then, evident that the two definitions conflict to some extent; or, rather, one (the second) is much more restricted than the other. The first is the broader and more useful from a practical standpoint.

COMPOSITION OF CLAYS

Mineralogical Composition—

Kaolinite.—A clay is not a homogeneous substance, but, like most of the more plentiful earth materials, it is ordinarily a rather complex mixture of several minerals. Among these the most important is undoubtedly kaolinite. This is a hydrous silicate of aluminum, with the formula $Al_2O_3.2SiO_2.2H_2O$. It usually occurs as an earhty, white, massive substance with a dull or slightly pearly luster. It is soft enough to be readily scratched with a finger-nail and is opaque in masses of any size. The fracture is either smoothly curving or irregular, and the feel is often smooth or slightly soapy. Undoubtedly the most characteristic property of the mineral is its smell, which can only be described by saying that it is clayey. It is, in fact, the presence of the kaolinite in clays and shales that imparts the strong odor to them. This odor is much more noticeable when the clay is moistened than when dry. Masses of the mineral may be compact or loose and mealy, and the microscope shows that such masses are often made up of minute six-sided monoclinic crystals. Pure kaolinite is not usually very plastic. Its fusing point is very high—about 1,850° C.—but a very small amount of impurities may lower this figure materially.

Kaolinite is often called "clay substance" or "clay base," and is that portion of a clay that is soluble in hot sulphuric acid or sodium carbonate. Some investigators claim that clays exist in which this mineral is unrepresented, but it is probably true that most clays contain a variable amount of it. Among other hydrous silicates of aluminum that may replace the kaolinite as "clay base" to a greater or less extent are the following: halloysite, indianaite, pholerite, rectorite, newtonite, allophane, cimolite, montmorillonite, pyrophyllite, collyrite, schrotterite, etc. In many cases these species differ from each other and from kaolinite to such a slight extent that they can hardly be identified with certainty without a chemical analysis. For this reason some clay-workers apply the word "kaolinite" to any of these species when pure, and call the impure, commercial article "kaolin."

Quartz.—This is silicon oxide; the formula is SiO_2. It occurs in clays as glassy, colorless, white, or iron-stained, round or irregular grains or pebbles. It is much harder than a knife and will scratch glass readily. It fuses at 1,830° C. when unmixed with other substances.

Practically all natural clays contain some quartz, and in certain classes of sandy clays it may constitute 50 per cent or more of the material. Even where present in considerable quantities, the grains are apt to be too small to be visible to the unaided eye. Such a clay may feel somewhat harsh, however.

Feldspars.—These are silicates of aluminum with alkalies, lime, or both. They occur in clays as tiny, white, opaque, pinkish, or greenish grains, with a stony luster. Feldspars break readily in two directions at nearly, or exactly, right angles, and the resulting cleavage faces may be very smooth and lustrous. While softer than quartz, they will still scratch glass. Several different mineral species are included under the term "feldspar," and their fusing points vary from about 1,200° C. for the alkaline ones to above 1,500° for lime feldspar.

Most clays are formed as a result of the decomposition of feldspar, as is explained later; and this accounts for the fact that unaltered residual grains are fairly common. In some sandy clays the proportion of feldspar grains is considerable, but in most cases the particles are microscopic.

Micas.—The two micas most common in clays are muscovite or white mica and biotite or black to brown mica. The former is a hydrous silicate of potassium and aluminum, while the latter is a hydrous silicate of potassium, aluminum, iron, and magnesium. Both occur in clays as minute, very soft, glassy scales with lustrous surfaces. The fusion points of the micas have not been determined with as much accuracy as might be desired, but they appear to be not far from those of the more alkaline feldspars. The fusing point of muscovite is about 100° C. higher than that of biotite.

Mica is nearly always present in clay to some extent, and the brilliantly flashing flakes may be quite conspicuous even when the total amount present is very small. Muscovite is much commoner than biotite, due to the fact that biotite decomposes easily.

Limonite.—This is a hydrated oxide of iron, with the formula $2Fe_2O_3.3H_2O$. It occurs in clays as a yellow or yellowish-brown powder which gives color to the material, as small rusty grains or spots, as concretions of some size, and as veinlets or stringers. When present as concretionary masses or stringers, it may be recognized by the fact that it has a dull luster, a brown or yellow color, a rather porous texture, is apparently rather soft, and the powder is always some shade of yellow.

Limonite is formed by the alteration of other iron minerals and is usually more plentiful near the surface of a clay deposit than elsewhere. At variable depths it is apt to be displaced by pyrite (q. v.) or, more rarely, by hematite or magnetite.

Pyrite.—This is sulphide of iron, with the formula FeS_2. This mineral has a bright metallic luster, a pale to deep yellow color, and such a hardness that it cannot be scratched with a knife. The color is black when it is finely pulverized; and it usually occurs in somewhat cubical or rounded crystals or grains, or as rounded nodules.

Pyrite alters readily to limonite (q. v.) when at or near the surface; so it is apt to appear only at some depth. It may then cause a considerable depreciation in the worth of a previously valuable clay, as is later explained.

Calcite.—This is carbonate of calcium or lime; the formula is $CaCO_3$. It occurs in clays in three forms: first, as microscopic grains disseminated throughout the clay; second, as soft, translucent, white or colorless, glassy-lustered veinless; third, as compact, dull-lustered concretions. In any case it can be identified with ease and certainty by the fact that, if a drop of hydrochloric (muriatic) acid is placed upon it, or if it is immersed in some of the acid, bubbles will form and the acid will appear to boil. Vinegar may be substituted for muriatic acid in making this test, but the effervescence is not then so vigorous as it is with the acid.

Calcite is not usually present in clays in a visible form, but is not uncommon as a disseminated impurity. When present in some quantity, the material is called *marl.*

Gypsum.—This is hydrous sulphate of calcium or lime; its formula is $CaSO_4+2H_2O$. It is a glassy-lustered, translucent to transparent, white mineral that is easily scratched with a finger-nail (calcite is harder than a finger-nail). It breaks or cleaves very easily in one direction, and the thin plates thus formed are somewhat flexible and have very smooth and lustrous surfaces. It usually occurs in clays as crystalline veinlets, but it is not uncommon as diamond- or lozenge-shaped crystals. It is occasionally disseminated throughout a clay in particles too small to be seen with the unaided eye, and it sometimes occurs as large transparent plates, called *selenite.*

Carbonaceous Matter.—This may be present in three forms: first, as roots and other parts of vegetation, in which case it is readily recognized; second, as asphaltic material, which may give the clay a distinctive odor, especially when heated; third, as coal. When present as asphaltic material or coal, it usually imparts a gray, bluish-gray, or black color to the clay.

Water.—Practically all clays as mined contain some water mechanically included in the pores. In the dry climate of Colorado very little of this moisture remains unevaporated from small pieces of clay after exposure to the air for a day or two.

Among other minerals rarely found in clays, or present in comparatively small amounts, are the following: *opal* (hydrated, amorphous silica), *magnetite* (oxide of iron), *hematite* (oxide of iron), *pyrolusite* (oxide of manganese), *rutile* (oxide of titanium), *ilmenite* (oxide of titanium and iron), *psilomelane* (hydrous oxide of manganese, etc.), *dolomite* (carbonate of calcium and magnesium), *magnesite* (carbonate of magnesium), *siderite* (carbonate of iron), *hornblende* (complex silicate), *garnet* (complex silicate), *tourmaline* (complex silicate), *glauconite* (hydrous silicate of potassium and iron), *lepidolite* (hydrous silicate of lithium, aluminum, and potassium), *vivianite* (phosphate of iron), *epsonite* (hydrous sulphate of magnesium), *melanterite* (hydrous iron sulphate), and soluble alkalies.

Chemical Composition—

Pure kaolinite contains 39.8 per cent of aluminum oxide (Al_2O_3), 46.3 per cent of silica (SiO_2), and 13.9 per cent of water (H_2O). No known deposit of pure kaolinite exists, although several approximate to purity, and others may show a composition similar to that just stated after impurities have been removed by washing.

Not only do the three components just mentioned occur in varying proportions, but many other substances are apt to be present in large or small amounts. A complete analysis of a clay should state the proportions of the following ingredients: silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3), ferrous oxide (FeO), lime (CaO), magnesia (MgO), potash (K_2O), soda (Na_2O), titanic oxide (TiO_2), manganous oxide (MnO), carbon dioxide (CO_2), sulphur trioxide (SO_3), water of crystallization (H_2O), moisture (H_2O), and organic matter. It is, however, not usually necessary or desirable to make such a complete analysis; so in most cases all the iron is reported as ferric oxide, and no attempt is made to detect the presence of titanic oxide, sulphur tri-oxide, carbon dioxide, manganous oxide, or organic matter. Often the presence or absence of some or all of these five substances is ascertained, although the amounts present are not determined. Manganous oxide is undoubtedly the rarest of the substances mentioned.

A chemical analysis does not really help very much in the classification of a clay; it is largely corroborative and explanatory rather than determinative. All the information required to classify a clay may be obtained from the physical tests alone.

About the only time when a chemical analysis is really useful is when a clay must be modified or improved by the admixture of other ingredients. It will then often point the way. It is true, nevertheless, that unusual amounts of certain ingredients have a decided bearing upon the properties of the clay, as will be indicated later; but it is safer to make actual physical tests of the sample rather than to try to predict its probable behavior from its chemical analysis.

Two kinds of chemical analyses are frequently mentioned in connection with clays. The process by which the proportions of the substances recently mentioned are determined is called the *ultimate analysis;* while the determination of the relative proportions of kaolin or clay substance, quartz, and feldspar is known as the *rational analysis.*

Methods of making ultimate analyses of clays are presented in all good text-books on quantitative analysis, as well as in Part I of Bulletin No. VII of the Wisconsin Geological and Natural History Survey, page 246; it has not been thought necessary to include directions for such work here.

Two methods of making rational analyses are given by Dr. Ries on pages 66 and 67 of his book on clays.[1]

A scheme for calculating rational analyses from ultimate analyses was used by Buckley[2] with results that are apparently satisfactory. He calculates the percentage of feldspar and kaolin from the ultimate analysis, assuming that they have the compositions given by Dana;[3] i. e.:

	K_2O	Na_2O	Al_2O_3	SiO_2	H_2O
Orthoclase	16.9%	......	18.4%	64.7%	......
Albite	......	11.8%	19.5%	68.7%	......
Kaolin	......	......	39.5%	46.5%	14%

Buckley says: "All the potash and soda were figured to feldspar. The alumina required for the feldspar was deducted from the total alumina, and the difference was taken for the starting-point from which to figure the kaolinite substance. The difference between the total silica (SiO_2) and that required by both feldspar and kaolin gives the quartz and the silica in silicates other than those mentioned." This method has been used in fig-

[1] Clays: Their Occurrence, Properties, and Uses, by Heinrich Ries.

[2] Wisconsin Geological and Natural History Survey, Bul. VII, Part I, p. 267.

[3] A Text Book of Mineralogy, pp. 371, 377, and 481.

uring the ultimate analyses given in this report. In addition, the lime is figured to calcite, or to gypsum if the ultimate analysis shows the presence of sulphur. The ferric oxide is figured to limonite. It is evident that part of the iron and sulphur ought to be figured to pyrite, and the lime to both calcite and gypsum, in some cases, but it is not desirable to introduce too many refinements into a process that is admittedly merely an approximation. The following formulae have been used in figuring rational analyses according to this method:

Percentage of feldspar in the clay $= (5.92 \times \%K_2O) + (8.48 \times \%Na_2O)$.

Percentage of kaolin in the clay $=$

$$2.53\left[\%Al_2O_3 - \left((1.09 \times \%K_2O) + (1.65 \times \%Na_2O)\right)\right]$$

Percentage of quartz in the clay $= \%SiO_2 - \left\{1.18\left[\%Al_2O_3 - \left((1.09 \times \%K_2O) + (1.65 \times \%Na_2O)\right)\right] + (3.83 \times \%K_2O) + (5.82 \times \%Na_2O)\right\}$

Percentage of calcite in clay $= 1.79 \times \%CaO$.

Percentage of gypsum in clay $= 3.08 \times \%CaO$.

Percentage of limonite in clay $= 1.17 \times \%Fe_2O_3$.

As an example of the use of these formulae, consider clay No. 58, which has the following ultimate composition: SiO_2 72.50%, Al_2O_3 17.11%, Fe_2O_3 0.74%, CaO 0.82%, MgO 0.20%, K_2O 3.73%, Na_2O 0.26%, water of crystallization 3.01%, moisture 0.82%, and with CO_2 present.

Substituting the values given in the above equations, we obtain the following results (the calculation was done on a slide-rule, and the results may not be exactly correct):

Percentage feldspar $= 5.92 \times 3.73 + 8.48 \times 0.26 = 24.3$	24.3
Percentage kaolin $= 2.53\ [17.11 - (1.09 \times 3.73 + 1.65 \times 0.26)] = 31.9$	31.9
Percentage quartz $= 72.5 - \{1.18\ [17.11 - (1.09 \times 3.73 + 1.65 \times 0.26)] + (3.83 \times 3.73 + 5.82 \times 0.26)\} = 42.0$	42.0
Percentage calcite $= 1.79 \times 0.82 = 1.5$	1.5
Percentage limonite $= 1.17 \times 0.74 = 0.9$	0.9
Total	100.6

If, as in the case just discussed, the calculated proportions total fairly close to 100 per cent, it is a good indication that the work has been correctly performed and that the assumptions are justifiable.

The rational analysis, especially when obtained in the manner just outlined, is much more apt to be correct and to possess practical value in the case of high grade clays than it is when many impurities are present.

As an illustration of the usefulness of rational analyses, suppose that a potter is using a clay of a certain composition which is low in feldspar. To each 100 pounds of clay he adds 50 pounds of feldspar, the whole being finely ground and well mixed. Assume that the resulting mixture has the following rational composition: kaolin 45.21 per cent, quartz 20.62 per cent, and feldspar 34.17 per cent. Now suppose that he finds it desirable to substitute a clay of the following composition for the one he has been using: kaolin 66.33 per cent, quartz 15.61 per cent, and feldspar 18.06 per cent. This clay is evidently deficient in quartz and feldspar and these must be added in order to duplicate the mixture first used. It is a simple matter of arithmetic to ascertain that 14.6 pounds of quartz and 32.1 pounds of feldspar must be added to each 100 pounds of the clay to secure the desired composition. If these two substances are finely ground and well mixed with the ground clay, the properties of the mixture will be practically the same as in the first instance.

ORIGIN OF CLAYS

Clays are always of secondary origin; that is, they are invariably formed by the alteration of other rocks. In most cases the rocks that alter readily into clay contain considerable amounts of acid feldspars, and this fact has led many to believe that clays are always the alteration product of feldspars. This idea is erroneous, however, since some very fine clays are produced by the decomposition of limestones or rocks composed largely of rather basic, non-feldspathic silicates. It is true, nevertheless, that the principal ingredients of most clays originally existed in acid feldspathic rocks.

A residual clay is one formed in place by the decomposition of the original or primary rock, of which it forms the outcrop. Where formed by the alteration of an igneous rock, there is usually a gradual transition from the comparatively soft clay near the surface to the unaltered, hard, primary rock at some depth. Where residual clays occur over impure limestones, the change from clay to primary rock is, however, sharply defined. This is because such a clay is not formed by the decomposition of the limestone, but represents insoluble impurities in the limestone which accumulate directly above the unchanged limestone as a result of the gradual dissolving of the latter by surface water.

A transported clay is one which has been formed by the alteration of particles of primary rocks that have been mechanically detached from their original position, carried some distance, and then deposited. The transporting agent may be water, ice, or the wind; and the decomposition may take place during or after transportation. The final deposition may be in running or standing water, or on land surfaces. Such clays are often more or less stratified, and, if deposited under water, they constitute a sedimentary rock.

Residual clays are, then, to be sought in areas where igneous rocks or impure limestone are plentiful; and thick deposits are hardly to be expected where the surface is, or has been in recent geological times, subject to much erosion either by water or ice.

The shape and extent of such deposits will evidently depend upon the rock from which the clay was derived. If the original rock were a great boss of granite or syenite, a laccolith of porphyry, or a surface flow of rhyolite, the clay derived therefrom may occur over a large area. Where, however, the igneous rock occurred as a dyke, the clay would be found along a comparatively narrow zone.

It seems to be a general practice to apply the word "kaolin" only to a white-burning, residual clay.

Transported clays may occur in present or ancient streambeds; they may be interbedded with other types of glacial deposits; and considerable quantities of rather poor quality sometimes accumulate on land surfaces through the action of the wind. The largest deposits are, however, undoubtedly those that are formed in lakes or seas by deposition from silt-laden water. Such deposits may cover miles to a considerable thickness. They are eventually covered with sandstones, conglomerates, and other types of sedimentary rocks, and are especially apt to be found where such rocks have been turned up on end, as in the hogback or foothill region of the Front Range. They may also outcrop almost anywhere in the plains region in the form of nearly horizontal beds, but there they are usually hidden beneath surface wash, excepting along the sides of valleys and arroyos.

Transported clays are not of so high quality, on the average, as the residual ones, but they are much more plentiful than the latter, and the total value of the products made from transported material is undoubtedly much higher than those manufactured from clay formed in place. It should not be supposed that transported and residual clays necessarily differ in appearance, properties, or uses. Some varieties can hardly be distinguished except by noting the manner of occurrence.

CHAPTER II

Physical Properties of Clays

PLASTICITY

Plasticity Defined.—Seger[1] defines plasticity as "the property shown by a solid body of absorbing and holding a liquid in its pores, and forming a mass which can be pressed or kneaded into any desired form, which it retains when the pressure is withdrawn, the mass hardening on the evaporation of the liquid." This is a very narrow definition, applicable only to clays. Physicists prefer the following: "Plasticity is the property which many bodies show of changing forms under pressure, without rupturing, which forms they retain when the pressure ceases." As thus defined, placticity is not confined to damp clays, but it is certainly often developed in them to a very high degree as compared with other minerals or mixtures of minerals. Finely ground gypsum or brucite has some plasticity, however.

Plasticity is one of the most important properties of a clay, since many of the products for which clay is used could not be manufactured from a non-plastic substance.

Cause of Plasticity.—The cause of plasticity in clays is unknown, although many theories have been advanced in explanation of the phenomenon. Early workers suggested that the property was the result of peculiar textural features, but this idea is now upheld by few. Plasticity may be produced by colloids or glue-like particles, and many believe that this is the most probable explanation of the property, although the exact nature of the colloids involved has never been certainly determined.

Improvement of Plasticity.—The plasticity of most clays may be increased by fine grinding. Some very plastic clays are, however, coarser-grained, than are others of lower plasticity; so this property is not wholly dependent upon size of grain.

[1]Beziehungen zwischen Feuerfestigkeit und Plasticität der Tone. Thonindustrie-Zeitung, 1890, p. 201.

A clay that has been aged—i. e., left lying under cover for several months—usually shows an increase in plasticity. This may be due to bacterial action, or to the development of an acid which neutralizes the alkalinity of the whole mass.

Allowing a clay to lie in the open air for some time usually improves the plasticity.

Testing or Measuring the Plasticity.—Plasticity, as defined, involves two factors; i. e., resistance to deformation, and the extent of flowage before rupturing. The first factor—resistance to deformation—is of so little practical importance that it hardly seems worth while to measure it. It is true that, where clay products are molded by power, more power is required to form articles from clays with a high resistance to deformation than would be needed if the resistance were low; but it is extremely doubtful if a clay were ever accepted or rejected because of its high resistance to deformation. Practically, this property is almost never considered.

Most of the methods recommended for the measurement of plasticity place equal stress upon both of the factors above mentioned. Theoretically, this is an admirable practice, but the results secured have no place in a practical report such as is this. It is certain that the most important factor is the extent or amount of flowage before rupturing, and this may be tested in several ways. Perhaps the most satisfactory procedure is to compress a cylinder of clay two inches long and three-quarters of an inch in diameter until cracks at 45° with the direction of pressure appear on the sides. The amount of flowage is then measured, quantitatively, by the percentage of increase in the diameter of the head. Long experience has proven that fully as satisfactory results may be obtained much more simply by using the following method, which has yielded the data incorporated in this work:

Grind the sample to forty-mesh and place half of it in an enameled or granite-ware pan. Slowly moisten with water, stirring constantly with a broad spatula. As soon as possible, take the mass in the hands and work into a ball, adding water until it seems as plastic as it is possible to get it. Continue to add water until the clay becomes sticky and looks shiny and wet on the surface. It will then have a very slippery feel, and it is certain that too much tempering water has been added—it has been overtempered. Next, add some of the dry, ground clay until its slippery, wet features have just disappeared. It will then have been tempered to a condition of maximum plasticity, and it should be a simple matter to temper the remainder of the ground sample to the same condition. Finally, form a ball, with a diameter of about two and a half inches, from the tempered clay, and press it out on a plate of oiled glass until a cake about a half-inch thick has been formed. The plasticity may then be expressed in the following terms:

Fine plasticity: Practically no fracturing around the edges of the cake; it may be readily molded to any form and holds its shape well.

Good plasticity: Shows small fractures around the edges of the cake: it may be molded to any shape and holds its shape well.

Fair plasticity: There is much cracking around the edges of the cake; cracks considerably when attempts are made to mold it, and molded pieces are easily broken.

Poor plasticity: Cracks very badly under slight pressure, and it can be molded only with the greatest difficulty and care.

This classification may be extended by adding very poor and very fine; these terms are self-explanatory. This makes a six-degree classification, but such refinement is useless in most cases. Clapp[1] has used the following terms descriptive of the plasticity of North Dakota clays: very good, good, moderate, fair, lean, very lean. This appears to be practically the equivalent of the six-degree classification just discussed. It is true that clays of low plasticity are often called lean, and those with a high plasticity are termed fat; but the writer is of the opinion that the former term should be so defined as to be applicable to all the three lower degrees of the six-degree classification, while the remaining three degrees should constitute the fat clays.

It is undoubtedly true that the method of testing the plasticity just outlined involves the personal factor to some extent, but it has been proven that the results are quite satisfactory and very useful if the tests are made with care.

COHESION

Cohesion Defined.—As used in connection with clays, cohesion is that property that causes masses of tempered clay to adhere after they are brought in contact and some pressure is applied. As thus defined, cohesion is not synonymous with resistance to rupture, although that is the result of cohesion between particles.

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[1]Fourth Biennial Report of the North Dakota Geological Survey, p. 49.

The cohesion of clays is not always tested, although it is important in cases where a clay is split in passing through a die and the halves are then united under pressure, as in making tile.

Testing or Measuring the Cohesion.—The cohesion should be tested by rolling two two-inch balls of tempered clay and pressing them together between the hands until the combined thickness is about two inches. If the two masses can then be separated only with difficulty or not at all, the cohesion is strong; otherwise it is weak.

WATER REQUIRED TO SECURE MAXIMUM PLASTICITY

The water added to a clay is called *tempering water,* and the amount varies with the kind and texture. As a rule, the finer-grained clays require more tempering water than the coarser, sandy ones, but they absorb water more slowly. In general it may be said that a high percentage of tempering water induces a high air shrinkage; but this may not be true if the clay contains coarse grains. These facts may be used in making a hasty field examination of a clay.

Where a clay is tested completely in the laboratory, a knowledge of the amount of tempering water required is of practically no importance, but such data may have some value to the practical worker, and the measurement is easily made; so the figures are included in this report.

Measurement of the Water Required to Secure Maximum Plasticity.—To determine the percentage of absorbed water, weigh a small piece of the freshly tempered clay; then allow it to dry for several days, and weigh again. Divide the difference between these two weights by the dry weight; the quotient is the percentage of tempering water, by weight, that must be added to the dry, ground clay to secure maximum plasticity.

The time required to dry the clay in the dry climate of Colorado varies from a day to a week, depending upon the condition of the atmosphere and the warmth and dryness of the laboratory. When tempering water is still present, the test-piece will have a dark color. It will dry first on the edges, and there will be a sharp line of demarcation between the wet and dry portions. If the test-piece be shaped like a Seger cone, as later described and recommended, it should be allowed to dry at least three times as long as it takes for all the dark coloration to disappear from the surface; and it should be turned once or twice during the process.

All authorities insist that the test-pieces should be dried in an air-bath at 212° F. before the final weighing. Such a procedure gives results that are useless from a practical standpoint, however, since no clay is absolutely free from moisture when mined; and treatment in an air-bath drives off all the moisture. It is true that the amount of moisture in the clay, when it is tested in the laboratory, is not in all cases the same as is present when the clay is used, but the method above recommended will give results that are nearer the truth than will be those obtained if all the moisture be expelled in an air-bath. The choice of methods should depend upon whether the investigator be interested in the total amount of moisture that the clay will contain when thoroughly tempered, or in the amount of water that must be added to the clay as it reaches his hands in order to temper it to maximum plasticity. The data last mentioned are evidently of more practical value than the others, and they have, therefore, been selected for incorporation in this report. It has been found by experiment that air-dried clays tested in the laboratory of the School of Mines at Golden contained very little tempering water, and it is likely that the results obtained in the manner outlined are quite comparable with those secured by other investigators who dried their clays in a hot air-bath.

The amount of tempering water in a clay will ordinarily vary from 20 to 35 per cent, but it may go a few per cent below the former, and 10 or 15 above the latter, figure.

AIR SHRINKAGE

Air shrinkage of a tempered clay is the result of the evaporation of the moisture separating the particles. It is a very important characteristic of the clay, since a high air shrinkage is usually accompanied by more or less distortion of the molded article. Even when no distortion occurs, due allowance must be made for both air and fire shrinkage, if a finished product of specified dimensions is desired.

Manner of Decreasing a High Air Shrinkage.—If the air shrinkage be too great, it may be lowered by "grogging" the clay; i. e., adding sand, ground bricks or crucibles, or cinders which have a fusing point as high as, or higher than, that of the clay. These increase the average size of the grains and produce the desired result, but they decrease the amount of tempering water required and lower the plasticity and tensile strength of the clay; so they must be used with care.

Measurement of the Air Shrinkage.—To ascertain the percentage of air shrinkage, it is only necessary to punch two holes exactly two inches apart on a piece of molded wet clay. Then dry the clay thoroughly and measure the amount of shrinkage that has occurred. It is then a very simple matter to calculate the percentage of air shrinkage.

It will be found most convenient to use a pair of sharp-pointed compasses that may be fastened with a set-screw as the instrument with which to punch the two holes in the piece of wet clay. After the clay has dried, these compasses are adjusted until both points exactly fit into the two holes, and the shrinkage is ascertained by placing the points against a scale divided to hundredths of an inch. If the points prove to be one and eighty-eight hundredths of an inch apart after drying, and it is known that they were two inches apart before drying, it is easy to see that the total shrinkage in the length involved has been twelve-hundredths of an inch. Twelve-hundredths of an inch in a piece two inches long is equivalent to six-hundredths of an inch in a piece one inch long, so the percentage of air shrinkage in this case is 6 per cent.

It is best to place the holes diagonally across the largest face of one of the bricklets later described. They may be placed on the test-cones, but there is considerable danger of breaking the tips of the cones if this is done.

Some authorities use large pieces of clay and rule lines four to six inches apart upon them. They are then able to report tenths and hundredths of a per cent. This is an utterly useless refinement, and it is doubtful if the results obtained in practice will come within half a per cent of those secured in the laboratory. It will also be found much more difficult to rule lines than to punch tiny holes at any desired distance apart; so the use of the method above described is strongly recommended as being simple, rapid, and sufficiently accurate for the purpose.

In case a clay warps very badly in drying, it may not be possible to measure the percentage of air shrinkage with any approximation to accuracy. Each face of a bricklet may give a different figure, and, when this is true, it is necessary to punch holes on all faces of a bricklet, and then average the figures obtained from each face.

TENDENCY TO CRACK ON DRYING

A clay which cracks on drying is practically valueless for any purpose for which tempered clays are used, although the defect may sometimes be remedied in the manner indicated later.

The finer the grain, the more apt is the clay to possess this detrimental feature, which is usually accompanied by a high air shrinkage and the ability to absorb a large amount of tempering water.

Manner of Decreasing the Tendency to Crack on Drying.—Slow drying may prove sufficient to overcome the difficulty if the cracking is slight, but in most cases it is necessary to add "grog" to the clay, as is described under "Manner of Decreasing a High Air Shrinkage."

Estimation of the Tendency to Crack on Drying.—No attempt has been made in this report to estimate the tendency to crack with any great degree of exactness. Four descriptive terms relating to this feature have been used, however, and they may be interpreted as follows:

No: No checks or cracks develop.

Slightly: The test-piece is somewhat checked on the surface.

Considerably: Deep, fairly wide cracks develop on the test-piece.

Badly: The test-piece breaks into two or more pieces.

The tendency to crack on drying is apt to be more evident the larger the piece tested, and for this reason a test-piece of some size should be used, as is later specified.

Great care should be taken not to confuse cracks produced by shrinkage on drying with those which are apt to appear when several pieces of clay are insufficiently worked or kneaded before the mass is pressed into a mold. The latter are smooth, while the former are uneven and rough.

SLAKING

Slaking Defined.—A clay is said to slake when the addition of water causes it to soften materially or to disintegrate. It is not supposed that a true chemical combination takes place, as when water is added to lime, and the term is, therefore, used rather inaccurately.

Some clays slake in a few moments; others require hours for complete disintegration; while still others do not slake at all—at least in a day or two.

The determination of the time required for slaking is of some practical importance, since the more quickly a clay slakes, the more easily it may be tempered unground; and clays that do not slake easily, or at all, must be ground before they can be tempered.

Determination of the Time Required for Slaking.—Immerse a one-inch cube of the unground clay in water and note the time required for complete disintegration. When the slaking is completed, the cube will have been replaced by a conical pile of loose material without a hard center. If the clay does not disintegrate noticeably in eight to ten hours, it is practically non-slaking and need not be tested further.

TENSILE STRENGTH OF UNBURNED CLAYS

Tensile Strength Defined.—The tensile strength of a clay is the resistance it offers to rupture produced by tension.

The tensile strength is an important characteristic of a clay, since, if this be low, the molded products may not be strong enough to stand the handling involved when they are piled in the kiln.

High tensile strengths and plasticities often accompany each other, but exceptions to the rule are not uncommon. The clays with the highest tensile strengths appear to be those which have a fairly fine, even grain. If a clay is very fine-grained, as when composed largely of kaolin, or if there is a considerable variation in the size of the grains, the tensile strength is lowered.

If the clay does not crack on drying, the tensile strength may be anything from fifty to five hundred pounds per square inch.

Testing or Measuring the Tensile Strength.—Briquettes exactly like those used in testing the tensile strength of cement are made from the clay in brass molds. These are thoroughly dried, and then placed under tension in a cement testing-machine until broken. The clay when molded has a cross-section of exactly one square inch, but this is decreased as the clay dries and shrinks, and the tensile strength must be calculated to accord with the new cross-section, according to the following formula:

$$T.\,S. = \frac{T}{S \times S'}$$

T. S.=Tensile strength in pounds per square inch.

T.=Number of pounds' tension exerted by the testing-machine at time of failure of briquette.

S and S′=Average length and width, respectively, of the smallest portion of the dried briquette (in most cases these two dimensions will be almost equal), measured in hundredths of an inch.

If the briquette does not break along its smallest section, it may have been imperfectly worked into the mold, or there may not be enough soft material between the briquette and the jaws holding it in the machine. In the former case the broken section will show one or more smoothly rounding surfaces or cracks; while a lack of proper padding will be revealed by bruises on the surface of the briquette. If the peculiarity does not appear to be due to either of these causes, the tensile strength is figured just as though the briquette had broken at its smallest section. It is, of course, impossible accurately to determine the tensile strength of a clay that cracks even slightly on drying.

Most clay-workers claim that several briquettes of each clay tested should be broken, but experience has proven that where care is used the results are quite uniform and any one briquette will yield data sufficiently accurate for all practical purposes. It is good practice to make two briquettes from each sample, and thus to guard against the accidental breakage of, or development of flaws in, one of them.

Great care must be exercised in making the briquettes; the edges must be sharp, the whole must be so completely mixed as to be absolutely homogeneous, and air bubbles must be absent. Some workers advocate cutting a lump of clay to approximately the size and shape of the mold, and pressing it in from both sides with the hands. This method probably insures the best results, but is quite difficult to apply. If care is used, equally good results can be obtained in a shorter time by proceeding as follows: Lay the oiled mold (machine oil of any kind may be used for this purpose) upon a sheet of oiled plate-glass, and fill the mold by pressing in small pieces of clay with the fingers. See that the pieces are well pressed into the edges at the beginning of the operation, and knead and press the whole mass thoroughly as the pieces are added. When the mold is filled, smooth the upper surface with a spatula moistened with water or oil, slide the filled mold off the glass, and force the briquette from the mold. For the last-mentioned operation a piece of metal shaped to fit the mold will be found useful, although a dry briquette will do.

BURNING TESTS

The test made on the burned clay are really more determinative than the others, although much may be predicted from the results of the operations already described, and the chemical analysis. It is, however, unsafe to attempt to classify a clay definitely until it has been burned. Some workers base their judgment upon the burning tests alone, but this is equally unsatisfactory; they should always be considered in connection with the other tests.

MEASUREMENT OF TEMPERATURES

In making the burning tests it is necessary to heat the clay repeatedly to different known temperatures; it is, therefore, essential that means be provided for determining the temperatures reached. Such means may take the form of electric or optical pyrometers, but these are expensive and delicate instruments which are found in the laboratories of but few investigators. Test-pieces of known compositions and fixed fusion points are quite reliable and much cheaper, and were used in testing the clays described in this report. They are called Seger cones and have the form of slender, three-sided pyramids. They are composed of varying proportions of pure quartz, kaolin, feldspar, calcite, ferric oxide, boracic acid, and lead oxide. All those with fusion points below 1,660°C. or 3,020°F. measure two and a half inches in length and have five-eighth inch bases, while those of greater refractoriness are one inch long and five-sixteenths of an inch broad at the base.

The following table shows the fusion points under oxidizing conditions of all the cones used in the manufacture of clay products. It also contains a color scale and gives data on the fusion points of various substances:

Seger Cone No.	Degrees Centigrade	Degrees Fahrenheit	Fusion Points of Various Substances	Color Scale
			Sulphur, 116°C. (240°F.)	
			Tin, 232°C. (450°F.)	
			Bismuth, 270°C. (518°F.)	
			Cadmium, 321°C. (610°F.)	
			Lead, 327°C. (621°F.)	
			Zinc, 419°C. (786°F.)	
	520	968		First visible red heat
022	590	1,094		
021	620	1,148		

Seger Cone No.	Degrees Centi-grade	Degrees Fahren-heit	Fusion Points of Various Substances	Color Scale
020	650	1,202		
019	680	1,256	Antimony. 630°C. (1,166°F.)	
018	710	1,310	Aluminum, 659°C. (1,218°F.)	Dull red
017	740	1,364		
016	770	1,418		
015	800	1,472		Full red
012½	875	1,607		Cherry-red
010	950	1,742		
09	970	1,778	Silver, 961°C. (1,762°F.)	
08	990	1,814		
07	1,010	1,850		Bright cherry
06	1,030	1,886		
05	1,050	1,922	Gold, 1063°C. (1,945°F.)	
04	1,070	1,958	Copper, 1,083°C. (1,981°F.)	
03	1,090	1,994		
02	1.110	2,030		
01	1,130	2,066		Deep orange
1	1,150	2,102		
2	1,170	2,138		
3	1,190	2,174		
4	1,210	2,210	Manganese, 1,225°C. (2,237°F.)	Bright orange
5	1,230	2,246		
6	1,250	2,282		
7	1,270	2,318		
8	1,290	2,354		
9	1,310	2,390		White
10	1,330	2,426		
11	1,350	2,462		
12	1,370	2,498		
13	1,390	2,534		
14	1,410	2,570	Silicon, 1,420°C. (2,588°F.)	Bright white
15	1,430	2,606		
16	1,450	2,642	Nickel, 1,452°C. (2,646°F.)	
17	1,470	2,678	Cobalt, 1,490°C. (2,714°F.)	
18	1,490	2,714	Chromium, 1,510°C. (2,750°F.)	
19	1,510	2,750	Iron, 1,520°C. (2,768°F.)	
20	1,530	2,786	Palladium, 1,550°C. (2,822°F.)	Dazzling white
26	1,650	3,002		
27	1,670	3,038		
28	1,690	3,074		
29	1,710	3,110		
30	1,730	3,146	Kaolin, 1,735°C. (3,155°F.)	
31	1,750	3,182	Quartz, 1,750°C. (3,185°F.)	
32	1,770	3,218	Platinum, 1,755°C. (3,191°F.)	
33	1,790	3,254		
34	1,810	3,290	Bauxite, 1,820°C. (3,308°F.)	
35	1,830	3,326		
36	1,850	3,362		
			Titanium, 1,900°C. (3,452°F.)	
			Alundum (brown), 2,025°C. (3,677°F.)	
			Alundum (white), 2,075°C. (3,767°F.)	
			Corundum, 2,110°C. (3,650°F.)	
			Chromite, 2,180°C. (3,956°F.)	
			Carborundum is unstable at 2,220°C. (4,028°F.), but does not fuse at 2,700°C. (4,892°F.).	

It will be noticed that consecutive numbers between Cones 022 and 010 differ by 30° Centigrade, while the difference between consecutive numbers above 010 is only 20°. The fusion point of any cone may be easily calculated from the following formulae. The second and third should be memorized by all clayworkers. They are so simple that the computation may be made mentally.

(1) For Cones 022 to 010:
Fusion point in degrees Centigrade $= 950 - (n - 10)30$.

(2) For Cones 010 to 01:
Fusion point in degrees Centigrade $= 1{,}150 - 20n$.

(3) For Cones 1 to 36:
Fusion point in degrees Centigrade $= 1{,}150 + (n - 1)20$.

"n" in each case is the numerical part of each cone number. Any ciphers to the left of the first digit should be ignored. 1,150°C. is the fusion temperature of an alloy consisting of nine parts gold and one part platinum. Under most conditions, Cone 1 fuses at this temperature.

Manner of Using Seger Cones.—To measure temperatures with these cones, they must be mounted upon a fire-clay slab into which the base of each cone is firmly imbedded. Care must be exercised not to obscure the cone number which is stamped near the base. The mounted cones should be thoroughly dried in a hot air-bath, and are then ready for use. If they are to be used in a kiln that is to be heated very gradually, the preliminary drying is unnecessary. They should, however, never be placed in a hot kiln or muffle without a thorough preliminary drying and heating.

The test-pieces are placed in kilns or muffles opposite peepholes; and when one of the cones has so softened that it bends clear over until the tip just touches the support, the fusion temperature of that cone has been reached.

Precautions to Be Observed in Using Seger Cones.—If the peep-hole is too large, or cold air reaches the test-cones in any way, a difficultly fusible skin may form on the surface, and this delays the bending until a point considerably above the normal fusion temperature.

Too rapid heating will cause the cones high in iron (the red ones) to swell and blister, and this also delays the bending.

Sulphurous fumes from the fuel may form a difficultly fusible skin to form on Cones 010 to 3.

Prolonged heating lowers the fusion point of all the cones up to 3, as does a reducing atmosphere.

A cone once heated will, if reheated, fuse at a temperature below that at which it would normally melt.

It is apparent from the above statements that the fusion temperature of any cone varies considerably with the conditions under which it is used, and that cones are not so accurate as pyrometers. They really measure or indicate thermal conditions rather than temperatures alone, but this is exactly what a clay-worker desires. If he has secured a certain result with a given clay and set of conditions at Cone 10, say, he can be sure that a repetition of all the conditions will give an exactly identical result. It makes no difference to him whether Cone 10 has fused at 1,330°C. or not.

Seger cones, then, furnish a simple and inexpensive means of measuring thermal conditions, such as exactly fits the needs of clay-workers. They give results that are perfectly comparable where the conditions are similar, and they may also be used as thermometers when absolute accuracy is not essential. They are manufactured in this country by Professor Edward Orton, Jr., University of Ohio, Columbus, Ohio; and they may be purchased from him at a cost of one cent each.

KINDS OF FURNACES USED

It is naturally impracticable to use large kilns in a laboratory where samples of clays to be burned to many temperatures arrive almost daily. The apparatus needed there is evidently a small furnace or kiln that does not use such fuel and develops high temperatures in comparatively brief periods of firing. It is also highly desirable that the appliance be of the muffle, rather than the crucible, type, as it is then easy to provide peep-holes through which the pieces to be tested and the standard cones may be observed. The merits of various kinds of heating outfits are summarized below:

Coal-Burning, Muffle Type Assay Furnaces.—Unless the furnace is especially well designed and the draft is unusually strong, it is difficult to melt Cone 1 in the ordinary coal-fired assay furnace. If the furnace is carefully cleaned, all cracks and holes are plugged with fire-clay, the holes in the muffle and door are reduced to about a quarter of their original size, the coking method of firing is employed, and forced draft is used, Cone 12 may be melted in such a furnace, and, under unusually favorable conditions, a temperature even higher than this may be reached. It takes, however, four or five hours to raise the temperature to such an extent, and the apparatus is not satisfactory for any but very low-grade clays with low fusing points.

Gasolene-Burning, Muffle Type Assay Furnaces.—It is possible to reach Cone 8 with a Case burner, manufactured and sold by the Denver Fire Clay Company, and gasolene under fifty pounds' pressure. An oxidizing atmosphere should be used. This makes a satisfactory combination for low-grade clays, since it heats much more rapidly than the coal-fired furnace.

Artificial Coal-Gas-Burning, Muffle Type Assay Furnaces.—Under favorable conditions, Cone 10 may be melted with this outfit.

Meker Compressed-Air Furnace No. 30.—This is a high-temperature furnace made in Germany, and sold in this country by the Scientific Materials Company, of Pittsburg, Pa. It is guaranteed to melt Cone 26, using natural gas, gasolene gas, or water or coal gas, and an air pressure of from fifteen to twenty pounds per square inch.

One of these furnaces was purchased by the Survey and installed in the clay-testing laboratory at Golden, where only gasolene gas was available. A little experimentation showed that the gasolene gas was of too low grade to produce satisfactory temperatures, so a Blau-gas outfit was installed, with most gratifying results. Blau-gas is a bottled, liquefied gas that is being extensively adopted for light, heat, power, etc., where natural or coal gas is not obtainable.

With the Meker furnace and Blau-gas it is possible to reach the melting point of Cone 10 in about half an hour after lighting the burner, which is considerably sooner than the needs of the ceramist demand. Fifteen minutes more suffices to melt Cone 26. Higher temperatures could certainly be reached if the furnace lining and the muffles were made of more refractory material. The muffles furnished with the furnace are most satisfactory for moderate temperatures, but they soften greatly and bulge inward at high temperatures under the influence of the great gas pressure then employed. Fire-clay muffles containing a considerable proportion of corundum were tried, but proved useless. For high temperatures, pressed graphite muffles have proven most satisfactory, but they exert a powerful reducing action and are apt to cause the formation of carbides by union with some vola-

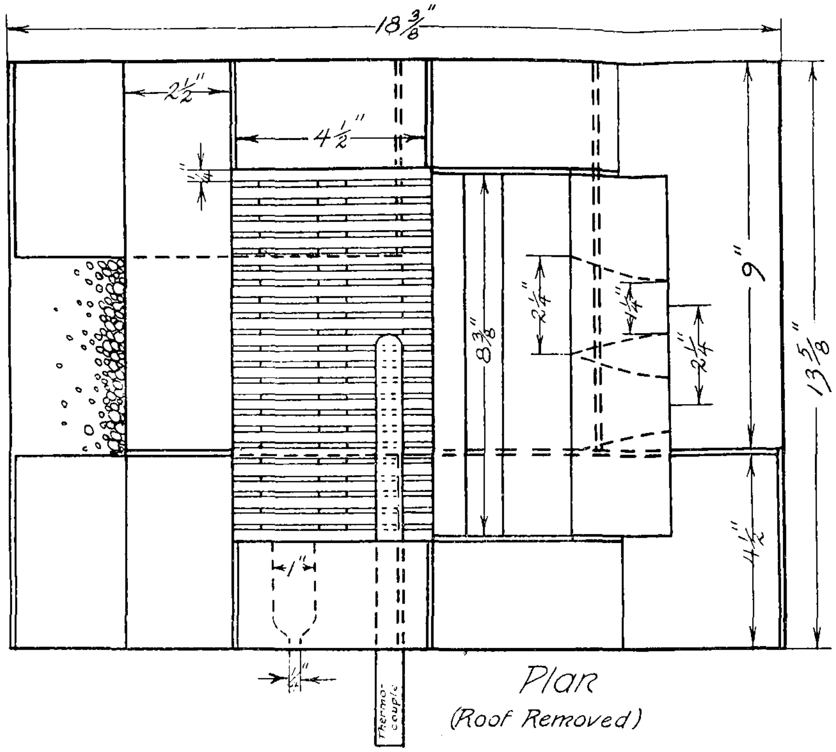
CRAMPTON KILN FURNACE

A LABORATORY FURNACE

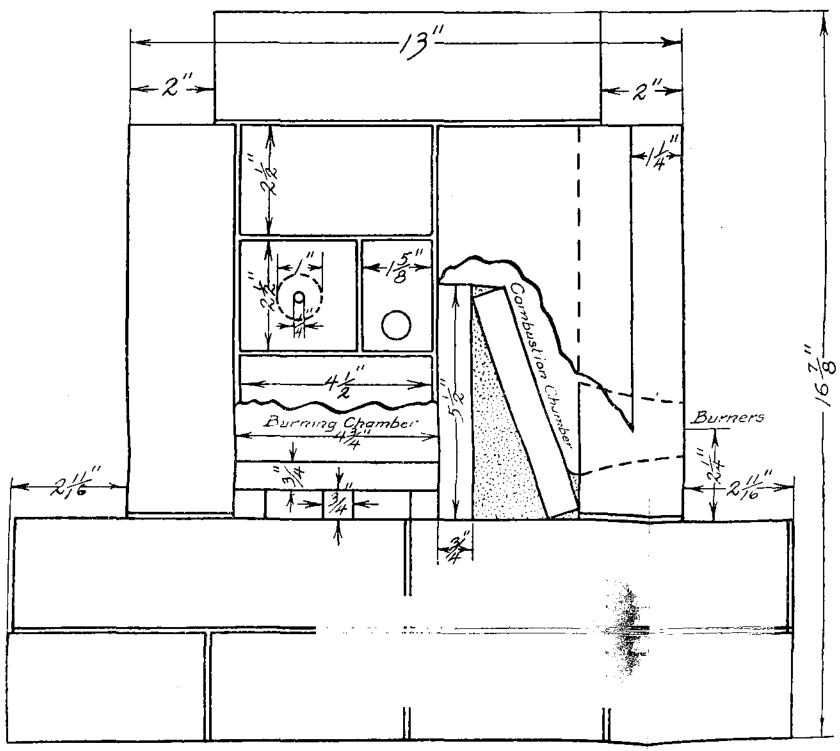
On the principle of a down-draft kiln

Designed by

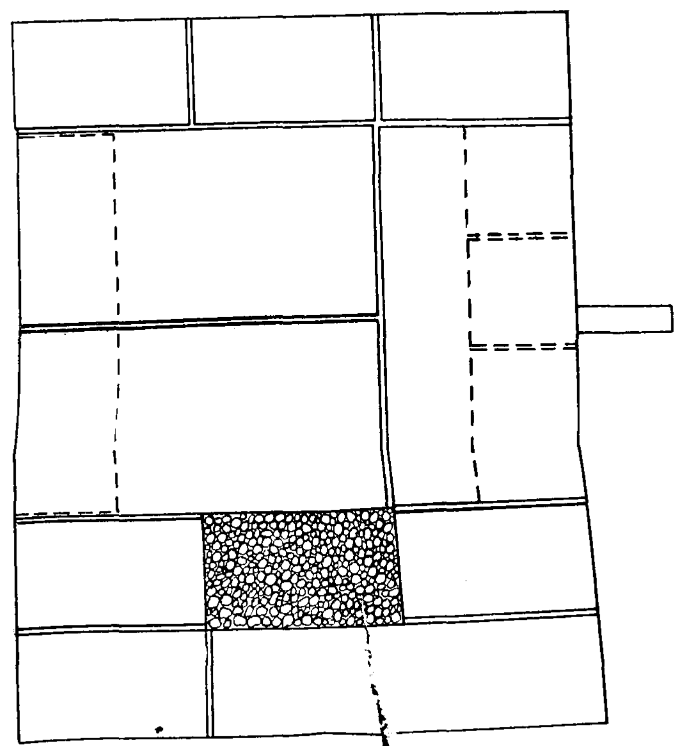
THEO. H. M. CRAMPTON



Plan
(Roof Removed)



Side Elevation



End Elevation

tilized ingredients of the clay or the gas. An attempt to neutralize the reducing action of the muffle by introducing a dish of sodium peroxide resulted in the rapid eating-away of the top of the muffle. Experiments with alundum muffles and furnace lining were planned, but were not completed.

Most of the clays mentioned in this report were burned in the Blau-gas-fired Meker furnace. The only drawback to the wide-use of this outfit by clay-workers is the fact that it is impossible to secure an oxidizing atmosphere except at low temperatures. In most cases the atmosphere is decidedly reducing—always so if the graphite muffles are used. The colors of the products burned in this furnace are, then, quite different from what would be obtained in ordinary kilns, and the viscosity temperatures of ferruginous clays are lowered several cones. Even white-burning clays often show a gray discoloration on the surface at low temperatures. This makes it necessary to reburn all the clays in an oxidizing atmosphere at moderate temperatures, in order to ascertain the colors of burned products and to check up the other characteristics.

Operators of the outfit just described should observe the following hints:

Use alundum cement in making permanent repairs in the furnace and for luting-in muffles.

If a muffle cracks while in use, turn off the gas, fill the crack with asbestos wool, and cover with ground fire-clay. Then raise the temperature very gradually. For temperatures above that of Cone 16, use bone-ash instead of asbestos wool.

If the muffle caves down from the top, raise the temperature gradually, and force the top back into its proper position while holding down the bottom.

If the muffle caves up from the bottom, it will probably be necessary to clean out or enlarge the grooves which direct the flame around the muffle.

Always open the door slowly in order to lessen the danger of the muffles caving at high temperatures and pressures.

Determine the time necessary to reach each cone, and do not open the muffle at all until just before the fusion point of the cone is reached.

Blue glasses, such as are used by workers in steel plants, are necessary in order to see the test-pieces when the muffle is very hot.

Small, Blau-Gas-Fired, Down-Draft Kiln.—This piece of apparatus was used for the reburning above mentioned, and was designed and constructed by Mr. Crampton. The following description is written from data furnished by him:

The Crampton Down-Draft Laboratory Furnace or Kiln is constructed of first-class fire-bricks and slabs and electrically calcined magnesite bricks, the latter being used only where it is necessary to pierce the bricks for gas- [illegible]
pieces are luted together with paste [illegible]
alundum cement.

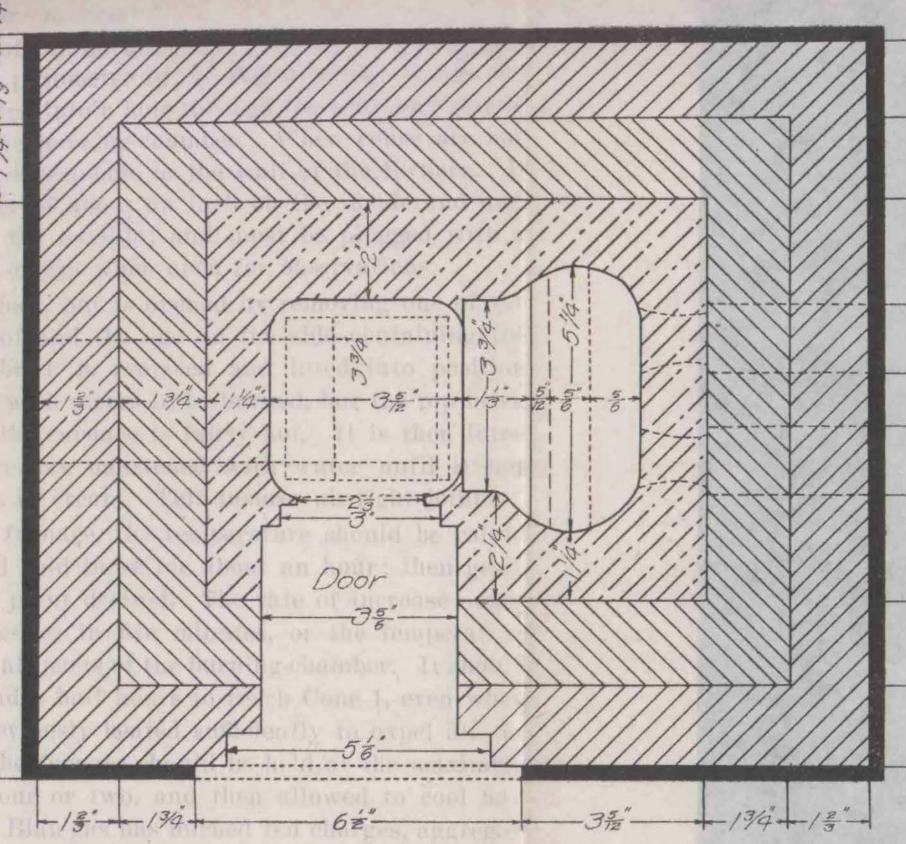
By referring to Plate I, it will be seen that the furnace consists of a combustion-chamber and a burning-chamber which are separated at the bottom, but connected at the top. A double-outlet, goose-neck burner from a Meker furnace is connected to the combustion-chamber. Each of the two outlets has a diameter of one and one-fourth inches, and is covered with the wire mesh characteristic of Meker burners. Gas and compressed air are admitted at and near the end of a metal extension of the burner, which is covered between the two inlets by a close-fitting sleeve. Three holes pierce both the sleeve and the sides of the gas and air-inlet chamber beneath the sleeve, and these holes may be opened or partly, or entirely, closed by revolving the sleeve. When the burner is in use, large or small volumes of air may be drawn through these holes and forced into the furnace along with the compressed air and gas. The holes through which the gas and air enter the combustion-chamber taper or flare toward the inside, as shown in the plate.

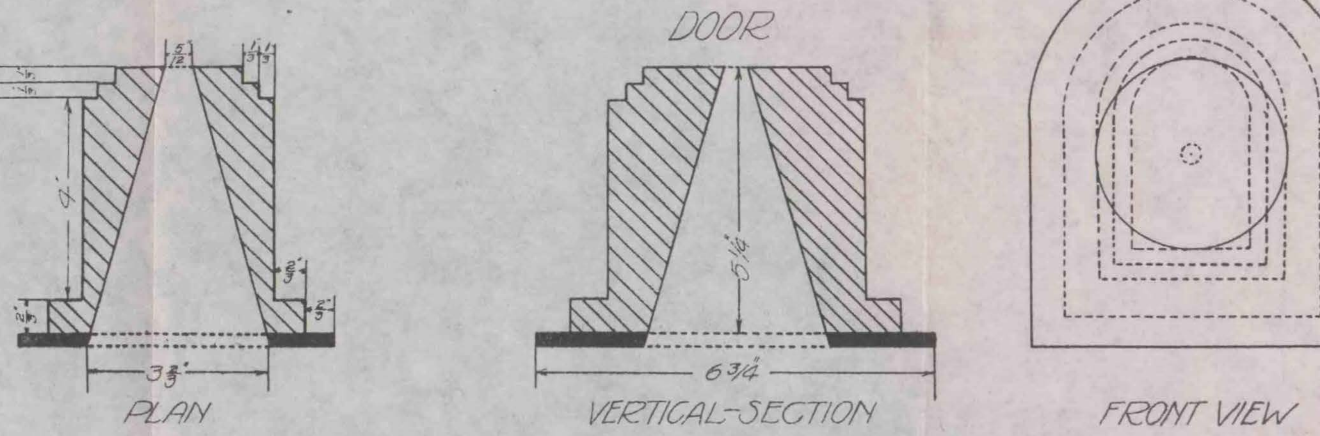
Combustion occurs in the combustion-chamber, and the hot gases are deflected from the top and forced down through the burning-chamber. Across the bottom of this burning-chamber is placed a grating of small, short bars made of a mixture of fireclay and alundum cement. These rest on three longer, larger bars made of fire-clay. The bricklets or cones to be burned are placed on top of the shorter bars in such a way as to permit the free passage of hot gases down through the ware.

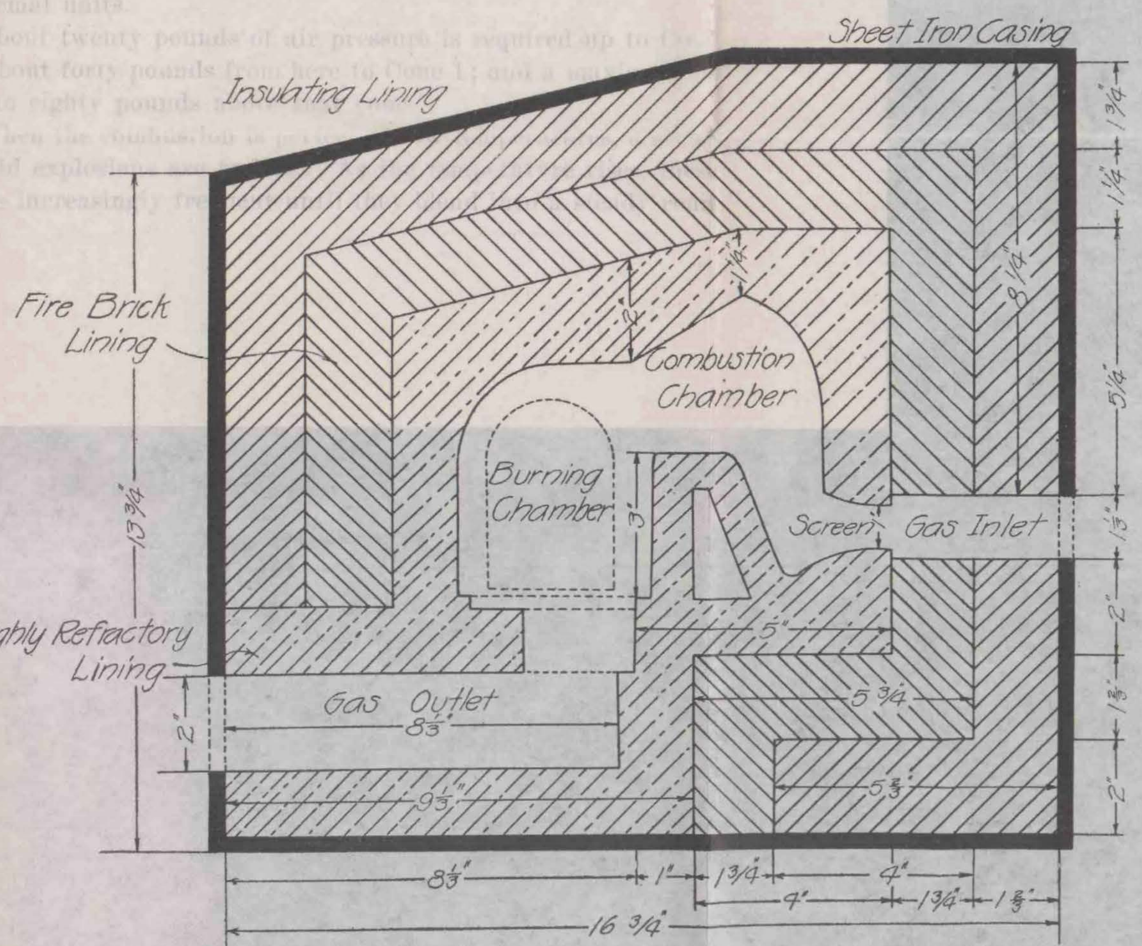
After passing downward through the burning-chamber and the grating which forms its floor, the hot gases continue to descend for some distance before they pass horizontally out to the air. This passage-way for the escaping gases is loosely filled with angular fragments of crucibles and muffles or burned fire-clay

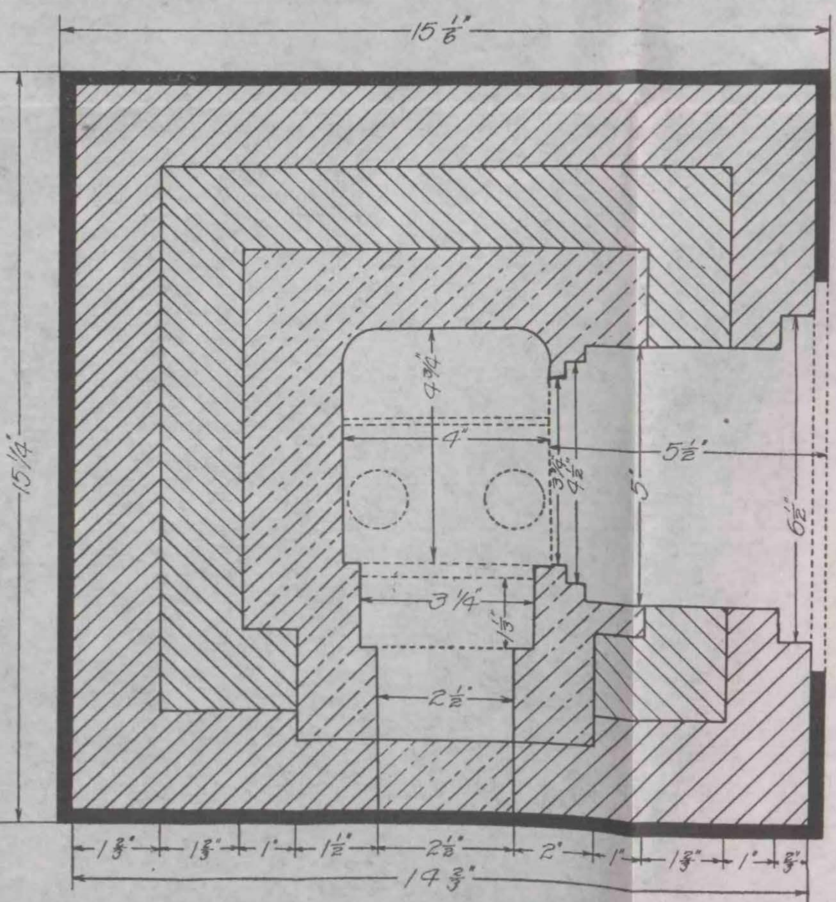
CRAMPTON REFRACTORY KILN FURNACE

Designed for Temperatures from 500°C to 1900+°C.
Complete Control of Temperature and Atmosphere.









which vary from one-fourth to three-fourths of an inch in size. This tends to prevent the undue escape of heat from, and to equalize the temperature in, the kiln.

The temperature of the burning-chamber may be determined either by means of a pyrometer or by Seger cones. When the former is used, it is luted into a hole through the wall, and should reach the center of the burning-chamber. When cones are employed, there must be a peep-hole in the wall of the furnace. It should have a diameter of about an inch on the inside and one-fourth of an inch on the outside; and must be plugged with a wad of asbestos wool, except when open for observations.

The kiln has no door, but is opened by removing one of the bricks forming the roof and the one on the side containing the peep-hole. The side brick is replaced and luted into position when the kiln is filled with pieces to be burned, but the top brick is not replaced until the furnace is fairly hot. It is then luted into position with fire-clay moistened with water until it has almost the consistency of cream. This insures air-tight joints.

In operating the furnace, the temperature should be raised slowly to dull red and held there for about an hour; then gradually increased to the point desired. The rate of increase ought never to exceed two cones in five minutes, or the temperature will not be uniform in all parts of the burning-chamber. It should require about three and a half hours to reach Cone 1, even when the ware has been previously heated sufficiently to expel all the occluded moisture. The furnace should be held at the maximum temperature for an hour or two, and then allowed to cool naturally. One bottle of Blau-gas has burned ten charges, aggregating over 600 bricklets, to Cone 5.

Gasolene gas may be used for the lower temperatures, but Blau-gas was found to be the only available fuel that would answer for the more refractory clays; and it may be used exclusively. Whether coal gas would work as satisfactorily as Blau-gas is doubtful, as the latter yields a considerably higher number of thermal units.

About twenty pounds of air pressure is required up to Cone 022; about forty pounds from here to Cone 1; and a maximum of sixty to eighty pounds above that cone.

When the combustion is perfect at low temperatures, a series of rapid explosions are audible. As the temperature rises, these become increasingly frequent until they blend into a steady roar.

The atmosphere of the kiln is then neutral, and may be made oxidizing or reducing by opening or closing the air ports in the burner.

It is necessary to use dark-blue glasses, such as are employed by founders, to observe the contents of the kiln at high temperatures.

The following are only a part of the advantages offered to ceramists by this furnace:

1. The flame is not directed against the ware, although there is no solid barrier completely separating burning- and combustion-chambers, as is the case when muffles are used.

2. The ware may be burned in a neutral, an oxidizing, or a reducing atmosphere, as desired; and the atmospheric conditions may be changed instantly.

3. There is an even distribution of the heat through the ware.

4. If the temperature begins to rise too rapidly, this may be readily remedied by introducing a slight excess of air.

5. The cost of the furnace is low.

6. Salt glazing may be done by introducing finely pulverized salt through the air-ports in the burner.

7. The contents of the burning-chamber may be examined visually at any time.

8. Cone 25 can be melted readily if Blau-gas is used.

Plate II shows sections of a modification of this furnace made by Mr. Crampton after the completion of the clay-testing. It differs from the type just described in that it has a door, a reflecting-roof above the combustion-chamber, and is not built of bricks. Although of more expensive construction, this is compensated by the fact that it gives generally better results than did the original style, and, it is claimed, will give a temperature of 1,900°C.—nearly two cones above No. 36.

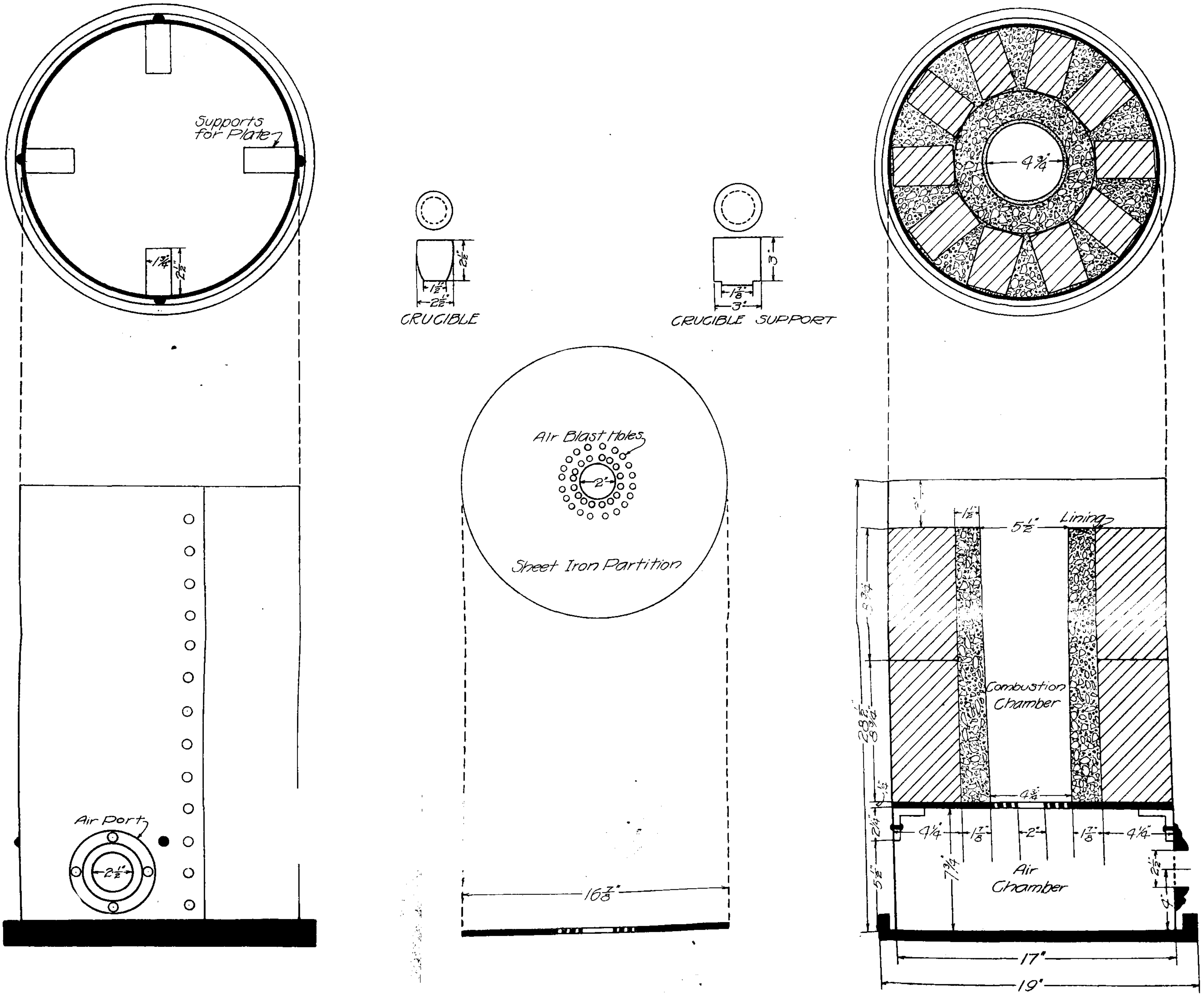
Deville Furnace.—Although this type of furnace does not have a muffle, it is the only available apparatus for obtaining the highest temperatures at which clays fuse—up to Cone 36. Mr. Crampton made the one in use at the Colorado School of Mines, and Plate III illustrates its construction. The fuel used in this furnace is gas coke.

Professor Edward Orton, Jr., uses an improvement upon this furnace, which he describes as follows:[1]

[1] Personal communication, dated March 24, 1910.

MODIFICATION OF DEVILLE HIGH TEMPERATURE FURNACE

Designed by Theo. H. M. Crampton



"I am using a gas-fired furnace exactly similar to the Deville in general construction, though I use two burners set tangentially to the circumference of the bore of the Deville furnace, so that a whirling motion of the hot gases is produced. Both burners are supplied with gas and air under pressure, so that the combustion can be controlled. I use an air pressure of about two pounds to the square inch. The placing of the crucible which contains the samples of clay is very much like the Deville furnace, and the crucible is made of the best fire-clay and alumina, half and half; and small briquettes of the same composition are placed around and above the crucible so as to form a checker-work for retaining heat. My superintendent has become very expert in the operation of this furnace, and he is able to melt any clay that has been brought before him. In fact, he has reached Cone 37, which is a mixture of the best clay with a small amount of pure alumina, but he cannot melt a mixture of alumina and clay, half and half."

It seems probable that such a furnace, fired with Blau-gas, would make an ideal high-temperature apparatus.

PHYSICAL PROPERTIES OF BURNED CLAYS

Color

In many cases a knowledge of whether a clay is white-burning or not is sufficient to enable a correct classification to be made, but for some purposes the attractiveness of the color has great influence upon the value of the product; so it is customary to note the color at many temperatures. As the color varies with the atmosphere of the kiln, uniformity of results can best be secured by testing all clays in the same atmosphere, so far as this may be possible.

In practice, the colors obtained are apt to be a bit brighter and more uniform than are yielded in the laboratory; so, in reporting colors, the worker will err, if at all, on the side of safety. It will be found convenient to recognize and use the following tints and abbreviations: dark brick (Dk Bk), brick (Bk), light brick (Lt Bk), pink (Pk), white (Wt), cream (Cm), yellow (Y), light buff (Lt Bf), dark buff (Dk Bf), brown (Bn), and black (Blk). Oxidizing atmospheres rarely yield other tints than these; if reducing atmospheres are used, the list may require extension.

The vitrification of a clay will usually deepen, and may change, its color, due to the formation of ferrous silicates.

Browns, greens, grays, and black are commonly produced in this way, or a yellowish-green color may develop if the clay is calcareous.

Improving the Color.—Very little along this line is attempted except in the case of art pottery, and even then the improvement is usually brought about by the use of colored glazes.

About the only improvement commonly made is produced by the use of manganese oxides. These produce small, dark-brown splotches which make gray or buff bricks quite attractive.

Fire Shrinkage

A high fire shrinkage will not produce cracks in the product, but it will cause warping and can be tolerated in very few cases. The percentage of fire shrinkage must always be determined at many temperatures, in order that a burned product of any required dimensions may be produced. Some clays swell slightly well below the temperature of fusion, but this is not common. An improperly burned clay will usually swell to an extraordinary degree just before fusion.

The fire shrinkage usually begins at a dull-red heat, or when the chemically combined water, carbonic acid gas, and carbonaceous matter are expelled; but the amount of shrinkage at this point is usually too small to measure—nearly always under 1 per cent. The shrinkage, in fact, rarely amounts to much, until the temperature of incipient vitrification (see p. 44) is reached, and the determination of this point may often be based upon a sudden increase in the shrinkage of the test-piece. As the temperature is raised above that of incipient vitrification, the shrinkage usually increases more or less regularly until the melting point is approached. It may amount to only 2 or 3 per cent, or it may reach 20 per cent or more in unusual cases.

Manner of Decreasing a High Fire Shrinkage.—The best way of neutralizing a high fire shrinkage is to add quartz, since this mineral expands at high temperatures. Only a limited amount may be used, however, as it has a detrimental effect upon other physical properties, as is explained elsewhere.

A grog of ground bricks, coke, graphite, etc., may be used instead of quartz to decrease the fire shrinkage, but they are not so good, as they do not expand. Like quartz, they must be used in moderation.

Measurement of Fire Shrinkage.—The fire shrinkage is measured linearly by scratching a couple of lines two inches apart on a test-piece of thoroughly air-dried clay, using a pair of sharp-pointed, rigidly set compasses for this purpose. The test-piece is then burned, the distance between the scratched lines is measured, and the fire shrinkage is computed. Great care must be exercised not to break the unburned clay while marking it. In case the clay warps badly, it may be necessary to average the fire shrinkage computed from several sides of a burned test-piece.

Absorption

Absorption Defined.—Absorption, as used by ceramists, refers to the amount of water that a burned product is able to absorb. This will vary from none up to 35 per cent of the weight of the water-free test-piece. Ordinarily the absorption is lower the greater the temperature to which a clay has been burned, but numerous minor irregularities are noticeable when the results of any considerable series of tests are examined. After vitrification (see p. 45) has been reached, the absorption will be very low, if the clay has been properly burned.

The determination of the percentage of absorption is of considerable practical importance when a clay is to be used to make structural materials, since the higher the absorption, the lower the crushing strength. Porous products are also more apt to be injured by freezing than are those of low absorption, and this is especially apt to be the case if the pores are small. Porous articles, likewise, are apt to dry mortar too quickly, and they get dirty sooner than do those which are more compact.

Purdy has shown[1] that the rate of decrease of the porosity with increase of burning temperature has a decided bearing upon the quality of the product. Since the porosity is merely the absorption multiplied by the specific gravity of the burned product, his statements apply with equal force to the rate of decrease of the absorption; and his conclusions have been incorporated in Chapter V.

Manner of Decreasing a High Absorption.—The application of pressure may lower the absorption somewhat, but usually the only way to decrease a dangerously high absorption is to glaze the product.

Measurement of the Absorption.—To determine the percentage of water absorbed, weigh a piece of freshly burned clay, soak it in water for at least two days, remove from the water and

[1]Illinois State Geological Survey, Bul. No. 9, p. 275.

allow to dry for fifteen minutes, reweigh, and divide the difference between the two weights by the weight of the dry piece. When full-sized bricks or other large pieces are tested, they should be soaked at least a week.

It is a fact that wares treated in the manner just described are not completely saturated after several weeks' emersion, but, in the case of the small test-pieces used, the amount of water absorbed after the second day is usually very small. In order to determine the total porosity, it is necessary to place the dish containing the submerged test-piece under a bell jar and then to exhaust the air. When this is done additional water is absorbed, and the absorption is increased to a figure from 5 to 70 per cent greater than what it originally was. Purdy[1] found that, in the case of seventeen samples treated in this way, the average percentage of increase of porosity after thirty minutes' treatment under the bell jar was 33.4.

Some workers advocate the use of kerosene instead of water in making absorption or porosity determinations, since the kerosene is absorbed considerably more quickly and to a greater extent. It is, however, the water (not the kerosene) absorbed under atmospheric pressure that is subject to freezing and which measures the surface porosity that causes too rapid drying of mortar or dirtying of brick; so it seems illogical to endeavor to ascertain the total porosity, unless it is desired to use the figures thus obtained in predicting the commercial availability of the product in the manner suggested by Mr. Purdy. Even then it will be sufficient in most cases to assume that the total absorption is one-third greater than the observed absorption, and that the porosity is equal to the total absorption multiplied by 2.5, the average specific gravity of burned clay products. These statements formulated give us:

$$\text{Total absorption} = \frac{4 \times \text{observed absorption under atmospheric pressure.}}{3}$$

$$\text{Porosity} = \frac{10 \times \text{observed absorption under atmospheric pressure.}}{3}$$

Incipient Vitrification

Incipient Vitrification Defined.—Incipient vitrification is the result of the first physical changes that take place when a clay

[1] Loc. cit., p. 266.

is burned. Some of the more fusible ingredients then soften or fuse to such an extent that the whole is quite firmly bound together and will no longer slake when placed in water. The clay is, in fact, "burned," although not vitrified. It is, then, very important to determine the temperature at which this change occurs.

Recognition of Incipient Vitrification.—In a clay that has been burned to incipient vitrification the larger particles will still be recognizable; this may or may not be true of the smaller ones. The material will be so hard that a knife will leave a shiny, gray mark when rubbed hard upon a smooth surface. All of the pores will not be closed, and few or no round pores will be seen. The fire shrinkage will begin to be measurable, or will suddenly increase a per cent or 2 if already large enough to be measured. Lastly, the absorption may have suddenly decreased slightly, but exceptions to this rule are not uncommon.

The texture of a burned test-piece must be examined on a broken surface. Where cones are used, the tips may be readily broken for this purpose, and the ease with which this is done will often help an experienced worker to decide whether incipient vitrification has been reached. This is certainly not the case if the test-piece crumbles in the fingers when an attempt is made to break it.

Vitrification

Vitrification Defined.—Vitrification is the result of complete obliteration of the original texture of the clay. This change may occur at temperatures that vary from 25°C. to 200°C. above those that produced incipient vitrification. Many clay products must be vitrified; so the determination of the temperature at which this condition occurs is necessary.

Recognition of Vitrification.—A vitrified object is very hard and dense. The natural pores are all closed, and only round bubble-holes remain. The maximum shrinkage is approached or reached, and the absorption is very low—often nothing. None of the original clay grains are visible, the piece breaks with a smooth, rounded fracture, and thin fragments are translucent. A vitrified clay is, in fact, practically a dull-lustered glass, but the surface may be shiny or have a glazed appearance.

Recognition of the vitrified condition must be made by examining a broken surface.

Viscosity, Fusion, or Melting Point

Viscosity Defined.—A clay is said to be viscous when it has softened to such an extent that it begins to flow and lose its shape. This is usually accompanied, and often preceded, by swelling, especially if the clay has been improperly burned. The determination of the viscosity temperature is of the utmost importance, since it goes a long way in determining the grade of a clay. True fire-clays need possess almost no other property than a high viscosity temperature. The vitrification and viscosity temperatures should be separated over 100°C. when a vitrified product is desired. If this recommendation is not followed, it will be difficult to burn a kiln of ware without melting some and underburning another portion.

Recognition of Viscosity.—Viscosity is reached when a test-cone bends to such an extent that its tip just touches the support upon which it is placed.

Chemical Ingredients That Influence the Fusibility.—Many attempts have been made to devise a means of determining or predicting the fusibility of a clay from its chemical composition, but the results are so unreliable that the methods are not presented here. Either the influence or texture is ignored in the schemes suggested, or else the process becomes too complex, and too dependent upon the personal element, to be very practical. It is much more satisfactory to determine the viscosity temperature directly, and this takes less time than does a chemical analysis.

In general, however, it may be said that the fusibility is proportionate to the amount of fluxes (K_2O, Na_2O, CaO, Fe_2O_3, MgO) present. Clays containing 10 to 15 per cent of these fluxes ordinarily fuse at 1,100°C. to 1,200°C. Those with more or less fluxes fuse at lower or higher temperatures, respectively. All the fluxes are not equally powerful, and a mixture of several is more powerful in its action than are one or two alone, but it is difficult to offer any generally applicable rules governing such matters. Fluxes are usually less active in their action when a clay burned to a low temperature contains an unusual percentage of silica; but silica and titanium oxide are fluxes at high temperatures.

CHAPTER III

Influence of Impurities and Physical Condition Upon the Properties of Clays

INFLUENCE OF IMPURITIES

The following pages contain a brief summary of the known effects of various substances upon the physical properties of clays. It should be recognized that, where so many impurities may be present, it is practically impossible to suggest general rules applicable to all possible combinations; but the facts presented will often serve to indicate why a certain clay behaves in a peculiar fashion, and they may point the way to a remedy.

Silica (SiO_2) in the Form of Quartz

Quartz tends to decrease the air shrinkage, plasticity, and tensile strength. It increases the refractoriness of clays with a high percentage of silica and fluxes, but makes highly aluminous, low-flux clays less refractory. The presence of some quartz usually makes it possible to burn a clay to higher temperatures, before serious fire shrinkage occurs, than would be feasible if it were absent. An excess of quartz causes the product to swell and become friable.

Free, Hydrous Silica, Probably in the Form of Opal

Only one natural clay known to contain this substance has been investigated, but several artificial mixtures containing it have been studied, and its effects seem to be as follows: It increases the translucency of the product at all temperatures, improves the color, increases the air and fire shrinkages, increases the tendency to warp on drying, lowers the vitrification temperature, and tends to cause the formation of a hard coating of H_2SiO_3 on the surface of the ware.

Compounds of Iron

Iron may exist in clays as a hydrous oxide (limonite), an anhydrous oxide (hematite or magnetite), the carbonate (siderite), a sulphide (pyrite), or in some silicate. The iron is present in the ferrous condition in siderite and pyrite, and is often then distributed through the clay rather unevenly in particles of considerable size. This makes these clays difficult to burn and tends to give them an irregular color, as will be explained shortly. For this reason, pyrite and siderite are usually considered very undesirable ingredients. In the other compounds mentioned, the iron is either present in the ferric condition or the amount is apt to be so small as to be negligible.

In general it may be stated that any compound of iron is apt to act as a coloring agent in unburned clays, give color to burned clays, act as a flux, cause swelling if not properly oxidized while being burned, and somewhat increase the air and fire shrinkage. These effects are so universal and important that it seems best to discuss each in order.

Coloring Effect of Iron in Unburned Clays.—The color of an unburned clay is usually dependent upon the presence or absence of some iron compound. Limonite causes brown or yellow tints, hematite gives a red color, while pyrite or siderite yields grays or blues when very finely divided and disseminated through the clay. Less commonly, glauconite (hydrous silicate of potassium and iron) imparts a green color.

The absence of the tints above mentioned should not be interpreted as necessarily indicating that the clay is free from iron, since carbonaceous matter may mask or almost obliterate the colors which would otherwise show plainly.

The Coloring Effects of Iron in Burned Clays.—The color of a burned clay is largely determined by its iron content, since all iron compounds are transformed to the red oxide, hematite, if burned in an oxidizing atmosphere; i. e., conditions resulting from the introduction of more air than is needed to support combustion. The color or depth of shade produced by iron depends upon the following six factors:

1. The amount of iron present.
2. The temperature to which the clay is burned.
3. The condition of the iron (whether ferrous or ferric, amorphous or crystalline).
4. The condition of the kiln (whether oxidizing or reducing).
5. The presence or absence of certain neutralizing substances.
6. The physical condition of the clay.

The influence of each of these may be thus summarized:

1. (The amount of iron present.) Clays free from iron nearly always burn white. If 1 per cent ferric oxide (Fe_2O_3) is present, a lime-free clay will burn slightly yellowish, while 2 to 3 per cent gives a buff-colored product under the same conditions. Red-burning clays contain 4 to 5 per cent, or more, of the same oxide.

2. (The temperature to which the clay is burned.) Other things being equal, the higher the temperature to which a clay is burned, the darker the color will be. In the case of the red-burning clays the change is from pale pink through brick-red to reddish purple or dark brown.

3. (The condition of the iron.) Ferrous oxide (FeO) burns green instead of yellow or red, and mixtures of the two oxides give various unusual tints.

Iron as the sulphide (pyrite or marcasite) is the bane of the clay-worker, since the sulphurous or sulphuric acids generated by oxidation of the sulphide are very apt to unite with some of the ingredients of the clay and form soluble salts which appear as a white coating or "scum" on the surface of the product. Another unfortunate effect of the presence of the sulphide is due to the fact that it does not relinquish its hold upon all the sulphur until heated to very high temperatures. This prevents the oxidation of the ferrous iron with which the sulphur is united, and, when the sulphur is finally expelled, this ferrous iron immediately unites with silica to form ferrous silicate. The black spots of slag-like ferrous silicate are not always considered unpleasing in appearance on a brick, but no clay containing iron sulphide will burn to a uniform-colored product of any kind.

If the iron is present as some amorphous compound (limonite), and is scattered naturally through the clay in very minute particles, the color is apt to be much more uniform than can be secured if the iron is crystalline or has been added in the form of finely ground ore.

4. (The condition of the kiln.) A reducing atmosphere (conditions resulting from the admission of less air than is needed to cause complete combustion of the fuel) in a kiln changes ferric to ferrous oxide, while an oxidizing atmosphere has a contrary effect; so the condition of the kiln has a direct effect upon the colors produced by the presence of iron.

5. (The presence of certain neutralizing substances.) Lime (CaO) is said to "wash out" the red color produced by ferric

oxide due to the formation of a yellow iron-lime compound. Alkalies (K_2O or Na_2O) have a similar effect, so far as "washing out" the color due to ferric oxide is concerned, but they do not form yellow compounds. Alumina (Al_2O_3) appears to exercise a similar power in some cases, but it cannot neutralize so much ferric oxide as can lime, and sometimes it appears to have no effect along this line, even when present in excessive amounts.

6. (The physical condition of the clay.) Coarse-grained, sandy clays can usually be heated to a higher temperature without injuring the color than can the finer-grained, fatter varieties.

The Fluxing Action of Iron.—Any compound of iron has a powerful fluxing action, since it is converted to an oxide when burned, and the oxides easily unite with silica to form fusible silicates. An excess of silica in the form of quartz is required to bring about this reaction, but very few clays do not contain quartz.

Ferrous oxide is a more powerful flux than ferric oxide, but even the latter is so active that low-grade clays should never contain over 8 per cent of it.

The Effect of Iron upon the Physical Condition of the Product.—If ferrous oxide is present in a piece of clay that has been burned to a high temperature, it will form a fusible iron silicate which evolves gases and causes the ware or test-piece to swell and assume a spongy consistency, or even to burst open. In other cases incomplete oxidation may be shown by a black core in the center of the burned product.

Ferrous oxide cannot be changed to ferric oxide until all the sulphur, carbonic acid gas, and carbonaceous matter have been driven, or burned, off. This explains why pyrite and siderite are particularly undesirable ingredients of clays. The SO_2 expelled when the pyrite is heated in contact with air may also bleach the ware. Where the substances just mentioned are present, the clay must be heated very slowly and carefully in a strong oxidizing atmosphere until a temperature of 950° C. (Cone 010) has been reached; and the larger the piece burned, the more gradually must the temperature be raised. Enough time must be allowed so that sufficient oxygen to oxidize all the iron can enter the clay while it is still porous—well below vitrification. It is believed that all the SO_2 is not expelled even at a temperature of 1,300° C.

The Effect of Iron upon the Air and Fire Shrinkage.—Clays containing limonite tend to absorb and hold more water than do those free from that substance. This may increase the air shrinkage somewhat; and the loss of water when the limonite is heated may raise the fire shrinkage. The first effect may be considerable, but the second is probably inappreciable.

Compounds of Lime (CaO)

Lime may be present in clays as a carbonate (calcite or dolomite), a silicate (one of the feldspars), or the sulphate (gypsum).

Calcite and gypsum are common ingredients of clay, and are not very harmful, so far as many common uses of clay are concerned, if they are uniformly distributed in microscopic particles and are not too plentiful. Lime silicates are very unusual ingredients of clays, except possibly in minute amounts, and have little effect on the properties of the clay, except to act as fluxes. While bricks have been made from clay which contained as much as 12 per cent lime in a finely divided condition, more than 1 per cent of lime in the form of carbonate or sulphate may be expected to produce the following effects, and even less than 1 per cent of lime may have a notable influence upon the properties of an otherwise high-grade clay:

1. Is a flux. Lime is always an active flux, and this is particularly true when it is finely divided.

2. Causes rapid melting. A considerable quantity of lime may bring the points of incipient vitrification and viscosity within 40° C. of each other. It would be impossible to burn such a clay without prohibitive losses. Gypsum does not seem so active in this particular as does calcite.

3. Causes porosity. Calcareous clays frequently burn to porous products which absorb much water.

4. Gives a product which may break when wet. If the calcite or gypsum is present as grains or lumps of some size, and the clay is only burned to a low temperature, the former may be burned to quick-lime and the latter to plaster of Paris. When these are moistened, they may swell and burst or crack the ware.

5. "Washes out" the color produced by iron. This effect has already been mentioned under the discussion of the effects of iron compounds. The action is said to be most marked if the weight of the lime is three times that of the ferric oxide.

6. Increases the fire shrinkage. This is due to the loss of the volatile carbonic acid gas and the sulphur dioxide.

7. Makes the product difficult to burn. The necessity of slow, careful burning when volatile ingredients are present has already been explained.

8. May cause a white efflorescence to appear. Some lime compounds are slightly soluble in water, and these may work to the surface of the green or burned products and cause a white discoloration.

Compounds of Magnesia (MgO)

Magnesia occurs in clays as a carbonate (dolomite, which also contains lime), a silicate (chlorite, pyroxene, etc.), or a sulphate (epsomite).

Magnesia has probably no appreciable effect unless present in amounts greater than 1 per cent. Then it acts as a flux, but causes the clay to soften slowly, even when lime is present in considerable quantities, provided the ware is burned slowly as it is in commercial practice. Magnesian clays may be made into wares of great length with thin walls, since the substance seems to prevent warping. Magnesia may also have a slight bleaching action upon iron coloration.

Compounds of the Alkalies (Na_2O and K_2O)

The alkalies in clays occur as a silicate (feldspar or mica). The mica is usually muscovite, since biotite decomposes very readily. When present, the latter acts much like iron oxide.

Alkalies are probably the most powerful fluxes that clays contain, and they determine the point at which a clay melts, if other fluxes are absent. Their action differs from that of lime in that the clay melts at a lower temperature, but softens very slowly. Vitrification is impossible if they be absent. They are, therefore, often considered a desirable ingredient, since they bind the grains together and permit the manufacture of a hard, white product at comparatively low temperatures. In order to secure such a result, feldspar is added to the clay and quartz used in making white-ware and porcelain. The finer-grained the feldspar or the smaller the particles of muscovite, the lower the temperature at which the fluxing action takes place. Clays used in making refractory goods cannot contain more than 1 or 2 per cent of alkalies, however, and it is best to have the amount well under these figures.

Both feldspar and muscovite lower the plasticity and air shrinkage, while feldspar lowers the fire shrinkage up to about 1,200° C.

Potash (K_2O) tends to deepen the color produced by iron compounds when a clay is burned.

Compounds of Titanium

Titanium is not usually determined in a clay analysis. When present, it is usually included in the figures given for alumina. It may occur, however, in invisible amounts, as an oxide (rutile or ilmenite.)

Titanium oxide (TiO_2) is believed to act as a flux, especially at high temperatures, when present to the extent of 1 per cent or more. At temperatures below about Cone 12 the presence of several per cent of this substance may cause a yellow discoloration to appear on an otherwise white product; while at higher temperatures, if quartz be absent, a beautiful blue tint develops. This is light to dark, according to the amount of titanium oxide present in the clay.

Compounds of Manganese

Manganese very rarely occurs in clays in appreciable amounts. When present, it doubtless occurs as the impure, hydrous oxide psilomelane. It is very similar to iron in its action, but differs therefrom in the colors imparted to the burned product. When iron is absent, even small amounts of manganese oxide will give the ware pink or purplish tints; while, if iron be present, the burned product will be brown to black. If it is not vitrified, and the manganese oxide is not thoroughly disseminated through the clay in a very finely divided condition, these colors may appear as spots on the burned material.

Water

Water exists in clays in two forms; i. e., moisture mechanically included in the pores of the clay, which may be driven out by heating the clay to the boiling point of water, and chemically combined water or water of crystallization.

Moisture.—Unless a clay is sandy, a large amount of moisture will cause a high air shrinkage and possible consequent cracking on drying. The average air shrinkages of one hundred non-sandy Colorado clays which require from 20 to 30 per cent of water to temper them to a condition of maximum plasticity are tabulated below. It is not supposed that a high moisture content, as determined by analysis, has any relationship to the percentage of water required to temper a clay to a condition of maximum plasticity, but the table plainly shows that there is a decided connection between the air shrinkage and the amount of moisture in a clay:

Percentage of Moisture.	20	21	22	23	24	25	26	27	28	29	30
Air shrinkage..........	3.1	3.5	3.7	4.4	5.1	5.6	5.8	6.3	6.9	7.3	8.2

Twenty Colorado clays that cracked on drying required an average of 43.7 per cent of water to mix them to maximum plasticity and had an average air shrinkage of 9.3 per cent. The unexpectedly low air shrinkage is due to the fact that several sandy clays with low shrinkages are included. There can, then, be no doubt that a high air shrinkage tends to produce cracking and is itself connected with the amount of water in a clay.

Another effect of the presence of moisture in a clay is the formation of stains, called scums or whitewash, which are produced when soluble salts in the clay are brought to the surface and deposited as a result of the evaporation of the moisture.

Chemically Combined Water.—Excessive amounts give a high fire shrinkage and tend to cause cracking of the burned clay. This is apt to be the case if the weight of the chemically combined water exceeds one-third the weight of the alumina in the kaolin.

Carbonaceous Matter

Carbonaceous matter may exist in clays in three different forms; i. e., unaltered vegetation, coaly matter, or bituminous substances.

Unaltered Vegetation.—Unaltered roots, stems, or leaves may be found near the surface of a clay deposit, but the amount is usually small, the material burns off readily, and does not affect the color or properties of the clay. Of course, large sticks or thick roots must be picked or screened out before the clay can be used.

Coaly or Bituminous Material.—These impart a gray, bluish-gray, or black color to the clay, even when iron is present; and they make the burning operations very difficult, since they act as strong reducing agents, and none of the iron can be oxidized or the sulphur driven off until the carbonaceous matter has burned out. Another difficulty is introduced by the fact that the iron is usually in the undesirable ferrous condition when these substances are present.

When coaly matter is present in fragments of small size which are rather uniformly disseminated through the mass, the clay may be left in a porous condition after these are burned out, and this may make it more refractory than it otherwise would be.

In some cases where much bituminous material is present, the heat generated by the burning of this substance may be sufficient to vitrify the ware before oxidation is completed. This may be prevented by burning very slowly with a small supply of air.

Soluble Salts

The soluble salts found in clays are usually sulphates of lime, magnesia, iron, and alkalies, but carbonates are sometimes present, and, rarely, other substances. The sulphates are usually formed by the decomposition of pyrite or are introduced from fuel containing sulphur, while the carbonates result from the decomposition of feldspars. Soluble salts may also be introduced in the tempering water.

As a clay dries, the contained moisture carries such substances to the surface and deposits them there as an incrustation or coating. This is white in nearly every case, but vanadium salts are supposed to be the cause of a green stain often seen on pressed bricks. Very rapid drying may prevent the formation of a coating on air-dried material, or barium carbonate or chloride may be added to the raw clay. This changes the soluble salts to insoluble compounds, the process in some cases being accompanied by the formation of very soluble substances which are easily washed from the surface of the product. The quantity of barium carbonate or chloride required varies with the nature and amount of the soluble material present.

Many Different Minerals

The more bases present, the lower the fusion point will be. Another effect brought about by the presence of many different minerals in a clay is the gradual softening of the mass—the melting time is extended over a wide range of temperature. This is an essential characteristic of a clay that is to be vitrified.

INFLUENCE OF PHYSICAL CONDITION

Fine-grained clays are less refractory than are coarse-grained ones; and compact clays are more fusible than porous ones, provided the compositions are similar in both cases. This is true in the case of coarse-grained clays, even when some individual grains have low fusing points.

CHAPTER IV

Detailed Procedure in the Field and in the Laboratory

FIELD OBSERVATIONS

All the field parties that worked for the Colorado Geological Survey on clay investigations were provided with printed blanks, folded once so as to form a two-page folder which measured five and a half by eight and a half inches. On the first or outer page were recorded the field observations, while the laboratory tests were recorded on the inner sheet. Three colors of these blanks were provided—white, yellow, and blue; and all the data on a sample of clay were recorded on a blank of each color. The white blanks were filed, when completely filled, under the names of the various localities where samples were taken; the yellow blanks were filed under the various geological horizon names; and the blue blanks were filed under headings referring to the various kinds of clays found. This greatly facilitated the writing of the later portion of this report. An example of the first page of a filled blank is given below:

State of Colorado STATE GEOLOGICAL SURVEY R. D. GEORGE Director	Number of Sample 198	Department of CLAY INVESTIGATION G. MONTAGUE BUTLER Geologist in Charge

SUMMARY OF TESTS

(To Be Recorded in Field)

Locality: Wheeler Sta., 18 mi. S. of Glenwood Spgs. on C. M. R. R. Ranch of C. H. Harris. 900′ N. of house. 3/16 mi. from R. R.

Geological horizon: Flaming Gorge (?)

Structure: Shaly.

Texture: Mostly fine; some is slightly sandy.

Hardness: Soft.

Color: Cream to yellow and brown.

Character of visible impurities: Little calcite and limonite.

Thickness of bed: Over 200′. Sample taken 50′ from base.

Dip: 25° N. Strike: S. 30° W.

Topographical occurrence: 300′ up from base of steep hill.
Depth below surface: 10 to 30′.
Thickness of overburden: None.
Remarks: Sample was taken all along the floor of a 70′ tunnel. Harris says that the clay was pronounced by the American Clay Machinery Co., Bucyrus, O., to be a fire-clay, with no fire shrinkage when burned to Cone 2 after being dry-pressed.

Locality.—The exact location where each sample is taken should be so noted that relocation of the spot will be a simple matter, even for one who has never been to the place before.

Geological Horizon.—Exact data on this point are also desirable. If possible, give the approximate number of feet from the top or bottom of a formation to the point sampled.

Structure.—A clay, as the term is here used, may be shaly (breaking easily into flat flakes) or massive (no platy structure evident); or it may be concretionary (containing numerous rounded or disk-shaped masses of iron sulphide, calcium carbonate, or iron carbonate).

Texture.—The texture of a clay is governed by two factors, both of which must be recognized in any scheme of descriptive terms that is used to describe this feature. The first factor is the fineness or coarseness of the soft grains of more or less impure clay-base that make up the ground-mass of all clays. The second is the amount of hard grains of quartz, feldspar, or other minerals that is present. In order to embrace both of these, a twofold nomenclature was adopted.

The fineness of grain of the clay-base may be described by using one of the following five terms:

Very fine: No grains visible in the ground-mass, even with a hand lens; looks amorphous and waxy.

Fine: Appears very finely granular under a hand lens, but the grains are hardly, or barely, visible to the naked eye.

Medium: Grains are easily visible to the unaided eye, if examined closely.

Coarse: Grains easily visible to the naked eye at first glance.

Very coarse: Like loaf-sugar in texture, or even coarser.

The amount of hard grains present may be indicated by using one of the following three terms:

Slightly sandy: Clay feels gritty between the teeth, but is smooth to the touch.

Sandy: Very gritty between the teeth; may be somewhat rough to the touch; some hard grains may be visible to the naked eye.

Very sandy: Many hard grains visible to the naked eye; decidedly rough to the touch.

A fourth degree—non-sandy—might be added, but this is really unnecessary, if it is understood that a clay is always non-sandy unless it is distinctly described otherwise.

A careful description of the texture is useful if a particular bed is to be relocated in the field; and a knowledge of the texture may help one to make a rough prediction concerning other physical properties, as is discussed elsewhere in this report.

Hardness.—The hardness has an important bearing upon the cost of mining a clay. In collecting data for this report, the following six degrees were recognized:

Very soft: Easily shoveled without picking.

Soft: Shoveled with some difficulty without picking.

Soft medium: Shoveled with great difficulty without picking.

Hard medium: Must be picked, but the process is easy.

Hard: Picked with difficulty.

Very hard: Almost of stony hardness. Cut with difficulty with a knife, and very hard to pick.

Color.—A knowledge of the color of a clay will often greatly assist in the relocation of a certain bed. Some idea of the physical properties may also be gained from the color.

Character of Visible Impurities.—These will usually be limonite, pyrite, gypsum, calcite, carbonaceous matter, or alkali. The presence of calcite may be determined by putting a bit of the clay in hydrochloric (muriatic) acid and noting whether any effervescence occurs. The alkali is indicated by white coatings or crusts with an unpleasant taste. These develop where the clay has been exposed to the weather.

Thickness of Bed.—The determination of this feature is naturally a matter of economic importance. Ordinarily a sample represents the average of a whole bed of clay, but, where the bed is very thick or is incompletely exposed, the thickness represented by the sample should be recorded.

Dip and Strike.—The first has considerable economic importance, and both will aid in the relocation of a given bed.

Topographical Occurrence.—This information, also, is economically important and will help one to find a particular bed previously sampled.

Depth below Surface.—As used in this report, this is the shortest distance from the point sampled to the air. On level ground it represents the depth of the trench dug to secure the sample. If the sample was taken from the side of a steep bluff, it represents the depth of the cut into the side of the bluff which was made before taking the sample. No matter whether vertical or horizontal, it is very desirable that every sample be taken just as far from the surface as is convenient, since surface clays that have been weathered are apt both to be more plastic and to have a higher percentage of alkali and carbonaceous matter than will be the case at some depth. Usually the color and appearance of a clay and its hardness will change noticeably as one gets below the surface, and it is always best to keep digging until all such changes cease.

Thickness of Overburden.—This feature has a great influence upon the cost of mining the clay and should be carefully investigated.

Remarks.—Any additional data obtainable should be recorded. The owner of the property may have had some tests made. Record such data, if you can get them. In most cases they will prove worthless, but sometimes some valuable pointers are thus secured.

An example of the second page of a blank, properly filled, such as was used in the clay-testing laboratory of the Colorado Geological Survey, is given below:

(To Be Recorded in Laboratory)

Plasticity: Fine..............	Air shrinkage: 1%...........
Cohesion: Strong............	Slacks in: 7 mins...............
Weight wet cone: 6.48 gms....	Cracks in air? No...........
Weight dry cone: 5.37 ...	Tens. strength briquette No. 1: 18........................
Difference: 1.11 ...	Tens. strength briquette No. 2: 16........................
Water required for max. plasticity: 20.6%..............	Avg. tens. strength: 17 lbs....

BURNING TESTS

Cone number.................	010	.05	03	01
Color	Wt.	Wt.	Wt.	Bf.
Fire shrinkage	0	0	0	1%
Weight wet....................	5.70	3.05	5.52	5.58
Weight dry....................	4.49	2.33	4.29	4.63
Difference	1.21	0.72	1.23	0.95
Absorption	37%	32%	29%	21%

Inc. vit. at 03. Vit. at 1. Vis. at 3.

Swells at .. Blisters at .. Cracks at ..

Remarks and conclusion: The low tensile strength is the worst feature. It should make an attractive, light-colored pressed brick, but there will be some loss in burning, due to the scant separation of the points of Inc. Vit. and Vit., and the absorption is very high—too much so for a face brick.

Kind of clay: Light-colored pressed brick for interiors.

ANALYSIS

SiO_2........
Al_2O_3......
Fe_2O_3......
FeO.......
CaO.....
MgO.....
K_2O.....
Na_2O....
TiO_2.....
Not analyzed.
MnO.....
Loss on ign.
Moisture...
CO_2........
SO_2........
Organic....
Total......

LABORATORY TESTS

1. From the uncrushed sample, select, break, or cut a piece approximating a one-inch cube in size for the slaking test. Also pick out another piece of about the same size, or slightly larger, to be saved in case it proves desirable to investigate the size of grain of the clay or to make a rational analysis. This second piece need not be in the form of a cube.

2. If the sample is of large size, it must next be crushed to pieces about half an inch in diameter and thoroughly sampled, either by quartering or mechanically. A couple of pounds of dry clay is more than enough for all the tests.

3. Crush the sample to forty-mesh, taking care that no more than necessary is ground finer than this. This process may be done in jaw crushers, followed by a small gyratory, or a bucking-

board may be used where only a few samples are to be ground. Experiment has shown that there is no danger of introducing iron into the sample from any of these operations.

Two or three grams of the crushed sample, together with the sample set aside for the rational analysis, should then be placed in a small paper sample-sack, such as is used by assayers. This sack should be properly numbered and saved for the ultimate or rational analyses, in case either or both of these are desired.

The rest of the ground sample and the inch cube of clay should then be replaced in the original sack.

4. Open a sack of ground clay and place the one-inch cube in a shallow pan of water. Note the time required for its complete disintegration. The piece has wholly slaked when it falls apart into a conical pile that contains no hard core. The absence of a hard core may be determined by pressing a slender wire into the little pile of slaked clay.

The piece should be examined frequently, especially during the first few minutes after putting it into the water.

It is best to use a white-enameled iron pan for the slaking test, and to have the bottom of the pan marked off into numbered squares. This may be done with paint or with the colored pencils adapted for writing on glass. If the number of the square on which the cube is placed is noted after the number of the clay on a separate piece of paper, it will be a simple matter to make the slaking test on many samples at once without danger of confusing the data.

5. Place the powdered clay in an enameled iron pan about a foot in diameter, and temper to maximum plasticity in the manner described on page 24.

6. Make twelve (12) full-sized cones, three bricks with dimensions of two by one by one-half inches, and two standard briquettes (for the tensile-strength determinations) from each sample.

The cones and bricks may be cut with a sharp, oiled knife from a flat cake of tempered clay, but, if any number of samples are to be tested, molds should be used. Since none were on the market at low prices, it was necessary for some to be designed and made to order of brass.

To make cones with the molds, the mold and a scraper should be well oiled with machine oil, and the scraper should be held upright against the base of the mold. The tempered clay is then pressed into the mold with a spatula, and the upper surface is smoothed off even with the top of the mold. Great care must be exercised, in filling the mold, to see that the clay is so firmly forced into the lower edge and corner that no cavities are left there. The scraper is then moved toward the small end of the cone, forcing the cone from the mold. The cones may be slightly shortened during the process of removing them from the mold, but this does not hurt them, and the amount of shortening is usually very small. No difficulty will be encountered in making or removing the cones after a little practice, provided the clay is properly tempered and the mold is kept well oiled. Each cone should be stamped, before removal from the mold, with the number of the sample from which it was made. For this purpose an ordinary font of metallic type, with a plain, sharp-lined face, is perfectly satisfactory.

When cones are cut from a cake of clay, they may be given a square, instead of a triangular, section, and the numbers can be scratched upon them with a pencil.

When the bricklets are molded, the mold is well oiled and placed upon a piece of oiled plate-glass. The mold is then filled with tempered clay, and the upper surface is smoothed with a wet or oiled spatula. The filled mold is then slipped off the glass, and turned upside down upon the glass. Any cavities or uneven places are filled in and smoothed off, and the filled mold is again removed from the glass. The bricklets are then pressed out of the mold with blocks provided for that purpose. If the surface of the block in contact with the bricklet has been well oiled, it is a simple matter to slide the completed bricklet from the block. The bricklets should be stamped with the proper numbers immediately after removal from the mold.

When the bricks are cut from a piece of flattened clay, great care must be exercised, or the result will be anything but attractive.

The briquettes for the tensile-strength tests should be made as described on page 31.

7. The last test-piece made—either cone or bricklet, but preferably the former—must be stamped in some distinctive fashion (W, for weight) and immediately weighed, the weight being recorded in the proper place on the blank.

8. At least two of the cones or bricklets, preferably the latter, must have tiny holes, two inches apart, punched upon them for the air-shrinkage determinations. When the holes are placed on the bricklets, they must be in the corners, as the bricklets are

only two inches long. If the holes are punched in the cones, great care must be exercised not to break the tip from the cone. In either case the holes should not be punched until the test-pieces have been removed from the molds.

All the test-pieces should be placed on clean cardboard to dry, and they should be moved around and turned several times during the first few hours. If this is not done, considerable warping is apt to occur.

9. All the tempered clay remaining, or enough to form two two-inch spheres, is rolled into two such balls. Then test and record the cohesion as described on page 26.

10. Roll the clay used in making the cohesion test and all the surplus clay into a single sphere, which must be stamped with the proper number and dried with the other pieces.

The ten operations just described complete the work that it is possible to do the first day in the laboratory.

11. The thoroughly air-dried clay is examined, and the cracking is recorded. The cracking shows most plainly upon the large ball made out of the surplus clay.

12. The tensile strength is determined as described on page 30.

The broken briquettes and the large ball should be returned to the original sack and saved for use in case it proves necessary to make more large cones or some small ones for very high-temperature tests.

13. Measure and record the percentage of air shrinkage as scribed on page 28.

14. The piece previously weighed and specially marked is reweighed, and the percentage of water required to temper the clay to maximum plasticity is thus determined and recorded, as described on page 26.

15. Scratch marks two inches apart on one face of each cone, placing the lower mark as far above the base as possible, and being very careful not to break the tip. This operation is best accomplished by using a pair of sharp-pointed compasses or dividers. Set them at two inches, and place one end as near the tip of the cone as possible. Then strike an arc across the base, scratching the surface until the line shows plainly. Lastly, set the other point on the line at the base and scratch a second mark near the tip. These marks are used in measuring the fire shrinkage.

16. The cones and bricks from each sample should be placed in small, separate boxes, numbered on the fronts, and filed away to await the burning tests. Care must be used in handling unburned test-pieces, as many are very fragile.

17. Temper some fire-clay to a condition of maximum plasticity, and mix some asbestos wool with the plastic mass. Varying amounts of alundum cement may also be added, or the fire-clay may be entirely replaced with alundum cement.

Roll or press the damp mixture on a sheet of oiled plate-glass until it is about half an inch thick, and from this sheet cut small slabs about three by six inches in length and width.

Along both edges of each damp slab imbed the bases of cones to be tested. Be careful to press the fire-clay around the base of each cone so as to hold it firmly, and also see that the number of each cone is not obscured. The cones should be bent slightly toward each other, and each cone should be so twisted that, after being bent, an edge is underneath and a flat face on top of the cone. Lastly, a standard Seger cone No. 010 is fastened to one end of the slab. From one to six of the cones to be tested may be mounted on a slab of this kind. It is best to press the edge of each slab upward, so that, if any cone melts to a thin liquid, there will be no danger of its running off the slab onto the muffle.

Where very accurate work is desired, another slab exactly like the first should be prepared, excepting that Cone 09 is mounted at the end instead of 010. Then another slab with Cone 08 should be made, and so on up to Cone 20 or more. Such a procedure would be very laborious, however, and would require twice as many cones as are usually made. The time necessary to make the burning tests would also be greatly lengthened. Probably the best plan is to make up eleven slabs and mount one of the following standard cones upon each: 010, 07, 04, 01, 3, 6, 9, 12, 16, 20, 26. This series gives a difference of three cones (60°C.) in the lower part, and four to six cones in the higher temperatures. Since twelve test-cones are made, and the cones are burned to only eleven different temperatures, it is evident that one extra cone is allowed for breakage.

In securing the data incorporated in this report, the following series was used: 010, 05, 03, 01, 1, 3, 5, 8, 10, 12, 14, 16, 18, 20. 2, 4, and 6 should have been substituted for 1, 3, and 5, but it was thought best to make no changes in the procedure as first begun. Experience has shown that the series suggested in the paragraph above is equally satisfactory and requires fewer cones.

Since the slabs hold but six cones, it is, of course, necessary to mount an additional series exactly like the first, if more than six samples are to be tested. In some types of furnaces or kilns it may be possible to use larger slabs and mount more cones on each.

18. Air-dry the slab bearing Cone 010 and the cone or cones to be tested, and heat it in an air-bath to the boiling point of water, or higher. While still hot, place it in the furnace or kiln. Gradually raise the temperature until the standard cone has fused, and then cool slowly.

19. Examine each cone to be tested, and note whether incipient vitrification, vitrification, or viscosity has been reached. (See pp. 44-46.) In case any cone has reached viscosity, remove the unburned cones of that number from the slabs to be burned to higher temperatures.

20. Test the fire shrinkage and absorption of each cone, as described on pages 42 and 43, and note the color in each case.

21. Repeat the operation described in the paragraph numbered 18, above, using the slab containing the standard cone of next higher fusibility; and continue to burn the slabs of cones until all have become viscous.

It is evident that in some cases a number of slabs will be left unburned after all the clays upon them have reached viscosity, but there seems to be no way to prevent the waste of time thus represented, since the slabs should be made up several days before they are burned.

22. If a clay does not melt at Cone 26, make up a dozen small-sized cones and burn them to higher temperatures in the Deville furnace.

23. Burn one of the bricklets to incipient vitrification, another to vitrification, and the third to an intermediate temperature.

The bricklets are burned for three reasons: First, they have a larger surface than the cones, and this enables one to judge better of the appearance of the product; second, the owner of a clay deposit usually feels curious about the appearance of his material when burned, and these burned bricklets form a valuable accompaniment to a report on a clay property; and, third, the fire shrinkage may be more easily determined from them.

CHAPTER V

Clay Products and the Properties Required of the Clays Used in Making Each of Them

It has been a rather wide-spread practice in the past to regard clay merely as the raw material from which bricks are made, whereas there are a dozen or more clay products that are much more valuable than brick. It would be just as foolish, for instance, to use silver nails to build a house as to employ a clay adapted to the manufacture of roofing tile for the making of a common brick. It is hoped that such an uneconomical procedure will become rarer as the properties of the clays adapted to different uses are better known, and it is for the purpose of extending information on this subject that this chapter is presented.

Literature on the properties of the clays used for various purposes is very meager. Some information along this line is contained in all books and reports on clays or clay deposits, but the inexperienced clay-tester would find it impossible properly to judge of the value of most clays from such data as have been available. The statements given in the following pages are, then, largely the result of experience, or have been gleaned from talks with practical workers along the various lines mentioned. Errors may, therefore, be present; and it may be that not enough latitude has been allowed in giving the properties needed by each kind of clay. Criticisms will be welcomed, and, if these lead to a perfectly correct and satisfactory list of the properties essential to the clays used in the manufacture of all the various clay products, a big step forward in ceramics will have been taken. It is believed, however, that this chapter will serve to point the way and should prove valuable to those who are interested in the classification of clays.

In discussing the nature of the clay used in making any particular product, only those properties are mentioned which it is absolutely necessary that the clay should possess in order that it may be used as found for the purpose specified. When a property is not mentioned, it should be understood that it has no influence upon the manufacture of the product under discussion. It should not be forgotten that many clays which are apparently worthless as found may be modified by washing, grogging, or admixture with other clays, so as to give them considerable value.

SOFT-MUD BRICK CLAY

Soft-Mud Bricks Defined.—After tempering recently mined or weathered clay, in any one of a great variety of fashions, until it has the consistency of soft mud, it is usually pressed into well-sanded wooden molds. Sometimes unsanded, wet steel molds are used, and the product is known as slop bricks. The bricks are then dried in the open air, drying-tunnels, on drying-floors, or on kiln tops, and are burned in any kind of temporary or permanent kiln.

Almost any clay or shale will answer for the manufacture of such bricks, but no clay product has less value, unless, possibly, it be ballast; so it would be a wasteful proceeding to use a high-grade clay for soft-mud bricks.

Although the rough surface of soft-mud bricks make them unattractive, they really form a better, stronger building material than pressed bricks, in many cases. This is because they adhere more firmly to the mortar and are very homogeneous. They resist the action of frost very well.

Soft-mud bricks are occasionally pressed in machines after molding as above described. This gives them a better finish, but considerably raises their cost.

Texture.—Very large sand grains or pebbles make the product weak.

Non-permissible Impurities.—Almost nothing is a non-permissible impurity, unless it is present in excessive amounts.

Air Shrinkage.—Eight per cent is about the upper limit; it should be less than this.

Slaking.—It does not generally pay to crush or grind soft-mud brick clays; so the clay should slake in a few minutes.

Cracking Allowed.—Little or none.

Tensile Strength.—Not less than 60 pounds, and should be around 100 pounds in order that the unburned bricks may be handled without excessive loss.

Incipient Vitrification.—Should be low—between 012 and 01.

Vitrification.—Should be at least two cones above incipient vitrification.

Color Burned.—Red bricks are best, since buff-burning clays are rarely hard enough at the temperatures usually attained in burning. Where high temperatures are used, the color is unimportant so long as not unattractive.

Fire Shrinkage.—Not over about 8 per cent, preferably lower. There should be a per cent or two of fire shrinkage in order to insure that the brick has a dense, hard body.

Absorption.—Not over 15 per cent, if the brick is to be used for exteriors.

Chemical Character.—The amount of ferric oxide usually varies between 3 and 7 per cent. The alkalies average about 3 per cent, but may run as high as 15 per cent. When this is the case, the bricks are very hard to burn, since they fuse easily. Lime averages 1½ per cent, but may reach as high as 25 per cent if very finely divided, provided the bricks are very carefully burned. Magnesia averages 1 per cent, but may reach as much as 7 per cent.

Washing.—It is never necessary.

Grogging.—Grog may be used.

STIFF-MUD BRICK CLAY

Stiff-Mud Bricks Defined.—The clay is disintegrated and tempered in any way, but only enough water to form a stiff mud is used. The tempered clay is then forced mechanically through a die, from which it emerges in the form of a rectangular bar, which is cut into bricks by means of fine, tightly stretched wires.

Unless they are repressed, stiff-mud bricks will have two rough faces, due to the use of wire in cutting them. They are usually so laid that the smooth faces are exposed, while much of the plaster is spread over rough faces. In this way they combine certain of the advantages of common soft-mud and repressed or pressed bricks.

Physical Properties.—The physical properties of a stiff-mud brick clay are exactly the same as those of a soft-mud brick clay (see p. 68), except that the plasticity should not be better than fair, the cohesion must be strong, no sand is permissible, and moderate cracking in drying is allowable.

If the plasticity is better than fair, the bricks will have a decidedly laminated structure, which is difficult to prevent under the best of conditions. A strong cohesion will, however, have a very favorable effect along this line. When sand is present in the clay, it will soon wear out the cutting wires, and the cut surfaces and edges are apt to be very rough. A little cracking in a test-piece need not cause any anxiety, since stiff-mud brick clay is not mixed to maximum plasticity. Test-pieces would probably show no cracking if they contained as small a proportion of water. Another factor that diminishes the danger of cracking on drying is the very considerable pressure to which the clay is subjected in forcing it through the die.

DRY-PRESSED BRICK CLAY

Dry-Pressed Bricks Defined.—The clay is disintegrated in any way, with or without previous aging, and is passed through a twelve- to sixteen-mesh screen. The dry powder is then pressed into steel molds, the pressure used being so great as to produce a brick strong enough to stand handling. These bricks are burned in any way, but down-draft kilns are most frequently used, since they produce a more uniform product—an essential for face bricks.

The process above outlined produces an attractive brick, with sharp edges and smooth faces, but pressed bricks have certain disadvantages already mentioned (see p. 68), and they are relatively so expensive that they are used almost entirely as facing. The high cost is due to the facts that a fairly good quality of clay is usually employed; the clay must be disintegrated, screened, and, often, aged; a longer time, and from one-sixth to one-quarter more fuel, are required to burn them; and the initial cost of the plant is high.

Texture.—Should not contain pebbles, as these either wear out the grinding apparatus or make it inefficient in its action.

Non-permissible Impurities.—Only small amounts of any impurity can be tolerated. No soluble salts are permissible, unless special means are taken to neutralize them.

Cohesion.—Must be high, or the unburned bricks will break easily.

Incipient Vitrification.—Should be as low as possible, but is often as high as Cones 7 or 8 in the case of non-calcareous, buff-burning clays.

Vitrification.—Should be at least two cones above incipient vitrification.

Color Burned.—The color of burned pressed bricks is very important. It must be of attractive tints, as they are used for face bricks. Red is not so desirable as are buff, cream, white, and gray. Brown is also used to a considerable extent, but yellow is not popular. If the color is too light, it may be darkened by the use of manganese or other oxides. The color should be the same over a range of temperature of fifty degrees or more, in order to insure uniformity of tint in the burned product.

Fire Shrinkage.—Eight per cent is the maximum allowable; it should be lower.

Absorption.—Twelve per cent is a high figure for a good quality of pressed brick.

Chemical Character.—Pressed-brick clays differ little in chemical character from soft-mud brick clays (see p. 69), but the tendency is to use a higher grade of clay for the former, with a total percentage of fluxes of only 5 or less.

Washing.—It is not necessary.

Grogging.—Grog may be used to decrease the fire shrinkage.

Warping, etc.—Absolutely no warping, splitting, blistering, checking, or swelling can be tolerated in a clay that is to be used for manufacturing dry-pressed brick.

SEMI-DRY PRESSED BRICK CLAY

Semi-dry Pressed Bricks Defined.—These are the same as dry-pressed bricks, excepting that a little water is added to the screened clay before molding. This makes the molded bricks easier to handle, but they must be dried before burning.

FRESCO AND FLASHED BRICK CLAY

Fresco Bricks Defined.—Fresco bricks are stiff-mud bricks which have had at least one face exposed to a reducing atmosphere, usually only at the end of the burn, and which have then cooled with a free access to air, so that a partial reoxidation has occurred. A relatively dark-colored, semi-vitrified surface results, and the bricks are laid with the rough, cut surface outside.

Flashed Bricks Defined.—Flashed bricks are almost the same as fresco bricks, except that any kind of brick may be subjected to the reduction and partial reoxidation, and the surface is well vitrified, and is, therefore, smooth.

It is claimed that, when just enough air is admitted to insure an oxidizing atmosphere, a reduction of 20 per cent of the air supply will make the atmosphere of the kiln sufficiently reducing to cause flashing.

Since any kind of brick may be flashed, the properties required for the manufacture of a flashed brick will depend partially upon the kind of brick desired. The following properties are, however, directly connected with the operation of flashing:

Texture.—The finer the texture, the more uniform the results.

Non-permissible Impurities.—Gypsum or calcite should not be present, since they exert a bleaching action upon the iron.

Slaking.—The clays used in making these products are often ground.

Incipient Vitrification.—Incipient vitrification usually takes place at a higher temperature than in the case of common bricks, since a relatively high heat is required to cause flashing. This condition (incipient vitrification) is rarely reached below Cone 01.

Vitrification and Viscosity.—The two temperatures at which these conditions are reached should be separated by at least five cones, in order that vitrification of the surface may occur without danger of loss of shape. Probably the average temperature at which vitrification occurs is Cone 5, but a lower flashing temperature may be used when conditions are reducing throughout the entire burn.

Color Burned.—Those clays which burn buff in an oxidizing atmosphere will yield golden or reddish browns when flashed, while red- or pink-burning clays give greens and dark browns. The longer the rate of cooling from the maximum temperature of the burn down to about 700° C., the darker the color will be. This cooling should take about twelve hours.

EARTHENWARE CLAY

Earthenware Defined.—Earthenware includes flower-pots, jugs, crocks, etc., and is made by tempering the clay in any way, kneading it until perfectly homogeneous and free from bubbles, molding it on revolving wheels or by mechanical processes called jiggering, jollying, or pressing, drying the molded pieces carefully in steam-heated rooms, and burning it in up-draft kilns. The ware may be decorated with incised or relief designs, or it may be covered with a glaze of low fusibility.

Texture.—Should be fine. If it is sandy, the ware will not be smooth.

Non-permissible Impurities.—Lime or gypsum in particles of some size or concretions of anything that will cause blistering.

Plasticity.—Must be at least good for nearly all processes.

Water for Maximum Plasticity.—Should be low, so as to make warping and cracking improbable.

Air Shrinkage.—Except for very coarse products, the maximum is 8 per cent, and lower figures are desirable.

Slaking.—Must slake in a few minutes, or grinding is required. This is usually too expensive, except in the case of the finest products.

Allowable Cracking in Air.—None.

Tensile Strength.—One hundred and twenty-five pounds per square inch, or more, is desirable, but as low as 100 pounds is permissible if great care in handling is exercised.

Incipient Vitrification.—This condition should be reached between Cones 010 and 05, although some grades of earthenware are not burned to incipient vitrification.

Vitrification.—Should be at least two cones above incipient vitrification, except in cases where the product is not burned steel-hard.

Color Burned.—This is not very important, so long as the ware is not actually ugly.

Fire Shrinkage.—Eight per cent is about the maximum allowable, and this is pretty sure to cause some warping.

Chemical Character.—Some rather low-grade clays high in lime are used in some cases. In fact, the composition is unimportant, except in so far as it affects the color.

Washing.—Rarely necessary or desirable.

Grogging.—Some very finely ground grog may be used.

Warping, etc.—Little warping or swelling, and no cracking, checking, or blistering, can be tolerated.

YELLOW AND ROCKINGHAM WARE CLAY

Yellow and Rockingham Ware Defined.—These include various ornamental and useful utensils which are made of material with a porous, buff-colored body. After burning, the wares are glazed and burned a second time. In the case of yellow-ware the glaze is colorless or yellow, while Rockingham ware has a brown or black glaze, produced by the addition of manganese oxide.

Texture.—Should be fine.

Color Unburned.—Should have no color indicating the presence of much iron.

Non-permissible Impurities.—Limonite,. calcite, gypsum, or alkali.

Plasticity.—Must be fine.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Should be under 8 per cent.

Allowable Cracking in Air.—None.

Tensile Strength.—One hundred and twenty-five pounds or more per square inch.

Vitrification.—Should be several cones above incipient vitrification; usually above Cone 8.

Color Burned.—White, yellow, or light buff for yellow ware; white, yellow, buff, or brown for Rockingham ware.

Fire Shrinkage.—Not over 4 per cent.

Chemical Character.—A fairly high-grade clay, low in fluxes, is usually used.

Washing.—Washing is rarely employed.

Grogging.—Finely ground grog may be used.

Warping, etc.—Little warping or swelling, and no checking, cracking, or blistering, can be tolerated.

STONEWARE CLAY

Stoneware Defined.—Stoneware includes many cooking and other domestic utensils, as well as much ornamental pottery. Stoneware is vitrified, and the product is completed in one burning, the glaze being applied to the raw clay, unless a salt glaze is used. The burned clay may have any color except white. The following two varieties are recognized:

Majolica: Majolica has a colored clay body concealed beneath an opaque glaze.

Fayence or Faience: Fayence has a colored clay body which is covered with a transparent glaze.

Texture.—Should be very fine.

Non-permissible Impurities.—No impurities in any but very small amounts should be present.

Plasticity.—Should be fine.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Eight per cent is about the maximum allowable.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be at least 150 pounds per square inch, but 125 pounds is permissible if the unburned product is handled very carefully.

Viscosity.—The temperature of viscosity must be at least five cones above vitrification, since the ware is vitrified. Cone 18 represents an average viscosity temperature.

Fire Shrinkage.—Eight per cent is about the maximum allowable, but there should be several per cent of fire shrinkage in order to insure a dense ware. Some claim that air and fire shrinkages should together amount to about 12 per cent.

Chemical Character.—Stoneware requires a clay somewhat better than is used for earthenware; a semi-refractory clay is often used. Ten stoneware clays used in Ohio potteries contain an average of 4.4 per cent of fluxes.

Washing.—Washing would not be required, or pay, in most cases.

Grogging.—Finely ground grog may be used.

Warping, etc.—It depends somewhat upon the nature of the ware whether any warping can be tolerated. Swelling, cracking, checking, or blistering makes it impossible to use the clay for stoneware of any kind.

WHITE-WARE CLAY

White-Ware Defined.—White-ware includes many varieties of domestic utensils, such as wash-bowls and pitchers, and cheap dishes. It is made of a white-burning mixture of kaolin, ball-clay, quartz, and feldspar. The ware is burned to incipient vitrification, then glazed, and reburned. The glazes used are usually of low fusibility, due to the presence of borax and lead, and are known as soft glazes. Very rarely clays are found of such compositions that they may be burned to white-ware without adding all, or any, of the other substances mentioned.

The characteristics required in such a clay are as follows:

Texture.—Should be very fine.

Color Unburned.—White or gray.

Non-permissible Impurities.—Anything in visible amounts.

Plasticity.—Should be fine.

Cohesion.—Should be strong.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Six per cent is about the maximum allowable when thin ware is to be made.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be 150 pounds or more per square inch.

Vitrification.—Should be several cones above incipient vitrification; it is usually above Cone 10.

Color Burned.—Perfectly white.

Fire Shrinkage.—Six per cent is about the maximum allowable.

Chemical Character.—The iron oxide should not exceed 1 per cent, and the total fluxes should amount to less than 5 per cent.

Washing.—Washing might be used to remove impurities.

Grogging.—Finely ground white quartz can be used if needed.

Warping, etc.—No warping, swelling, checking, cracking, or blistering can be tolerated.

PORCELAIN (CHINA) CLAY

Porcelain Defined.—Porcelain includes all the better grades of dishes and considerable ornamental pottery. It is like white-ware so far as ingredients are concerned, but the proportions of these differ, and the mixture is burned to vitrification before glazing and reburning. The glaze used consists chiefly of feld-spar and kaolin, and is called hard glaze.

BALL-CLAY

Ball-Clay Defined.—Ball-clays are white-burning, plastic clays that are used with kaolin, feldspar, and quartz in the manufacture of high-grade pottery. Their function is to give plasticity, cohesion, and tensile strength to the mixture.

Texture.—Should be very fine.

Color Unburned.—Should be white or gray.

Non-permissible Impurities.—Anything except mica and a little quartz and feldspar, which might be removed by washing.

Plasticity.—Should be very fine.

Cohesion.—Should be high.

Tensile Strength.—As high as possible; certainly well over 100 pounds per square inch.

Vitrification.—Should not take place much below Cone 10. Some ball-clays are very refractory.

Color Burned.—Must be white.

Chemical Character.—Ferric oxide should not be present in amounts much over 1 per cent, and the rest of the fluxes should be comparatively scanty.

Washing.—Washing is often required to bring the clays to the required purity.

DRAIN-TILE CLAY

Drain Tiles Defined.—Drain tiles are porous, cylindrical, unvitrified pipes. In manufacturing these, the clay is tempered in any way and forced through a die, from which it issues in the form of a hollow cylinder, which is then cut into any desired lengths. Drying may be done in any way, and the tile is often burned along with common bricks.

Texture.—Should not contain coarse sand grains.

Plasticity.—Should be fine.

Cohesion.—Must be strong, as the tile is split lengthwise just previous to passing through the die, and these two halves will not reunite solidly as the result of pressure alone unless the cohesion is strong.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—A high or medium air shrinkage will cause warping and cracking in large pieces like drain tile. A clay with an air shrinkage of over 6 per cent will almost certainly require grogging.

Slaking.—Should slake in a few minutes.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be at least 150 pounds per square inch.

Incipient Vitrification.—Should be low—between Cones 012 and 01.

Vitrification.—Should be at least two cones above incipient vitrification.

Fire Shrinkage.—Should be as low as possible; 4 per cent is about the upper limit.

Absorption.—Not less than 15 per cent; higher is desirable.

Chemical Character.—Iron oxide varies between 2 and 7 per cent. The alkalies average 3 per cent, but may reach 15 per cent, in which case the tile is hard to burn without loss. The lime content should be low—not much over 1 per cent. A high magnesia content is desirable, but this substance does not average over 1 per cent.

Washing.—This is never necessary.

Grogging.—Finely ground grog is often employed, or the same result may be secured by mixing two different clays of the proper characteristics.

Warping, etc.—Warping and cracking cannot be tolerated, and even very slight swelling, checking, or cracking is most undesirable.

SEWER-PIPE CLAY

Sewer Pipes Defined.—Sewer pipes are vitrified cylindrical pipes provided with flanges at one end. They are made by tempering the clay in any fashion, and then molding it in specially designed pipe presses, from which it issues in completed form. After careful drying, the pipes are usually burned in circular down-draft kilns and are salt-glazed.

Texture.—Should not be sandy.

Non-permissible Impurities.—No impurity is harmful unless present in considerable quantity.

Plasticity.—Should be fine.

Cohesion.—Must be strong.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Six per cent is probably about the maximum allowable, and a lower shrinkage is much to be preferred.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be at least 125 pounds per square inch.

Vitrification.—Vitrification should take place at as low a cone as possible—the average is about Cone 3.

Viscosity.—Must be at least five cones above vitrification.

Fire Shrinkage.—Four per cent is about the maximum allowable. The total shrinkage in the clay must never be over 10 per cent under any circumstances.

Absorption.—Must be above 1 per cent below Cone 02 in order to avoid brittleness.

Chemical Character.—Iron oxide and other fluxes are usually rather high—10 to 12 per cent. The ratio of silica to alumina must be between 4.6 to 1 and 12.5 to 1, in order to make salt-glazing possible. Soluble salts make salt-glazing difficult or impossible, unless the process is conducted at Cone 8, or above; then as much as 3 per cent of these may be present.

Washing.—This is never necessary.

Grogging.—Finely ground grog must often be employed. The same result may frequently be secured by mixing two clays of the proper characteristics. One of these is often a fire-clay.

Warping, etc.—Cracking, warping, or swelling cannot be tolerated. Blisters and checks cause the ware to be classed as "seconds."

CLAY FOR HOLLOW STRUCTURAL MATERIALS

Hollow Structural Materials Defined.—Hollow structural materials are unvitrified and are made in larger, thinner pieces than bricks. The larger pieces are strengthened with cross-webs, and all combine relatively light weight with sufficient compressive strength and superior heat-, cold-, and dampness-resisting qualities. The following three varieties of hollow structural materials are recognized:

Fire-Proofing: Hollow material used in the partitions, interior arches, and as wall-furring in fire-proof buildings.

Terra-Cotta Lumber: Hollow material that is very soft and porous, due to the admixture of much sawdust with the clay. This burns out and leaves a product that is so porous that nails can be driven into it. Terra-cotta lumber is much used for partitions.

Hollow Bricks and Blocks: Rectangular hollow material from the size of a brick up to dimensions of a foot or more. These are used for exterior walls.

All varieties of these products are made by forcing the tempered clay through a die of the proper shape, after which it is cut into the desired lengths with wire, dried, and burned in down-draft kilns.

Texture.—Should not be sandy.

Non-permissible Impurities.—No impurity is harmful unless present in considerable quantity.

Plasticity.—Should be fine.

Cohesion.—Must be strong.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Should be less than 6 per cent.

Slaking.—Should slake in a few minutes.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be at least 125 pounds per square inch.

Incipient Vitrification.—The lower the temperature at which a steel-hard condition can be obtained, the better.

Vitrification.—Should be at least two cones above incipient vitrification.

Fire Shrinkage.—Should be below 4 per cent.

Chemical Character.—A low refractory or non-refractory clay is often used.

Washing.—This is never necessary.

Grogging.—Finely ground grog is often used, or a non-refractory and a low-grade fire-clay are mixed to decrease the shrinkage and tendency to warp.

Warping, etc.—No warping, swelling, blistering, or cracking can be tolerated.

ROOFING-TILE CLAY

Roofing-Tiles Defined.—Roofing-tiles, as the name indicates, are water-proof tiles used for roofing purposes. They are generally made in one of the following three shapes:

Shingle Tiles: Thin, flat plates which are usually vitrified.

Roman Tiles: Vitrified or unvitrified material that has the shape of a hollow cylinder split longitudinally.

Interlocking Tiles: Vitrified or unvitrified material so shaped as to interlock into a water-tight whole.

In making all varieties of roofing-tiles, the clay is usually ground to twenty-mesh, carefully tempered, and forced through a die of proper shape. The shingle and interlocking tiles issue from this die as a flat ribbon, which is cut into desired lengths, while the ribbon from which the Roman tiles are cut has the form of a trough with a semi-circular section. To shape the interlocking tiles, the flat plates of damp clay are repressed in special machines, and are kept in wooden or plaster molds until dry.

If the product is too porous, it may be covered with a lead glaze or salt-glazed.

Texture.—Although the clay is ground, pebbles or coarse sand interfere with this process and make it expensive.

Non-permissible Impurities.—Calcite, gypsum, pyrite, carbonaceous matter.

Plasticity.—Should be fine.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Should not be over 4 per cent for interlocking tiles, and not much higher for other types.

Allowable Cracking in Air.—None.

Tensile Strength.—Should be at least 150 pounds per square inch.

Incipient Vitrification.—Should be as low as possible.

Vitrification.—Should be at least two cones above incipient vitrification.

Viscosity.—If the tiles are vitrified, the viscosity temperature should be at least five cones above the vitrification point.

Color Burned.—Red tiles are the most popular, but brown and buff ones are sometimes used. If the tiles are to be glazed, the color does not matter.

Fire Shrinkage.—Should not be over 2 per cent for interlocking tiles, and not much higher for other types.

Absorption.—The tile must be glazed if the absorption is above 10 per cent.

Chemical Character.—This depends upon whether the tile is to be vitrified, the color desired, and the kind of glaze used.

Washing.—This is not necessary.

Grogging.—Finely ground grog is usually needed to lower the shrinkage and decrease the warping.

Warping, etc.—A very little warping is permissible in the case of shingle or Roman tiles, but absolutely no warping or cracking can be tolerated in the case of interlocking tiles. The tests previously described will hardly suffice to prove conclusively that a clay is adapted to the manufacture of interlocking tiles. For this purpose, some tests on specially shaped pieces should be conducted, as follows:

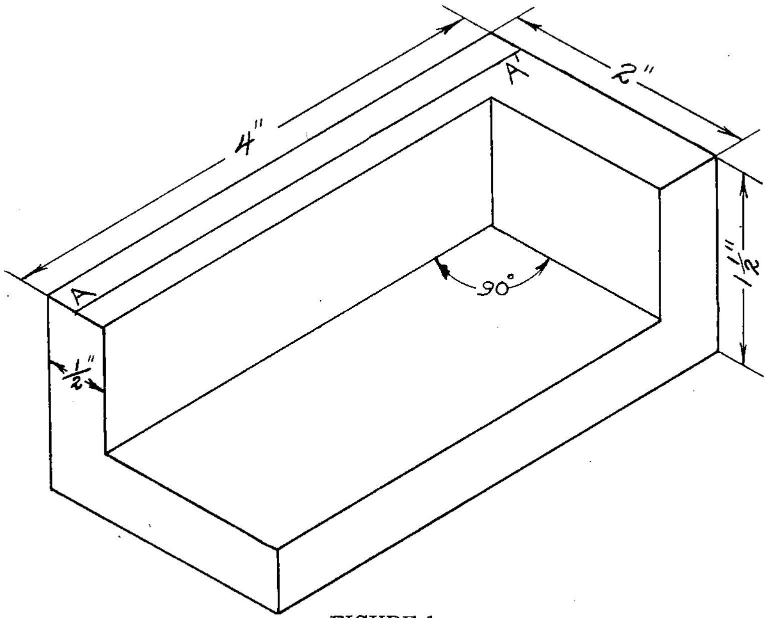


FIGURE 1

Specially shaped test-piece for ascertaining whether a clay is adapted to the manufacture of interlocking roofing-tiles

Special Tests for Interlocking Roofing-Tiles.—Temper the ground clay to a condition of maximum plasticity, and mold a piece into the shape and dimensions shown in Figure 1. Be certain that the upright portions are thoroughly amalgamated to each other and to the base. Then smooth the surface A-A′ with a piece of oiled plate-glass, and press a shallow line onto this surface with a perfectly smooth, sharp straight-edge. After the clay has completely dried, examine it for signs of cracking, particularly at the junctions of the three pieces, and see whether the straight-edge will still fit perfectly into the line pressed onto the surface A-A′. Repeat the operation after the test-piece has been burned. If any cracking or warping takes place under these conditions, the clay is not adapted as found to the manufacture of interlocking roofing-tiles.

REFRACTORY-GOODS CLAY (FIRE CLAY)

Refractory Goods Defined.—Refractory goods include, as the term indicates, all objects whose chief function is to withstand high temperatures, although they may also serve as containers or structural material. Among such articles are crucibles, scorifiers, muffles, fire-brick, furnace and stove linings, glass pots, retorts, etc. Nothing should be called a fire-clay that does not have a viscosity temperature above Cone 27.

As might be expected, the properties of clays used in making refractory goods vary with the purposes for which they are to be used. Two varieties are recognizable, however; i. e., those which are naturally plastic or which develop plasticity when finely ground, and the so-called flint-clays, which are non-plastic under all conditions and must be mixed with plastic material before they can be used. The flint-clays sometimes have a conchoidal fracture and a dull vitreous luster.

In making refractory articles, a certain amount of finely ground fire-brick or quartz is often added to the ground and screened clay, or it may be added before grinding and the mixture ground together. If the tensile strength or plasticity is too low, a stronger or more plastic clay must be added even at the expense of refractoriness. The mass is then well tempered and molded. This is usually done by hand, but some products are pressed. After partial drying, the articles are usually repressed. Down-draft kilns are commonly employed to burn refractory goods.

Color Unburned.—White or gray.

Non-permissible Impurities.—Anything except carbonaceous matter and quartz.

Plasticity.—The higher, the better. A plastic clay must often be mixed with the one under consideration, in order to develop sufficient plasticity to enable the clay to be molded.

Allowable Cracking in Air.—None, unless it is to be grogged.

Tensile Strength.—It is desirable that the tensile strength should be as high as possible, but it is as low as 25 pounds per square inch in some fire-clays.

Viscosity.—Must be above Cone 27.

Color Burned.—Always white or very light buff.

Absorption.—Where the ware is exposed to corrosion, as in crucibles, blast-furnace lining, glass pots, zinc retorts, etc., the absorption must be low—only a few per cent; but when the product is subjected to sudden changes of temperature, it must be porous—have a high absorption. The absorption is of no importance when the clay is made into locomotive, furnace, and stove linings, grate backs, gas retorts, and many other articles. The best fire-clay has an absorption of over 5 per cent at Cone 10.

Chemical Character.—Fire-clays usually approach kaolin in composition, but the silica is apt to be slightly excessive, and up to 4 per cent fluxes may be present. It should be remembered that quartz acts as a flux at high temperatures, and that it must be added cautiously.

Washing.—Washing is sometimes employed in preparing the clay used in the manufacture of glass pots as well as other refractory articles.

Grogging.—Ground grog is nearly always used.

Warping, etc.—Warping, cracking, etc., rarely take place in burning refractory articles, doubtless due to the grog used.

TERRA-COTTA CLAY

Terra-Cotta Defined.—Terra-cotta is an ornamental structural material that simulates carved stone.

Terra-cotta is made from ground clay that has been thoroughly tempered and forced through a die, from which it issues in the form of a square prism with eight-inch sides. This prism is cut into cubes, which are piled away and covered with a damp cloth until needed. When a single piece is wanted, it is carved by hand, but duplicates are made in plaster molds into which the clay is pressed by hand. Large pieces are made in sections and are not over two inches thick. Cross-webs are used where needed to give strength. Drying takes place on floors, and may be retarded so as to prevent warping in the case of very large pieces. After the drying is completed, a coating or slip of a mixture of kaolin, ball-clay, quartz, feldspar, and various fluxes is often sprayed upon the raw clay. It is then dried again, and is finally burned. Circular down-draft kilns are usually employed.

When the ware is coated, the process just described gives a product with an impervious surface of any desired color that usually has a matte or semi-matte finish. High-lustered glazes are sometimes used, however.

Non-permissible Impurities.—Calcite, gypsum, pyrite, much carbonaceous matter.

Plasticity.—Must be good if made in molds, and very fine if carved by hand.

Cohesion.—Must be strong.

Water for Maximum Plasticity.—Should be low.

Air Shrinkage.—Should be well under 6 per cent.

Allowable Cracking in Air.—None.

Tensile Strength.—At least 100 pounds per square inch.

Vitrification.—Should be at least five cones above incipient vitrification, since, although the ware is not vitrified, it must burn very dense and hard.

Color Burned.—Should be attractive, if the product is not coated.

Fire Shrinkage.—Should be less than 4 per cent. The total shrinkage must not be over 8 per cent.

Absorption.—Should be under 6 per cent, unless the product is coated.

Chemical Character.—Semi-fire-clays or mixtures are often used for terra-cotta. In any case, the clay must be low in lime and soluble salts, since the former causes shrinkage and the latter come out through the slip in drying.

Washing.—This is sometimes done, at least so far as part of the ingredients are concerned.

Grogging.—Finely ground grog may be used, if it does not decrease the plasticity too much.

Warping, etc.—No warping, cracking, etc., can be tolerated. It is best to test clays that seem adapted to the manufacture of terra-cotta according to the method outlined under "Special Tests for Interlocking Roofing Tiles," on page 81.

VITRIFIED OR PAVING-BRICK CLAY

Vitrified or Paving-Bricks Defined.—No definition is necessary, as the names are self-explanatory.

Vitrified bricks are usually made by grinding, screening, and tempering the clay, and then making a stiff-mud brick out of it. The green brick is then usually repressed to make it denser, reduce the laminated structure, and round its corners. The repressed bricks are commonly dried in tunnels and burned very slowly in down-draft kilns, after which they are very gradually cooled.

Whether a clay will make a satisfactory paving-brick can be determined with certainty only by testing the completed brick itself in a piece of apparatus, called a rattler, which tests the hardness, toughness, and strength of the product. It is, however, not even worth while to make a rattler test upon bricks made from clays which do not conform to the following specifications:

Texture.—Should be coarse, but not sandy.

Non-permissible Impurities.—Limonite is the only visible impurity permissible, but fine-grained quartz, feldspar, and calcite are often present in good grades of material.

Plasticity.—Should be fair.

Cohesion.—Should be strong.

Air Shrinkage.—Should not be over 8 per cent.

Slaking.—Should slake in a few minutes, unless the raw material is ground.

Cracking Allowed.—Slight cracking is permissible.

Tensile Strength.—Sixty pounds per square inch is the minimum allowable, and higher figures are very desirable.

Vitrification.—A long fusion period is necessary in order to produce a strong, tough product; so the vitrification temperature should be several cones—the more, the better—above incipient vitrification.

Viscosity.—Must be at least eight cones above vitrification, in order to secure a product of the first quality, but a difference of five cones may answer in some cases.

Color Burned.—Red-burning clays are most apt to make good vitrified bricks.

Fire Shrinkage.—Should not be over 8 per cent.

Absorption.—The ware is vitrified, and the absorption will thus be low; but a good tough product cannot be made if a test-piece shows an absorption of 1 per cent or less before Cone 5 is reached.

Chemical Character.—Fifty analyses of vitrified brick clays show an average of 13 per cent fluxes. It is often necessary to mix several clays to secure the required chemical and physical properties.

Washing.—This is not employed.

Grogging.—Finely ground grog may be, and often is, used.
Warping, etc.—No warping, cracking, etc., can be tolerated.

FLOOR-TILE CLAY

Floor Tiles Defined.—Floor tiles are polygonal, usually square or hexagonal, tablets used as flooring. The following varieties are recognized:

Face-Tiles: A thin facing of carefully selected and prepared material is backed by cheaper clay of the same air and fire shrinkage.

Tesserae: The whole tile is composed of the same material throughout.

Encaustic Tiles: This term is used rather loosely for two quite different products. The first is a tile which shows a vari-colored pattern as a result of the presence in each tile of a number of carefully arranged masses of clay which burn to different colors. This variety is often called *inlaid tile.* The second type also shows a pattern when laid, but this result is produced by the use of solid-color tiles of various shapes, sizes, and tints. The individual tiles in this latter variety may, evidently, be of either the face-tile or tesserae type. Inlaid tiles are usually face-tiles, but inlaid tesserae have been made.

Face-tiles and tesserae may be white or colored. They are usually vitrified, but vitrification is not possible when red tints are desired.

At the present time practically all floor tiles are made by the dry-press process (see p. 70). Face-tiles are made by sprinkling a layer of the facing material in the bottom of a die, filling the die with backing clay, and then applying pressure to the whole. Inlaid tiles are molded in a die which contains a loose, inner framework of thin brass strips which outline the pattern desired. Clays which burn to the desired colors are sifted into the various areas thus outlined. The brass framework is then removed and the material is pressed. In the case of inlaid face-tiles it is, of course, necessary to use the brass framework only while placing the facing material in the die.

Various kinds of clay are used in making floor tiles. These may, in unusual cases, be used alone as mined, but usually they are mixed with more or less quartz and feldspar. Fine, white, vitrified tiles are often manufactured from high-grade porcelain- or ball-clays, mixed with feldspar and quartz. Fire-clays frequently form the base of buff tiles, while red ones may be made of fairly low-grade material. Burning is carried out in down-draft kilns.

The following properties are essential in clays or mixtures used in making floor tiles:

Texture.—Tile material is always ground; so the texture is immaterial. No pebbles should be present, however, as these wear the grinding apparatus and make it inefficient in its action.

Color Unburned.—Must be white or gray for making white tiles.

Non-permissible Impurities.—Visible impurities must be lacking, except when colored tiles are desired. The impurity must then be limited to that substance which produces the color. No soluble salts can be present.

Cohesion.—Must be high, or the unburned tiles will break readily.

Vitrification.—Should be several cones (the more, the better) above incipient vitrification, since a hard, tough product is essential. Should be at least eight cones below viscosity, if the tiles are vitrified. It is desirable that vitrification should occur at as low a temperature as possible, if the ware is unvitrified. If vitrified, a tough, hard product can rarely be reached below Cone 5.

Color Burned.—Must be pure white for white tiles and of attractive tints for colored ones.

Fire Shrinkage.—Should be less than 8 per cent.

Absorption.—Will be very low in most cases when vitrified. The maximum allowable is about 8 per cent in all instances.

Chemical Character.—As has already been stated, many grades of clay are used, depending upon the kind of tiles to be made.

Washing.—Washing is often applied to at least a portion of the ingredients of some tiles.

Grogging.—Finely ground grog may be used.

Warping, etc.—Absolutely no warping, cracking, blistering, checking, or swelling can be tolerated.

Additional.—Great hardness and shearing and crushing strength are essential in floor tiles. A soft or brittle product is sure to prove unsatisfactory.

WALL-TILE CLAY

Wall Tiles Defined.—Wall tiles are rectangular tablets, glazed on one face, which are used as a wall-covering. They are made of white-burning clay which is molded by the dry-press process (see p. 70), burned to incipient vitrification, glazed, and reburned at a considerably lower temperature. The tiles may be decorated by molding a design in relief upon the surface, printing or painting designs upon them, or using colored glazes.

The only requirements of a wall-tile clay is that it shall be fine-grained or be ground fine, contain no visible impurities, have a high cohesion, burn perfectly white, show no warping, cracking, etc., when green or burned, and conform to the fire shrinkage of the glaze used.

CONDUIT CLAY

Conduits Defined.—Conduits are hollow blocks of various dimensions and sections which have rounded edges and are used as containers for electrical transmission wires underground. They may be divided by longitudinal partitions into several compartments.

Conduits are made in the same way as hollow structural material (see p. 79), but the ends are smoothed or rounded before drying, and salt-glazing is used. The clay used for conduits is identical with that from which hollow structural ware is formed, except that it is essential that it burn dense and hard.

ENAMELED-BRICK CLAYS

Enameled Bricks Defined.—Enameled bricks are commonly pressed—rarely, soft- or stiff-mud—bricks that have one enameled surface. They are usually used in interior work, but are sometimes employed in trimming exteriors. They should be laid with tight, neat joints, and this is facilitated by molding indentations on the unenameled surfaces, or making holes through each brick.

The enamel is either an artificial mixture or a natural slip—usually the former. It may be white or of many attractive tints, and is applied to the green brick in most instances.

The only requirements of a clay that is to be made into enameled bricks are those essential to the process used, and the additional ones that the brick shall have a neat appearance, burn to a buff or white tint, and conform in air and fire shrinkages to the enamel used.

SLIP OR GLAZE CLAY

Slip Defined.—Slip is a clay which melts at a low temperature to a glass or glaze, usually of green or brown color. It is considerably used on pottery.

Slip is applied to the ware by mixing it with water to the consistency of paint, and then using it as a spray or dip.

Texture.—Must be uniformly fine-grained.

Non-permissible Impurities.—No visible impurities, except a stain due to limonite, may be present.

Air Shrinkage.—Should be under 8 per cent.

Cracking Allowable in Air.—None.

Viscosity.—Should be as little as possible above Cone 5.

Color Burned.—Should be attractive.

Fire Shrinkage.—Should not be over 4 per cent.

Chemical Character.—A high percentage of fluxes is always present. These usually amount to from 15 to 30 per cent of the weight of the clay. Sometimes the fusion point is lowered by the addition of artificial fluxes.

Washing.—Washing is often necessary in order that a smooth glaze may be produced.

Grogging.—Grog is never employed.

Warping, etc.—No cracking, blistering, or swelling can be tolerated.

GUMBO OR BALLAST CLAY

Gumbo Defined.—Gumbo is an exceedingly fine clay which is very plastic and has a high cohesion, but which dries slowly, and shrinks and cracks very badly in the process. True gumbo is usually colored black by organic material. When lighter in color, it is called ***hard-pan.***

Railroad ballast is made from gumbo by spreading a thick layer of the wet clay on top of a pile of cord wood, which is then lighted. Enough heat is developed to drive off the moisture and combined water, and to break the mass up into small angular fragments which make splendid ballast.

Any clay which breaks up badly on drying can be used in this way to make road ballast.

PORTLAND-CEMENT CLAY

Portland Cement Defined.—Portland cement is made by burning to incipient vitrification and then grinding very fine a mixture of calcite, kaolin, and silica. When this product is moistened with water, it sets slowly into a mass of stony hardness, due to the slow formation of minute, interlocking crystals. The usual usage is to employ about 75 per cent of pure limestone and 25 per cent of siliceous clay or shale, but occasionally a calcareous clay or shale, called a marl, is found which contains all three ingredients in the correct proportions.

Portland-cement clays must be free from concretions, pebbles, or coarse fragments of any kind. Otherwise, they vary widely in characteristics.

CLAYS USED IN AN UNBURNED CONDITION

Mineral Paint.—Some clays stained with carbonaceous matter or iron or manganese oxides form inexpensive and satisfactory paint for wood when ground and mixed with oil. Ocher, umber, and sienna are names given to some of these, and the natural colors shown are yellows, browns, drabs, and grays. Some paint-clays are used after burning as well as in the raw state. In order to be adapted to such a use, clay must be fine-grained and free from grit, and have a desirable and homogeneous color. The value also depends somewhat upon the amount of oil required to give it the proper consistency.

Paper Clay.—Large quantities of high-grade clay are used by paper-makers as a filler. Such clay must be fine-grained and free from sand, very plastic, and of pure white color. Washing is usually necessary to secure the desired qualities.

Fuller's Earth.—Fuller's earth is a non-plastic clay containing an unusually high percentage of water of crystallization. It is used to remove the grease from (fuller) woolen cloth, to purify oils, and in the manufacture of soaps for removing grease. No study of physical or chemical properties suffices to enable one to decide whether a clay is adapted to any of these uses. Its value can be ascertained only by actual tests under normal working conditions.

Polishing-Powder.—Many polishing-powders have a clay base. For such use a clay must contain a great deal of very finely divided quartz.

Abrasive Material.—The well-known Bath brick, which is employed so extensively for scouring steel utensils, is made out of a very fine-grained, quartzose clay found along the banks of the Parrot River in England. Clay is also used as the cementing or bonding material in emery wheels. The mixture of clay and emery is molded and burned until the clay particles fuse, and this cements the emery grains together. Clay so used must fuse to a tough, hard mass at a low temperature.

Ultramarine Clay.—Very fine-grained white clay, which has usually been washed, is used in the manufacture of ultramarine. Such clay must contain little iron and lime, and no excess of silica.

Adobe.—Adobe is a fine-grained transported clay of considerable plasticity and high tensile strength, which is mixed with straw and used in the manufacture of unburned bricks and plaster. Houses constructed of this material are cool and otherwise satisfactory where the climate is arid.

Food and Candy Adulterant.—Large quantities of very fine-grained, non-sandy clays of the proper color are used, unfortunately, for such purposes as food and candy adulterants.

Medical Plasters.—Clay forms the base of many medicated plasters much used for reducing inflammation, such as Antiphlogistine, Ka-o-tol, and Denver Mud. Such clays are highly aluminous, absolutely non-gritty, plastic, and very fine-grained.

Additional Uses of Clay.—Clay is also used to retard the setting of cements used in place of lime mortar, and in the manufacture of alum.

CHAPTER VI

The Classification of Clays

Almost as many classifications of clays are in use as there are clay-workers. Some are based on the origin of a clay, and others on its fusibility alone; some take into consideration only the physical characteristics and the uses to which the clay is adapted, while others take cognizance of two of these factors.

The following classification according to origin is a combination of those suggested by Ries and Buckley:

I. Residual derived from—
  A. Granitic or gneissoid rocks.
  B. Basic igneous rocks.
  C. Limestone.
  D. Slate or shale.
  E. Sandstone.

II. Transported by—
  A. Gravity assisted by water (near the heads and along the slopes of ravines).
  B. Ice (resulting mainly from the melting of glacial ice, and often stony).
  C. Water.
    a. Marine (in the sea).
    b. Lacustrine (in lakes and swamps).
    c. Streams (flood-plain deposits).
    d. Estuarine (in estuaries).
    e. Chemical deposits.
  D. Wind.

The following classification by Ries, based on the fusibility alone, is in general use:

Highly Refractory or No. 1 Fire-Clays: Fuse above Cone 33.

Refractory or No. 2 Fire-Clays: Fuse between Cones 31 and 33, inclusive.

Semi-refractory Clays: Fuse between Cones 27 and 30, inclusive.

Low Refractory Clays: Fuse between Cones 20 and 26, inclusive.

Non-refractory Clays: Fuse below Cone 20.

The following classification is based upon fusibility and three other physical features, and all the clays described in this report are classified according to this scheme. Clays used unburned are not mentioned in this tabulation:

I. Semi-refractory or Refractory Clays: Fuse at Cone 27 or higher.
  - Vitrifying (V): At least five cones between vitrification and viscosity.
    - White-Burning (W).
      - High Shrinkage (H): Total shrinkage at vitrification 12 per cent or more.
        - (Refractory goods, vitrified floor tile, ball-clay, wall tile, stoneware.)
      - Low Shrinkage (L): Total shrinkage at vitrification less than 12 per cent.
        - (Porcelain, refractory goods, vitrified floor tile, ball-clay, white-ware, yellow or Rockingham ware, wall tile.)
    - Colored-Burning (C).
      - High Shrinkage.
        - (Stoneware, vitrified floor tile.)
      - Low Shrinkage.
        - (Yellow or Rockingham ware, vitrified floor tile.)
  - Non-vitrifying (N): Less than five cones between vitrification and viscosity.
    - White-Burning.
      - High Shrinkage.
        - (Refractory goods, ball-clay, wall tile, non-vitrified floor tile.)
      - Low Shrinkage.
        - (Refractory goods, white-ware, ball-clay, yellow or Rockingham ware, wall tile, non-vitrified wall tile.)
    - Colored-Burning.
      - High Shrinkage.
        - (None-vitrified floor tile.)
      - Low Shrinkage.
        - (Non-vitrified floor tile, yellow or Rockingham ware.)

II. Low Refractory and High Grade Non-refractory Clays: Fuse at Cone 12 or higher.

Vitrifying.

White-Burning.

High Shrinkage.

Strong Cohesion (S).

(Ball-clay, vitrified floor tile, stoneware, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)

Poor or Weak Cohesion (P).

(Stoneware, earthenware, soft-mud brick.)

Low Shrinkage.

Strong Cohesion.

(Porcelain, white-ware, ball-clay, vitrified roofing-tile, terra-cotta, hollow structural material, conduit, yellow or Rockingham ware, vitrified floor tile, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

(Porcelain, white-ware, vitrified roofing-tile, yellow or Rockingham ware, earthenware, soft-mud brick.)

Colored-Burning.

High Shrinkage.

Strong Cohesion.

(Stoneware, vitrified floor tile, earthenware; flashed or fresco, pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

(Stoneware, earthenware, flashed and soft-mud brick.)

Low Shrinkage.

Strong Cohesion.

(Sewer pipe, vitrified roofing-tile, terra-cotta, hollow structural material, conduit, yellow or Rockingham ware, vitrified floor tile, earthenware, drain tile; flashed and fresco, pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

(Vitrified roofing-tile, yellow or Rockingham ware, earthenware, flashed and soft-mud brick.)

Non-vitrifying.
- White-Burning.
  - High Shrinkage.
    - Strong Cohesion.
      - (Ball-clay, non-vitrified floor tile, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)
    - Poor Cohesion.
      - (Earthenware, soft-mud brick.)
  - Low Shrinkage.
    - Strong Cohesion.
      - (White-ware, ball-clay, non-vitrified roofing-tile, terra-cotta, hollow structural material, conduit, yellow or Rockingham ware, non-vitrified floor tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)
    - Poor Cohesion.
      - (White-ware, non-vitrified roofing-tile, yellow or Rockingham ware, earthenware, soft-mud brick.)
- Colored-Burning.
  - High Shrinkage.
    - Strong Cohesion.
      - (Non-vitrified floor tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)
    - Poor Cohesion.
      - (Earthenware, soft-mud brick.)
  - Low Shrinkage.
    - Strong Cohesion.
      - (Non-vitrified roofing-tile, terra-cotta, hollow structural material, conduit, yellow or Rockingham ware, non-vitrified floor tile, earthenware, drain tile; pressed, enameled, stiff-mud, and soft-mud brick.)
    - Poor Cohesion.
      - (Non-vitrified roofing-tile, yellow or Rockingham ware, earthenware, soft-mud brick.)

III. Low-Grade Non-refractory: Fuse under Cone 12.

Vitrifying.

White-Burning.

High Shrinkage.

Strong Cohesion.

(Vitrified floor tile, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

Low Shrinkage.

Strong Cohesion.

(Vitrified roofing-tile, terra-cotta, hollow structural material, conduit, vitrified floor tile, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

(Vitrified roofing-tile, earthenware, soft-mud brick.)

Colored-Burning.

High Shrinkage.

Strong Cohesion.

(Vitrified brick, vitrified floor tile, earthenware; flashed and fresco, pressed, enameled, stiff-mud, and soft-mud brick; ballast.)

Poor Cohesion.

(Vitrified brick, vitrified floor tile, earthenware, flashed and soft-mud brick; ballast.)

Low Shrinkage.

Strong Cohesion.

(Vitrified brick, sewer pipe, vitrified roofing-tile, terra-cotta, hollow structural material, conduit, vitrified floor tile, earthenware, drain tile; flashed and fresco, pressed, enameled, stiff-mud, and soft-mud brick.)

Poor Cohesion.

(Vitrified brick, vitrified roofing-tile, earthenware; flashed and soft-mud brick.)

Non-vitrifying.
White-Burning.
High Shrinkage.
Poor Cohesion.
(Non-vitrified floor tile, wall tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick.)
Poor Cohesion.
(Earthenware, soft-mud brick.)
Low Shrinkage.
Strong Cohesion.
(Non-vitrified roofing-tile, terra-cotta, hollow structural material, conduit, non-vitrified floor tile, wall tile, earthenware, slip; flashed and fresco, pressed, enameled, stiff-mud, and soft-mud brick.)
Poor Cohesion.
(Non-vitrified roofing-tile, earthenware, slip, soft-mud brick.)
Colored-Burning.
High Shrinkage.
Strong Cohesion.
(Non-vitrified floor tile, earthenware; pressed, enameled, stiff-mud, and soft-mud brick; ballast.)
Poor Cohesion.
(Earthenware, soft-mud brick, ballast.)
Low Shrinkage.
Strong Cohesion.
(Non-vitrified roofing-tile, terra-cotta, hollow structural material, conduit, non-vitrified floor tile, earthenware, slip, drain tile; pressed, enameled, stiff-mud, and soft-mud brick.)
Poor Cohesion.
(Non-vitrified roofing-tile, earthenware, slip, soft-mud brick.)

Precautions to Be Observed in Using the Preceding Classification—

1. It should not be assumed that all the products mentioned under the word "vitrifying" are necessarily vitrified. Some may be, but others will not be, vitrified. It is perfectly possible

to make a non-vitrified object out of a clay that will vitrify nicely, but this usually entails an economic waste. The same principle applies throughout the table.

2. It is not necessarily true that any refractory, vitrifying, white-burning clay with a low shrinkage is a ball-clay. The plasticity may be poor, and it may be deficient in other ways. Neither is it true that all ball-clay is refractory, vitrifying, white-burning, and has a low shrinkage. Ball-clay is mentioned in several places on the table. The same thing is true of other kinds of clay.

3. It should be remembered that the table is so made out as to apply only to the unmodified clay as mined. It is quite possible that, by washing, grogging, or mixing it with other material, a clay may be so changed as to be useful for purposes for which it is decidedly deficient as mined.

Manner of Using the Classification—

To find for what purposes a clay may be used, the following procedure should be followed:

1. Determine the refractoriness of the clay; i. e., whether it falls under heading I, II, or III of the classification.

2. Note whether it will vitrify; i. e., whether there are at least five cones between vitrification and viscosity, or not.

3. Observe whether it is white or colored when burned.

4. See whether the total shrinkage is high or low—above or below 12 per cent at vitrification.

5. Note whether the cohesion is strong or weak.

It will be found convenient to use the letters suggested on the table for these various properties. Thus, the clay described in Part III as No. 128 is a low-grade non-refractory (III), non-vitrifying (N), white-burning (W) clay with low shrinkage (L) and weak cohesion (P). It can, then, be briefly described by using these initials and the numeral—IIINWLP. Now, the table shows that clays of this type may be used, other conditions being favorable, for non-vitrified roofing-tile, earthenware, slip, and soft-mud bricks. It is, therefore, necessary to investigate the characteristics essential to each of these, as set forth in the last chapter. It will prove a simple matter to ascertain that the tensile strength of the unburned clay is so low as to cause a very great loss from breakage of any product; and the absorption is also too high for most purposes. There are, then, no products which it appears possible to make from this clay.

In case a clay proves to be of type IIVCLS, yet has a total shrinkage of 10 or 11 per cent, it should be remembered that grogging will undoubtedly reduce the shrinkage considerably.

It should never be assumed that a clay is adapted to the manufacture of any given product or products until it has been ascertained that it possesses all the features essential to that product or products, or that it can be so modified as to possess all such features. If it differs but slightly in one or two particulars from the ideal, it may still be possible to use it by exercising special care in the molding and burning processes. Experience is, however, needed to teach one how much latitude of this kind is permissible.

PART II

The Geology and Topography of the Clay-Bearing Formations Examined

CHAPTER I

The Area South of Colorado Springs and East of the Front Range

GENERAL GEOLOGY OF THE AREA

The clay- and shale-bearing formations of southeastern Colorado represent more or less consolidated sediments of many different kinds that settled in old sea- or lake-beds—both salt and fresh; outwash deposits carried by rivers, rain wash, and gravity from the higher land to the west; and some wind deposits. They were originally laid down in nearly horizontal layers, sometimes of great thickness, and still retain that position over great areas. In some places, however, they have been bent or folded upward, so that individual beds are inclined at an angle with the horizontal. This is especially true where they border the old crystalline rocks which are usually to the west of them. There they may be vertical or even overturned. Subsequent stream and rain erosion has removed varying, but often very great, thicknesses of these beds over the entire area, so that rocks of quite different nature and age are often exposed in neighboring localities, even when the layers are horizontal.

Not only were these beds deposited at different times, but they differ more or less in kind or color from each other; and certain names have been given to them and are in general use. These are given in the following table, in which is also indicated the generally accepted geological age, the oldest beds being those at the bottom of the table:

Period and System	Epoch and Series	Formation	
Pliocene (Tertiary)		Nussbaum	
Eocene (Tertiary)	Shoshone	Arapahoe or	Cuchara Poison Canyon
		Raton (in part)	
Cretaceous		Laramie	
	Montana	Trinidad	
		Pierre	
	Colorado	Apishapa Timpas	or Niobrara
		Carlile Greenhorn Graneros	or Benton
		Dakota	
Comanchean		Purgatory	
Jurassic		Morrison	
Permian-Triassic (?)	Upper Wyoming	Lykins	
		Lyons	
Pennsylvanian	Lower Wyoming	Fountain	

Recent alluvial gravels, sands, and clays, and wind deposits of sand or loess, may overlie, any of these.

The exact age of the Fountain and Nussbaum is in doubt, but is probably as given.

The outcrops are usually hidden below a covering or mantle of soil or wash, sometimes many feet thick. Then, exposures of the beds should be sought in gullies, canons, near hill-tops, or in artificial excavations.

The clays and shales examined are, then, not "dykes" or "veins," as so often styled by the uninformed, but all constitute integral portions of these sedimentary formations. All of the latter do not contain workable deposits of clay or shale, but all are briefly described in this chapter, since it is often difficult to locate a given horizon unless the nature of underlying and overlying beds is understood. The data for the descriptions are taken principally from the publications of the United States Geological Survey, supplemented by personal observations in the field.

In some places molten rocks have worked up into or through fissures, or have flowed out on the surface. These form dykes and sheets of igneous rock when hardened. Weathering may ultimately reduce these to residual clays, but none were noted in the region under consideration.

In a few localities the rocks have cracked, and one side has slipped on the other, causing a "fault." In this way beds or hogbacks may be displaced considerable distances from their normal position.

It should be remembered that the following descriptions of the various formations are of a general nature, applicable to wide areas, and that local variations may be found in all of them. These, however, will not usually be of much magnitude.

RELATION OF GEOLOGICAL STRUCTURE TO TOPOGRAPHY

The topography depends to a considerable extent upon the structure and hardness of the underlying beds. Where these are horizontal and contain some thick, hard, resistant bed or beds, mesas or buttes are apt to develop. If, however, the hard beds are thin or the different layers do not differ very materially in hardness, bad land topography will be shown, provided the relief is great and aridity prevails. Where the relief is lower, the rainfall normal, or the beds are practically of equal softness, the surface will be rolling or gently undulating, or flat plains will result.

If the beds are inclined a little from the horizontal, a stepped topography will exist in which the harder beds outcrop as prominent cliffs or escarpments, all of which face in the same general direction.

Where the layers are upturned to a considerable extent and are of unequal hardness, relatively rapid erosion of the underlying soft beds will undermine the harder ones and leave them projecting as long, narrow, sharp-crested ridges, with one slope steeper than the other. These are called hogbacks. If several notably hard beds outcrop in an area, a series of parallel hogbacks will develop, all of which will have their gentle slopes on one side—the eastern, say—and their steep slopes on the other—the western, in this instance. The hardest or thickest beds will then form the highest hogbacks.

If the beds are vertical and of unequal hardness, hogbacks may still develop, but then the sides may slope with equal or unequal steepness, and the gentle slopes may or may not be on the same sides.

Dykes and sheets of igneous rocks are usually very hard, and, where parallel to the sedimentary beds, they may cause the same topographic features as hard sediments. When the igneous layers are not parallel to the sediments, hogbacks of igneous rocks may cross mesas or hogbacks formed of sediments; or sedimentary hogbacks may run beneath the igneous capping of mesas.

Faults do not usually cause topographic peculiarities other than the sudden truncation of outcrops or hogbacks; but they are, in general, lines of weakness, and may cause the formation of long, straight valleys or furrow-like depressions.

One familiar with the principles above outlined may often determine the structure of underlying beds, even when they are covered with gravel and soil.

Fountain Formation

Character of the Rocks.—The Fountain formation has, together with some underlying beds, been called the Badito formation around Walsenburg. There it consists of about 100 feet of pebble beds cemented into a solid rock called a "conglomerate." The color is reddish brown. On top of this lies 100 feet of brick-red sandstone—cemented sand, which may possibly be the equivalent of the Lyons sandstone mentioned elsewhere.

Farther north, southwest of Pueblo, the thickness expands to 2,100 feet, and the material is mostly coarse-grained, deep-red, feldspathic sandstones. Conglomerates are common in the lower part, however, while red and chocolate-brown shales are plentiful near the top. The shales may be, in part at least, the equivalent of the Lykins formation described elsewhere.

Near Canon City, still farther north, the maximum thickness of the Fountain beds is 1,000 feet, and red sandstones and conglomerates, with a few light-colored beds, prevail.

In areas between the above, rocks of an intermediate nature may be expected.

Topography.—The formation usually outcrops in a fairly broad valley between the Dakota hogback (see p. 107) and the older rocks—either Cambrian-Ordovician quartzites, limestones, and sandstones, or Pre-Cambrian crystalline rocks.

Clays and Shales.—The Fountain shales are so red that their iron content is believed to be too high to make them useful for anything except, possibly, slip. Also, they outcrop in sparsely settled regions and are rarely well exposed; so no attempt has been made to use them. Indeed, they gave so little promise, as compared with the higher, younger formations, that they were not sampled.

Lyons and Lykins Formations

In the region under discussion the Lyons and Lykins formations are known to outcrop only in an area about half-way between Colorado Springs and Florence; but the Lykins, at least, is recognizable in the canon of the Purgatory River and in Two Buttes in Prowers and Baca Counties.

Because of their limited distribution and the meagerness of the data concerning their exact nature in these areas, their general discussion is reserved until the next chapter (see p. 124). Slight modifications of the descriptions there given will doubtless make them applicable to the southern area.

Morrison Formation

Character of the Rocks.—Near the southern boundary of the state, the Morrison formation has a total thickness of about 275 feet. It there shows 60 feet of soft, white sandstone underlain by a conglomerate at the base. Above follow hard, shaly beds of pink and green color; and on these lie varicolored, marly shales and clays, containing thin layers of hard, fine-grained limestone in the lower part, and some sandstone and a bed or two of conglomerate in the upper portion. In the Cuchara-Huerfano canon only the upper beds are present.

Farther north the marls of the upper portion lose their shaly nature, and are so hard as to constitute an argillite, which is said to have a "blocky" structure. Near the top is found 10-75 feet of gray, brown-spotted sandstone, which is doubless the same as that in which saurian remains are found farther north. Above this lies 40 feet of red, drab, and green argillite and shale.

Southwest of Pueblo the maximum thickness is only 70 feet, and the beds exposed are chiefly red shale, with some thin layers of red sandstone.

North of Canon City the total thickness of the formation is 350 feet. It consists of greenish, pinkish, and gray shale and marl, with a thin basal bed of limestone overlain by sandstone.

Limestone also occurs at numerous horizons in the upper portion. About 100 feet from the top is the saurian or spotted sandstone that has yielded the remains of numerous gigantic dinosaurs. Locally there are several beds of gray and white gypsum near the base, although beds of this mineral are uncommon in the Morrison.

Topography.—The Morrison beds usually outcrop along the side of the Purgatory-Dakota hogback (see p. 107) facing the mountains, or else, where the beds are not much upturned, below the Purgatory-Dakota escarpment or cliff, especially near the bottoms of canons. The outcrops are rarely well exposed.

Clays and Shales.—It has been generally believed that the Morrison clays and shales were too marly—contained too much calcium carbonate—to be useful; but the tests made show that this is not always—or even usually—the case in this area. Nevertheless, in the majority of cases, their use is limited to the manufacture of ordinary bricks, that are apt to be soft and of buff or brown colors. Most of the samples fused at Cone 5, or lower; but several did not become viscous until Cone 8, and one resisted fusion until Cone 10 had been reached. In only three instances were the points of vitrification and viscosity so far separated as to permit the manufacture of vitrified bricks which might be used in pavements; and the quality of these is very doubtful.

The results of the tests indicate that one seeking a low-grade clay that is to be burned only to incipient vitrification should not ignore this horizon.

Purgatory Formation

Character of the Rocks.—Until 1905 it was believed that all of the beds previously called Dakota were of Cretaceous age, but it is now known that those rocks below, and including, the lowest bed of refractory clay and shale, about two-thirds of the whole, were laid down during the Comanchean period. These have been named the Purgatory (or Purgatoire) formation.

In the extreme south the total thickness is 230 to 260 feet, and the rocks are mostly yellowish or brownish, coarse-grained, rather porous sandstones and fine-grained conglomerates, separated by thin bands of shale. Farther north, in the canon of the Purgatory River, the thickness is somewhat less, and the lower two-thirds is almost entirely white sandstone, while the remainder is largely shale containing thin beds of sandstone. A bed of gray to black—rarely white—clay or shale, of various thicknesses up to 20 feet, usually forms the top, and this is sometimes so hardened as to form an argillite.

East of Pueblo the formation is missing, but it is well developed to the southwest and northwest. There it consists of 200 to 500 feet of white, light-buff, or gray sandstone, with a few shale partings, a conglomerate at the base, and the persistent shale or clay zone at the top. The greatest thickness is near Beulah, where the rock is almost entirely sandstone, with conglomerates at, and near, the base.

Topography.—The general hardness of the Purgatory beds makes them resistant to erosion to a notable degree, and the outcrops are, therefore, well exposed and prominent. The largest hogback bordering the mountains is composed principally of these rocks and the overlying Dakota beds. Where the layers are more nearly horizontal, the Purgatory-Dakota sandstones form prominent cliffs or escarpments. Above these is frequently found a level or slightly inclined, smooth floor, sparsely covered with vegetation; and the escarpments themselves are often divided into two portions by a shelf or bench at the persistent shaly zone which forms the top of the Purgatory beds.

Clays and Shales.—The uppermost bed or beds of the Purgatory formation, consisting of shale or clay, or both, is certainly the most uniformly valuable in the area. Part or all of this zone is often white-burning and of a decidedly refractory nature—true "fire-clay," in fact. Even where this is not the case it is apt to possess qualities that give it value. It is always worth testing, as it and the overlying Dakota formation contain the only ball-clay, as well as refractory clay, known to exist in this area. Often, however, the material at this horizon is deficient in plasticity and tensile strength, is not cohesive, and must be washed or mixed with other clays possessing the properties it lacks before it is adapted to the manufacture of high-grade products other than refractory ware.

Beds of clay or shale below the uppermost zone are usually too thin to work profitably; so they were rarely sampled. They are of various characters, but several tested have value, provided the beds be thick enough to permit profitable working and are favorably situated.

Dakota Formation

Character of the Rocks.—According to the classification here used, the name "Dakota" is applied only to those beds above the clay or shale zone about two-thirds of the way up from the base of what was called the Dakota formation previous to 1905, and which is still often thus designated when no subdivision is made.

In the southernmost districts the Dakota as thus defined consists of about 125 feet of compact, grayish-white, fine-grained sandstone, containing several beds of light- to dark-colored shale. The individual sandstone beds are not so thick as in the Purgatory, and the shale is somewhat more plentiful.

Farther north, half-way between the southern edge of the state and Pueblo, the formation has a maximum thickness of only 85 feet, the shales are less plentiful, and the sandstone is in thick beds. The sandstone is still light gray in color on a fresh surface, but it weathers yellow or brown, and is often covered with a thin, dark-brown film called "desert varnish," on which pictographs have been cut by Indians. The shale bands are usually thin and black.

Southwest and northwest of Pueblo the rocks are similar to the above-described occurrence, but the lower beds are more or less conglomeritic, and some of the sandstone has a pinkish tint.

Southeast of Pueblo a portion of the unweathered sandstone has a buff tint.

In general, the Dakota sandstone is finer-grained and more compact than the Purgatory, and is also differentiated therefrom by the fact that it is never conglomeritic. Except in the extreme south, it is also of a darker color, especially when weathered. The thickness of the whole formation or of any component bed varies considerably from point to point, and it is rare that any one layer can be identified over a considerable area.

Topography.—The Purgatory and Dakota formations form what is practically a petrologic unit; and what has been said of the topography resulting from outcroppings of the former applies equally to the latter (see p. 107). Where the Dakota is horizontal and outcrops on the surface, it sometimes weathers into knob- or turret-like forms.

Clays and Shales.—Clays or shales do not usually form any considerable part of the Dakota, but they exist in most localities at one or more horizons in beds from a foot or 2 up to 10 feet thick. These are practically always gray or black in color, and resemble closely the uppermost zone of the Purgatory (see p. 106). They are not quite so apt to be very refractory as the material in that zone, however, but make up for this in greater tensile strength and plasticity, and stronger cohesion.

The beds are not persistent for great distances, and their character varies considerably from point to point, but, as a whole, they probably have wider industrial application than those found in any other formation. Probably every known clay product, except possibly roofing-tile, could be made from Dakota clay or shale found in this area.

The tests showed that 36 per cent of the samples collected were true fire-clays, fusing at Cone 30 or above; 40 per cent were adapted as mined to the manufacture of products other than brick and earthenware; 13 per cent were good brick or earthenware clays; and only 11 per cent were practically worthless. In a number of instances, however, the beds are too thin to make profitable exploitation possible.

Graneros Formation

Character of the Rocks.—Early writers on Colorado geology included the three formations now called Graneros, Greenhorn, and Carlile under the name "Benton." They are, however, easily differentiated in the area under discussion, and the threefold subdivision is now generally recognized; so it is used in this chapter.

The Graneros formation consists essentially of gray to black clay-shale, which is somewhat darker in the middle than at the top or bottom, but which is very uniform in texture and general appearance throughout, and over wide areas. Between the underlying Dakota sandstone and the Graneros shale there is usually a transitional zone of alternating thin beds or laminae of sandstone and shale, but in some cases the change from one to the other is quite sudden.

In the extreme south large calcareous concretions are fairly common in the upper half; and a hard, concretionary limestone a foot or 2 thick lies about 30 feet above the base. This limestone weathers into cobblestone-like pieces of bright yellow or orange tint. The total thickness of the formation is 200-210 feet.

A little farther north the lower half sometimes contains thin layers of white, plastic clay associated with thin limestone beds; neither is persistent for any considerable distance. The orange-weathering sandstone is there only about a foot thick, and the underlying beds are 35-45 feet thicker than farther south.

A few feet above this limestone is a 6-inch bed of hard sandstone. About 45 feet from the top occurs a 1-foot bed of platy, fossiliferous, sandy limestone.

Southwest, northwest, and east of Pueblo the thickness is slightly greater, and the fossiliferous bed near the top is as much as 2 feet thick. It is there more nearly a calcareous sandstone than a limestone. Non-persistent beds of oyster shells occur in the lower portion of the formation.

Near Canon City the rocks are very similar to those already described, but they reach thickness of 250 feet and 350 feet south and north, respectively, of that city.

Topography.—The shales weather easily and rarely form prominent topographic features, but the highly colored, concretionary limestone bed and the thin sandstone above form a persistent and noticeable bench in some localities south of Pueblo. As a usual thing, Graneros outcrops are to be sought on the smooth slope below the hard Greenhorn limestone; but, when the upturning has been considerable, the lower beds form a part of that side of the great Purgatory-Dakota hogback which faces away from the mountains, and also extend below the little valley between that hogback and the low Greenhorn ridge mentioned later (see p. 111). The shales are very non-fertile and are almost wholly free from vegetation, except where debris from other beds has washed over them.

Clays and Shales.—It is very difficult to speak in general terms of the economic possibilities of Benton shales, for the reason that their properties change so from place to place, and are even unlike at different horizons in the same locality. Their varied nature seems to be in no way connected with their appearance, since beds that appear to be identical often prove to possess quite different qualities. An actual test is necessary before it is possible to say anything concerning the value of material from any given point. It can be said, however, that the Benton is very apt to yield brick material of unusually high grade. In fact, only about 10 per cent of the samples collected are unsuited for such use. The color of the unburned product is apt to be some shade of pink, and is often light and very attractive; but a few white-, buff-, or red-burning shales were also found.

The test pieces usually became viscous at a comparatively low cone (85 per cent at Cone 8, or below, but none below Cone 1), and only three samples resisted fusion to Cone 12. They rarely vitrified well, and but 20 per cent of the samples possessed qualities indicating the possibility of utilization as paving-bricks. None of these appeared very promising. One-fourth of all proved to be adapted to the manufacture of other products than brick or earthenware. It is interesting to note that, contrary to what might be expected, the bands of white, plastic clay in the lower part of the formation appear to have little or no value and detract from, rather than augment, the value of samples containing them. This is due to their very great shrinkage, and the probable presence of a high percentage of fluxes.

Greenhorn Formation

Character of the Rocks.—The Greenhorn formation usually comprises 30-50 feet of fine-grained, compact, shaly limestone, with included bands of shaly material. It often contains fossils of bivalve shells, and, less frequently, coiled ammonite shells. The formation is usually transitional into the Graneros below and the Carlile above.

Near the southern boundary of the area the limestone beds are gray and less than a foot thick, while the shales are much thinner; but farther north, and around Pueblo, the shales are thicker than the limestones and are sometimes white. They never reach a thickness of over 18 inches, however.

East of Pueblo the limestone is dove-colored, and the shales are a darker gray and somewhat sandy.

North of Canon City the thickness increases to 60 feet, due to the thickening and the increased number of the shale beds; while in Webster Park only 10 feet, mostly limestone, is present.

In most places the limestone breaks readily into very thin plates or slabs, which are scattered abundantly over the outcrops; but around the town of Graneros it splits into slender, four-sided, somewhat wedge-shaped fragments.

Topography.—The Greenhorn outcrop is usually narrow but prominent, but it may widen to as much as a mile when the beds are horizontal. Then, however, it ordinarily forms an irregular, pinon-fringed bench or terrace on the slope below a Timpas (see p. 113) capped mesa ore on the flat above a Purgatory-Dakota escarpment. Sometimes it itself caps a low, pinon-covered mesa.

When the beds are upturned, they develop into a low, pinon-covered ridge or hogback not far from the base of the great Purgatory-Dakota hogback, on the side away from the mountains.

Clays and Shales.—No shale bed in the Greenhorn is thick enough to work profitably, and most are rather calcareous; so none were sampled.

Carlile Formation

Character of the Rocks.—The Carlile formation consists of 170-230 feet of dark-gray clay-shales, lighter at the top and bottom than elsewhere, and often black somewhat below the middle. At the top lies 6 inches to 4 feet of dark-colored, often purplish, sometimes bituminous limestone, made up largely of fragments of fossils, but which often contains fine, large, coiled ammonite shells in the southern and central parts of the area. Another distinguishing feature is the frequent presence of small, dark-colored pebbles. Just below this limestone occurs 3 to 30 feet of soft, shaly sandstone of yellow, yellowish-gray, or brownish color. It is thickest in the western part of the area and thinnest east of Pueblo.

In the east-central part of the area the upper third of the formation is mostly sandy shale, containing thin lenses of calcareous sandstone in which are found coiled ammonite shells.

Spheroidal or ovoid, calcareous concretions from 6 inches to 6 feet in diameter are common everywhere in the middle and upper beds. They are usually full of calcite veinlets, which run in all directions and give the appearance of a turtle's shell. They are called *septaria*.

Topography.—The Carlile formation outcrops where the beds are horizontal on the steep, barren slopes below Timpas (see p. 113) escarpments, or on flats above Greenhorn (see p. 111) outcrops. When the layers are upturned, they lie in the narrow valley between the Greenhorn ridge or hogback and the greater Timpas hogback.

Clays and Shales.—The shales of the Carlile are similar in properties to those of the Graneros, but are somewhat inferior to the latter in several ways. They fuse at about the same temperatures, but a considerably larger proportion (35 per cent) burn red instead of pink. While 15 per cent of the samples tested seemed worthless, the rest would make good, often very attractive, bricks; and the Carlile is distinctly a brick-making formation, since less than 10 per cent of the beds tested can be used to make other products. Fully 75 per cent of the samples have such low tensile strengths when unburned as to be unadapted to the economical manufacture of earthenware or stiff-mud bricks. The vitrifying properties are good, since 30 per cent may make paving material. Several such samples seemed worthy of serious consideration.

Timpas Formation

Character of the Rocks.—Early geologists included what are here designated the Timpas and Apishapa formations under the name "Niobrara." Except for the basal limestone in the former, the two subdivisions are not very different, but they are now usually separated as is done in this chapter.

The Timpas formation comprises 175-200 feet of limestone and marly shale of comparatively uniform nature throughout the area. At the base occurs about 50 feet of compact, fine-grained, white or light-gray limestone, which is apt to appear creamy when weathered, and often has a more or less chalky appearance on the surface. It occurs in beds of from less than a foot up to 3 feet thick, separated by very thin, marly partings. The individual beds are thickest in the center of the area. It weathers into thin, curved plates a few inches long; and this, as well as the lighter color, will distinguish it from the Greenhorn limestone (see p. 111). Large, concentrically ridged bivalve shells are rather common in it, as are also small spherical or cylindrical nodules of iron sulphide, which are altered to a brown oxide of iron on the surface.

Above the basal limestone lie hard to soft marly shales. Their color is usually light, but varies in different localities from almost white to lead-gray. Thin limestone bands are present at several horizons, especially near the top, where they sometimes reach a thickness of as much as 3 feet. Fish scales and bivalve shells are fairly common in the shales.

Topography.—The Timpas limestone outcrops in topographic features that are almost as prominent as those formed by the Purgatory-Dakota sandstone at a lower horizon. Prominent bluffs and mesas of great size are capped with the limestone; and, when the layers are upturned, they develop into a hogback parallel to the Purgatory-Dakota hogback, but of considerably smaller size. The marly shales either underlie undulating flats above the horizontal limestone outcrops, or form part of the valley on the side of the limestone hogback farthest from the mountains.

Clays and Shales.—The Timpas beds are too calcareous to be of interest to ceramists, and therefore were not sampled.

Apishapa Formation

Character of the Rocks.—The Apishapa formation may be described, in general terms, as comprising marly shales at the top and bottom, sandy shales which are also calcareous in the center, and thin limestone beds at and near the top; but the color, thickness, and other details vary considerably in different localities.

At the base is usually found 50 feet or less of bluish-gray to dark-gray, marly shale, overlain by 100 feet or less of soft, "rotten" calcareous shale that often has a darker color and which shows a paper-like lamination. Then follows 300 feet or less of calcareous shale, which is decidedly sandy and frequently contains hard, flag-like layers. It is more or less bituminous, and is apt to be coarsest in the upper part. The color is some tint of gray when fresh, and yellow to gray when weathered. The greatest thickness is found around Pueblo. At the top is 100 feet or less of material similar to that at the base, which contains two or more thin beds of limestone, one of which constitutes the top of the formation. This limestone is grayish white in the southern part of the area, but is cream-colored or yellow farther north. Near the lower part of the upper zone is often found a layer of flat, lens-shaped, calcareous concretions, some of which have a diameter of as much as 20 feet. They are usually full of light-blue barite veinlets.

Fish scales up to 1 inch in diameter are found throughout the formation, but are commonest in the central, sandy portion. There, also, patient search will sometimes reveal the tracks of a crustacean in the form of a double row of short, straight lines, those in one row being inclined to those in the other.

Topography.—The Apishapa beds are rarely well exposed, but occur beneath extensive undulating plains. The limestones at the top occasionally make low ridges or benches, however; and, where the concretionary zone near the top is exposed on the surface, the larger concretions may protect the softer shales below from erosion, and give rise to low, rounded knolls or hills.

Clays and Shales.—The Apishapa beds are too calcareous to be of interest to ceramists, and therefore were not sampled.

Pierre Formation

Character of the Rocks.—The Pierre formation is made up almost entirely of shale. It is 1,250 feet thick in the extreme southeast, 2,300 feet east of Pueblo, and over 4,000 feet around

Florence. In the southern part of the area the base and top are composed of soft, gray to yellowish-gray clay-shales, which weather greenish-gray and are sandy toward the top of the formation. The central portion is much darker—almost black in places—and is apt to yield paper-like flakes when weathered. Near the middle are numerous bands of concretions composed of carbonates of lime and iron, some of which are as much as 3 feet in diameter. They crumble into small, reddish pieces when exposed to the air, and this gives the outcrop a rusty appearance.

Around Pueblo and Florence the nature of the rocks is similar to those just described, but the lowest zone is 400-500 feet thick, and is apt to be bluish gray, except right at the base, where it may be yellowish in color. The rusty zone is there about 600 feet thick, and is overlain by 100-200 feet of pale-gray shale, containing numerous fossils called baculites. These have the form of a flattened, slightly tapering cylinder from a fraction of an inch up to 2 inches in diameter. Above this zone lies 500-1,000 or more feet of light-gray shale, containing numerous layers of flattened concretions that are very fossiliferous; and, also, many cylindrical, calcareous, fossiliferous, light-gray concretions, 5-30 feet in diameter and 50 or more feet long. They lie with their greatest dimensions perpendicular to the beds, and are called tepee cores. Above this tepee zone the shales are darker in color, contain fewer fossils and concretions, and become increasingly sandy toward the top.

North of Canon City there are only a few hundred feet of Pierre beds. They are there rather sandy, and gray to rusty brown or red in color.

Topography.—The Pierre usually underlies broad, flat or undulating areas, but the beds also outcrop on the steep slopes beneath Trinidad escarpments or mesas capped with lava flows or Nussbaum (see p. 119) material. Where the tepee cores outcrop they give rise to small, steep-sided, conical hills.

Clays and Shales.—The Pierre is essentially a formation of low-grade brick shales. Almost all the shales will fuse below Cone 5, and over 60 per cent will burn red; while, of the remainder, about 90 per cent will burn pink. Over 40 per cent of the samples tested, however, are so deficient in tensile strength that they are unadapted to the manufacture of stiff-mud brick or earthenware. Twenty per cent of all the beds tested are probably worthless, and the same proportion might be used in making other products besides brick. The worthless beds sampled all lie near the top of the formation, except one case where a lower shale has been metamorphosed or changed by the intrusion of a mass of igneous rock. Fifteen per cent of the samples vitrified fairly well, but none gave much reason to suppose that a good paving-brick could be made from them.

While much of the formation will make good red brick, the product is not usually so attractive as that obtained from the Graneros and Carlile shales, and the absorption is apt to be rather high.

Trinidad Formation

Character of the Rocks.—The Trinidad formation is also known as the Vermejo formation. In the southern half of the area it is composed mostly of sandstone, but is divisible into two portions of about equal thickness, the whole amounting to 150-225 feet. The lower half consists of fine-grained, dark-gray sandstone in layers which are usually only a few inches thick, separated by thin shale partings; while the upper portion is made up of light-gray, massive sandstone that often has a greenish or yellowish tint. The top is sometimes represented by a few feet of brown sandstone. Near Trinidad there is a prominent, coarse-grained sandstone several feet thick near the base of the lower division; and the massive, light-colored sandstone is overlain by thin shale and sandstone beds. Imperfect baculite fossils are sometimes found in the lower beds, and pitted, cylindrical, branching casts of a sea-weed, called a fucoid, are everywhere plentiful in the upper sandstone.

South of Florence the Trinidad formation is supposed to be represented by a yellow to greenish sandstone 50-100 feet thick. Although lithologically similar to the Trinidad sandstone found farther south, it does not contain the fucoid fossils there so plentiful. As these are found in a sandstone bed in the so-called Laramie above, it is possible that the Trinidad of the Florence district is somewhat older than the horizon represented by the same name farther south; and it may not even be youngest Pierre in age. Some have used the term "Fox Hills" for the so-called Trinidad of this district, but the rocks are so different in many ways from the Fox Hills of the northern part of the state, and so similar to the Trinidad of the southern portion, that the latter name is preferable. Also, if the lower Raton is equivalent to the Mesa Verde (see below), the Trinidad is older than the Fox Hills.

Topography.—The Trinidad formation outcrops as a prominent escarpment or bench below the coal-bearing beds in nearly all places.

Clays and Shales.—No workable clays or shales are known to occur in the Trinidad; so this horizon was not sampled.

Raton and Laramie Formations

Character of the Rocks.—The formation now called the Raton in southern Colorado and New Mexico was previously known as the Laramie—a term long applied to the coal-bearing beds farther north. It is now generally believed, however, that none of the Raton beds are of Laramie age, some being older and others younger. The former are correlated with the Mesa Verde Cretaceous beds of western Colorado, which are of Pierre age; and the latter are thought to be Eocene. The two divisions are everywhere separated by an unconformity or erosion surface which represents a time when the lower beds were above water and subject to erosion or degradation; and the lowest bed of the upper division is a conglomerate or conglomeritic sandstone.

South of Florence and Canon City the coal-bearing rocks appear to be of different age from those farther south, and have been correlated with the Laramie of the northern coal fields. It seems probable, however, that the lower coal-measures of the Florence-Canon City field are older than the lowest Laramie to the north. They may even include strata of Trinidad and upper Pierre age.

As the rocks of the coal-measures are rather similar throughout the area discussed in this chapter, no attempt to differentiate them was made in the field, and they are here all described together.

The total thickness of the Raton formation south of Trinidad is 2,500 feet, but it thins to 800 feet east of that city and to 1,000 feet north of Walsenburg. In the southern part of the area the lower 200 feet is made up of thin beds of greenish-gray, fine-grained sandstone, separated from each other by thinner beds of sandy shale of drab to dark-gray color. Occasional layers of coarser, light-gray sandstone and gray to black clay-shale, containing coal beds, also occur at this horizon. About 100 feet from the base lies a persistent bed of massive, light-gray, coarse-grained sandstone. Dark-brown carbonate-of-lime concretions, seamed with brown carbonate-of-iron veinlets, are found in these lower beds. They measure 3 feet or less in diameter.

Above the rocks just described the sandstone gets more and more plentiful, and the shale and coal scarcer, until the upper half is reached. This is almost wholly massive, coarse-grained, gray sandstone, but some coal and very sandy shale, or soft, shaly, micaceous sandstone, are found throughout the formation. A conglomerate or conglomeritic sandstone may occur 200 feet above the base. Most of the sandstones weather to a buff tint.

The principal coal horizons lie below and just above the thick bed of sandstone about 100 feet above the base, but workable coal is also found at two higher horizons; i. e., between 700 and 850 feet, and between 1,000 and 1,100 feet, respectively, from the base. Individual beds, both of coal and other rocks, can rarely be traced for considerable distances unless they are thick and prominent. Fossil leaves are plentiful in some of the beds.

Around Walsenburg the general nature of the formation is similar, but there is not so much sandy shale in the lower portion as farther south; and the prominent sandstone layer that separates the two lower coal horizons (the only ones represented in the Walsenburg district) is 30-60 feet thick and lies 75-110 feet above the base.

South of Florence and Canon City the so-called Laramie formation comprises 800-1,250 feet of heavy-bedded sandstone, containing layers of sandy shales or clay-shales, of various colors from white to black, and a number of coal seams. The last are confined to the lower 600 feet. The rocks of the upper portion of the productive measures are principally shale in the eastern and sandstone in the western part of the district, and the thickness decreases toward the east. The fossils found include fucoids and leaves.

Topography.—The Raton and Laramie formations usually underlie a rolling country, and often outcrop as prominent escarpments where the hillsides are steep. When the beds are horizontal, they often cap mesas; and, where upturned, they form a prominent ridge or hogback.

Clays and Shales.—Good-looking clay or shale beds in the Raton or Laramie formations of the area under discussion are usually thin, and the thicker beds are apt to be sandy and unpromising; so few were sampled. Several beds were found, however, that appear to be adapted to many uses; and it is believed that any fairly thick layer of clay shale in these formations is worthy of careful investigation, if conveniently situated.

Arapahoe Formation

Character of the Rocks.—The Arapahoe formation outcrops only in a comparatively small area south of Canon City. There it consists of about 550 feet of hard to soft conglomerates and sandstones in thick beds. The former usually forms the lower portion, and alternations of both contitute the upper part. The color of the sandy portion is apt to be buff, but may be gray, brown, pinkish, or white. West of Walsenburg and Trinidad there occur 2,000 feet of similar rocks of the same age, which are there called the Poison Canon and Cuchara formations.

Topography.—Rocks of Arapahoe age usually underlie an undulating or rolling surface, and outcrop around the higher points.

Clays and Shales.—The Arapahoe rocks are not known to contain workable clays or clay shales; so no attempt was made to sample them. The Poison Canon and Cuchara formations contain some clay shales, but they outcrop so far from present markets that it is doubtful if any beds in them could be profitably exploited. For this reason they were not sampled.

Nussbaum Formation

Character of the Rocks.—In the southern part of the area under consideration the Nussbaum formation consists of 10-50 feet of gravels. The lower 5-10 feet is cemented by carbonate of lime into a conglomerate, but the upper portion is still unconsolidated. Around Pueblo the thickness may be as much as 100 feet, of which the upper half is mostly unconsolidated sands. The remainder consists of gravel, and the lower few feet of this is cemented into a conglomerate.

Topography.—The Nussbaum formation occurs as the capping of low mesas, which are all small in the southern half of the area, but attain considerable size north of Pueblo.

Clays and Shales.—No clays or shales occur in the Nussbaum gravels and sands.

Recent Formation

Character of the Rocks.—The Recent rocks include mostly unconsolidated gravel, sand, and clay, which have usually been deposited in stream flood-plains, or in lakes or ponds on top of the eroded outcrops of older rocks. Many outwash deposits, as well as some accumulations of wind-blown material, are also of this age. Single beds are usually of limited extent, and the nature of the deposits varies greatly in different localities.

Topography.—The beds are so soft that they rarely form prominent topographic features, except in the case of the low hills or dunes formed of wind-driven sand. Outcrops of Recent rocks should usually be sought along the banks of the larger streams.

Clays and Shales.—Recent clays and shales are apt to occur in thin beds, to be sandy, to burn red unless calcareous, and to have a low fusing point. They are frequently adapted to the manufacture of ordinary soft-mud bricks, however, and are quite extensively used for this purpose. Where the material is fine-grained and non-sandy, it may sometimes be used for other products not requiring a high-grade clay.

CHAPTER II

The Area East of the Front Range and from Colorado Springs Northward

GENERAL GEOLOGY OF THE AREA

The remarks at the beginning of the preceding chapter apply equally well to the northern area; but the age of a few of the formations there, and the names given to some of them in the two localities, differ somewhat, as shown in the following table:

Period and System	Epoch and Series	Formation	Equivalent Formation in Southern Area
Pliocene (Tertiary)		Ogallala or Nussbaum	Nussbaum
Miocene (Tertiary)		Arikaree	....
Oligocene (Tertiary)	White River	Brule or Castle Rock	....
Eocene (Tertiary)	Shoshone	Denver or Dawson	Cuchara
			Poison Canyon
		Arapahoe or Dawson	Raton (in part)
Cretaceous		Laramie	Laramie
	Montana	Fox Hills	Trinidad
		Pierre	Pierre
	Colorado	Niobrara	Apishapa
			Timpas
		Carlile, Greenhorn, Graneros or Benton	Carlile, Greenhorn, Graneros or Benton
		Dakota	Dakota
Comanchean		Lower Dakota	Purgatory
Jurassic		Morrison	Morrison
		Sundance	....
Permian-Triassic (?)	Upper Wyoming	Lykins	Lykins
		Lyons	Lyons
Mississippian (?)-Pennsylvanian	Lower Wyoming	Ingleside	....
		Fountain	Fountain

Recent deposits similar to those to the south may overlie any of these.

The Dawson and Castle Rock formation were, until recently, together called the Monument Creek formation. Some geologists have suggested the use of this last name for what is here called the Dawson formation alone; but it seems best to retain it as a series name for both, synonymous with Shoshone.

The Niobrara formation is readily divisible into two parts, corresponding with those recognized farther south, but the names "Timpas" and "Apishapa" have not been used in the northern area.

The Lower Dakota formation is identical with the Purgatory formation and should be so called, but this is not customary.

It is possible that at one or more points in northern Colorado the base of the Fountain formation is of Mississippian age, but there is some doubt whether the fossils indicating this are in place.

Many of the formations are abnormally thin, and some quite disappear, in the vicinities of Golden and Boulder.

A very few residual clays were found and sampled in this area, while none were noted to the south.

RELATION OF GEOLOGICAL STRUCTURE TO TOPOGRAPHY

All that was said under this heading in the last chapter could well be repeated here. In part of this area, however, the rainfall averages somewhat greater than farther south. Where this is true the topographic features are more rounded and less prominent.

Fountain Formation

Character of the Rocks.—The Fountain formation usually overlies Pre-Cambrian schists, gneisses, or granites; but thin beds of older rocks, such as Cambrian, Ordovician, Devonian, and Mississippian quartzite, limestone, and sandstone, underlie the Fountain formation near Colorado Springs, Perry Park, Rattlesnake Mountain, and, possibly, elsewhere.

The thickness of the formation varies greatly, due to the irregularity of the erosion surface on which it accumulated, but averages about 1,000 feet near Colorado Springs, thickens to 2,500 feet north of Morrison, and then again thins down to 500 feet at the Wyoming line. The rocks are everywhere conglomerates, grits, sandstones, and shales which may be either sandy or clayey, but the relative proportions of these materials vary considerably at different points. Fragments of granitic rock re-cemented so as to resemble granite, called arkose, are common at most points. The color is prevailingly some shade of red, but streaks or irregular patches of white or gray rocks occur in many places and may give the rocks a mottled appearance. There is nearly always a conglomerate at the base; and, as a rule, the color is lighter and the texture finer toward the top.

Near Colorado Springs there are several non-persistent beds of dark-red, purplish, or green clay shale interbedded with the coarser material. These occur at several horizons, but are most numerous near the base. In the central part of the area the shales are scarce, but they appear again farther north, where they are apt, however, to be sandy and micaceous.

From Denver Basin northward a few beds of limestone, usually compact and drab-colored, occur at one or more horizons.

Near Golden the color is uniformly some shade of red, but northward pink, gray, and white beds again appear and make the general tint pink as viewed from some distance.

North of the Cache la Poudre the formation becomes more calcareous, many of the conglomerate beds, even, effervescing in acid.

Topography.—The Fountain formation usually underlies a valley between the old, crystalline rocks of the mountains and the first hogback east therefrom. At many points, however, the lower beds have resisted erosion to a notable degree and rise high on the sides of the crystalline rocks forming the mountains. This gives rise to the so-called "flat-irons." Frequently the harder rocks outcrop in the valley above mentioned as interrupted ridges or in fantastic forms. This is true in the Garden of the Gods near Colorado Springs, the Garden of the Angels near Morrison, south of Platte Canon in Washington Park, and elsewhere. Where the Lyons or Ingleside hogback (see pp. 124 and 125) is well developed the Fountain beds may outcrop on the western side; and in several instances the first hogback east of the mountains is largely composed of Fountain material. Near Boulder, Fountain rocks even form the crest of this hogback.

Clays and Shales.—Promising clay or shale beds are extremely scarce in the Fountain formation, and only one was tested. That turned out to be so unexpectedly good, however, that further investigation in this horizon might prove profitable.

Ingleside Formation

Character of the Rocks.—The name "Ingleside" has been adopted for a succession of sandstones and limestones found from Lyons northward. The formation is supposed to be, at least in part, the equivalent to the Tensleep formation in Wyoming. It is not known whether the beds disappear near Lyons or whether they are represented by the lower 6 to 8 feet of what is called the Lyons formation from Lyons southward. The thickness gradually increases northward and reaches 125 feet at the Wyoming line. At Masonville the rocks are all sandstone, and the total thickness is less than 100 feet; and no limestone is found south of here. At Stout, however, where the thickness is 85 feet, two calcareous sandstone bands occur; and west of Fort Collins there are two lenses of limestone. Between there and Ingleside one to three limestone beds are found, but the two lower ones are sandy. They vary in thickness in short distances and disappear entirely for a short distance north of the Cache la Poudre. North of Ingleside there is everywhere a limestone at the top and at two lower horizons, with sandstone between and below. The color of the sandstone is usually pink or creamy, but grays and reds are also noted at some points. The limestone is pinkish, white, gray, or mottled, and individual beds reach a maximum thickness of 15 feet.

Topography.—The Ingleside formation outcrops as a prominent ridge nearly everywhere until its southern extremity is approached. There it may merge with the lower Lykins (see p. 127) ridge.

Clays and Shales.—No clays or shales are known to occur in the Ingleside formation.

Lyons Formation

Character of the Rocks.—It has been supposed until recently that the Lyons formation was more closely allied with the Fountain formations than with the Lykins; so it was included in the Lower Wyoming series with the former. It is now known, however, that it is merely a sandy development of the lower part of the Lykins, and this makes it necessary to assign it to the Upper Wyoming series. It is possible that a very small part of the lower portion may be of Ingleside—Lower Wyoming—age between Boulder and Lyons, or even, possibly, south of Boulder.

The thickness of the Lyons varies from 50 to 400 feet, the maximum occurring south of Golden. Everywhere it is a hard, massive sandstone or grit, the latter being coarse enough in some places to constitute fine-grained conglomerates. Cross-bedding is common, especially at the top. It is usually pink in color in the southern and northern parts of the area, but is white or creamy in the center, and is known as the creamy sandstone in the Denver Basin. Even where light-colored, there may be pink or red bands or patches, especially near the base. Leaching and concentration of the iron may cause gaily tinted rings or bands and red concretions north of Boulder. North of Carter Lake the lower 25-30 feet is softer, or, at least, it contains softer, sandy beds; but the upper 30-40 remains hard and resistant. North of this point the upper, hard sandstone gets gradually thinner, and disappears not far north of Ingleside. At the same time, the lower, softer zone gets softer and more shaly, and its thickness also increases until it reaches 100 feet at Ingleside. There it consists of dark-red shales and soft, pink sandstones, some of which are calcareous. These are so typically Lykins, lithologically, that there seems no doubt of their age.

Topography.—Where the Ingleside is represented by a thin bed, or not at all, the Lyons sandstones usually outcrop in a prominent hogback, the first one east of the mountains. Near Boulder, however, they form a minor ridge on the eastern flank of that hogback, which is locally capped with Fountain sandstone. From Carter Lake to Arkins there are two ridges or hogbacks developed. One is in the lower, softer portion, and the other in the hard, massive division of the formation. North of Arkins the western ridge dies out; and north of Ingleside the Lyons is no longer a ridge-maker.

Clays and Shales.—The only clays or shales existing in the Lyons formation are found in the lower, softer member north of Carter Lake. As these are lithologically like, and merge into, the Lykins, their discussion is postponed until that formation is considered (see below).

Lykins Formation

Character of the Rocks.—The Lykins formation has been called the Chugwater in Wyoming, and that name is also sometimes used in northern Colorado, but it has not been adopted by the Colorado Geological Survey. The thickness varies from 140 feet near Colorado Springs to 800 feet four miles north of Boulder, but is often between 300 and 500 feet. The most striking feature of the formation is its deep, rich color—usually brick red, but occasionally brownish red. Some beds in nearly every section exhibit other tints, but the rocks as a whole are red and have long been known as "Triassic red beds." The only fossils found are of Permian age, however, and there is no evidence that any Triassic rocks are included in the formation. The Lykins beds are easily traced, even when they fail to outcrop prominently, by means of the red soil formed by their disintegration. While the details differ from point to point, there is usually, in the southern and central parts of the area, a comparatively thin lower zone of red sandstones and sandy shales, containing several limestone layers, any one of which is rarely over 5 feet thick when pure. Above lies a greater thickness of sandy shales, with more or less shaly sandstones, mostly red in color; and, in the central and southern parts of the area, these are often overlain by gypsum. The top is apt to be marked in the same regions by a soft, thin-bedded, white, pink, yellow, or brown sandstone that is often calcareous and seldom outcrops. It is possible that this is the equivalent of the lower bed assigned to the Sundance formation in this report (see p. 127).

In the limestone zone near the base occurs a bed composed of alternations of very thin layers of white limestone and red or pink shale or sandstone. It has been compressed until a section shows a beautifully wavy appearance, and is known as the crinkled limestone or sandstone. Toward the south two such bands are present, separated by shales. This feature can be traced from Perry Park to Arkins.

The Lykins limestone is sometimes very pure and has been extensively used in the manufacture of lime. In it are frequently found cavities containing that crystalline habit of calcite known as "nail-head spar."

The gypsum reaches a thickness of 80 feet at Perry Park, and thick beds are known at other points. Toward the south it sometimes constitutes the highest bed of the formation. In the northern part of the area several bands of gypsum of fair thickness occur at about the crinkled-sandstone horizon. Near Arkins gypsum also occurs near the top of the formation beneath 14-20 feet of plastic, dolomitic clay-shale.

North of Boulder, where the formation is thickest, the lowest 230 feet is wholly dark-red sandstone—an unusual feature.

A description of the lower Lykins beds north of Carter Lake is given in the discussion of the Lyons formation (see p. 125).

Topography.—The greater part of the Lykins formation usually occupies a valley just east of the Lyons hogback, but the lower beds often outcrop well toward the ridge of that elevation. The upper beds are apt to be concealed beneath the wash in the valley east of the Lyons hogback, but they may be exposed on the western side of the first hogback, either Sundance or Dakota, east therefrom. The ridge-making propensities of the beds below the so-called Lyons north of Carter Lake have already been discussed (see p. 125). Near the Wyoming line an 8-foot, fossiliferous limestone bed, 225 feet above the base, also outcrops as a ridge. The gypsum beds in Perry Park and outside of the Gateway of the Garden of the Gods are also ridge-makers.

Clays and Shales.—The Lykins shales are usually too sandy to make them worthy of consideration, and the high iron content indicated by the color has prevented any attempt to use them for high-grade products. For these reasons few samples were taken. All those tested are red- to pink-burning, have comparatively low tensile strengths, and are non-vitrifying; but the air shrinkage is usually low, and they do not crack on drying or burning. Several ought to make good brick or earthenware, and some ought to answer for more valuable products. Any of the less sandy beds appear worthy of consideration, but a considerable proportion will probably prove worthless.

Sundance Formation

Character of the Rocks.—On the Wyoming line there lie between the Lykins and Morrison formations two sandstones, aggregating about 150 feet in thickness. The lower member is pink and approximates 100 feet in thickness, while the upper is yellow to creamy and is half as thick. The upper is certainly continuous with the marine Jurassic beds of Wyoming, which are called the Sundance formation. The age of the lower member is wholly problematical. It may be Lykins, Sundance, or a transition from one to the other. Lithologically it is more nearly allied to the Sundance than to the Lykins formation, however, and neither contains clays; so it was found most convenient to assign it to the Sundance in this report. The lower member is supposed to pinch out west of Loveland, and the yellow to disappear near the Cache la Poudre; but the frequent presence of somewhat similar sandstones at the top of the Lykins and base of the Morrison in the Denver Basin, and even south thereof, suggests the possibility that the Sundance formation is much more widely distributed than has been supposed.

Topography.—The Sundance formation may outcrop in a ridge or hogback, but this is rather interrupted, and, in general, the beds are not well exposed.

Clays and Shales.—The Sundance formation contains no clay or shale.

Morrison Formation

Character of the Rocks.—Some geologists believe that the Morrison formation is part of the Comanchean system, but those most familiar with the criteria relating to its age are inclined to think it is Jurassic.

The thickness of the Morrison formation varies from 130 feet near Colorado Springs to 200 feet south of Golden and 420 feet near Lyons. Farther north it is less than 100 feet thick in some places, due, apparently, to the absence of the upper beds. Near Boulder, in the Denver Basin, and perhaps elsewhere, there is 10-15 feet of white, gray, or yellow sandstone at the base. It is somewhat calcareous, as are all the Morrison sandstones. Next comes a zone of varicolored marls, containing a number of non-persistent bands of compact limestone, which weather brown, but are dark bluish-gray to drab when fresh. These are often, although erroneously, called lithographic limestones. The thickness of these limestone beds is rarely over a few inches or feet in the southern part of the area, but they reach a maximum of 40 feet near Boulder. The marls and limestones constitute the greater part of the formation, but south of Lyons they are overlain by a considerable thickness of sandstones and marls, either of which may locally develop almost to the total exclusion of the other. At a distance varying from 10 to 180 from the top is usually found the spotted or saurian sandstone described on page 105. It varies from 5 to 35 feet in thickness, and is commonly divided into several beds by layers of drab clay, which reach the very unusual thickness of 20-30 feet near Turkey Creek. Above this sandstone lie soft to hard marly shales, which contain shaly sandstones in some places. Their color is red near Golden, but green, yellow, and purple tints are shown elsewhere. In several localities the saurian sandstone is underlain by a conglomerate which is often confused with that found at the base of the Lower Dakota (see p. 130). It has a maximum thickness of 8 feet.

Near Turkey Creek the formation contains a fairly thick bed of gypsum.

At all points north of Boulder one or more beds of very hard, siliceous, green shale or argillite lie above and below the saurian sandstone. A section measured near Berthoud, on the main road west of town, where these green beds are typically developed, shows the following succession:

Lower Dakota sandstone.	
Concealed	20 feet
Hard, green shale	5 feet
Saurian sandstone	5 feet
Hard, green shale	10 feet
Calcareous sandstone	2 feet
Hard, green shale	10 feet
Sandstone	3 feet
Marly shales, containing "lithographic limestones".	?

Remains of gigantic reptiles are found in both marls and sandstones in several localities.

Topography.—The Morrison beds usually outcrop on the west side of the Dakota hogback (see p. 132). The lower beds may be exposed well up on the side, or they may be concealed by the wash in the valley below. North of Boulder, however, the crest of this hogback occasionally follows the hard, thick Morrison limestone beds there found.

Clays and Shales.—Due, probably, to its known calcareous nature, the Morrison formation has usually been ignored as a source of clay, but several successful attempts to use it have recently been made; so the beds were sampled where they appeared promising and were well exposed. The tests conducted on these samples indicate that good brick and, less frequently, earthenware, usually of a flesh or buff color, can be made from most of the finer-grained shales or marls, but that very few of them can be used for other products. A rather surprising feature is the relatively high fusing point of many of the samples, half of which remained erect at Cone 5. One fused at Cone 12, one at 16, and one at 20. The shales would doubtless have far wider applicability if it were not for their rather low tensile strengths. Fully 75 per cent proved deficient in this respect, and 40 per cent were lacking in plasticity. No very promising material for the manufacture of paving-brick was found, although 10 per cent of the samples are worthy of further investigation with this purpose in view.

Lower Dakota Formation

Character of the Rocks.—The Lower Dakota or Purgatory formation averages about 100 feet in thickness and is everywhere composed of massive, hard, compact sandstone capped by one or two zones of clay or shale, and with 30 feet, or less, of pebble conglomerate at the base in many places. The quantity, size, and distribution of the pebbles vary greatly from point to point. In some places the conglomerate is represented only by thin streaks of small pebbles imbedded in sandstone. The color of the conglomerate and the sandstone is usually white or gray, but yellow or light-pink beds of sandstone occasionally occur. Spotted sandstones are sometimes present, but the color of the spots is apt to be red or purple, and of the sandstone brown, instead of brown spots on a white sandstone, as in the case of the saurian sandstone below. One or two thin conglomerate beds may occur locally below, or near, the middle of the formation.

Near Golden one thin bed is a peculiar, concretionary limonite.

In the absence of paleontological evidence and any marked unconformity, it is impossible to fix upon the exact upper limit of the Lower Dakota. In the southern part of the state the Purgatory is known to include the zone of clay or shale above the massive sandstone, but in the area under discussion there are often, and north of Platte Canon always, two beds or zones of such material separated by from 1 to 25 feet of sandstone. For convenience, as explained later, both of these shale zones are included in this report in the Lower Dakota.

The upper shaly or clay zone or zones, as thus defined, differs greatly in texture, color, thickness, and physical properties in different parts of the area. From Colorado Springs to a few miles north of Golden there are one or two beds of hard, dark bluish-gray to black clay or shale, which vary from a foot or 2 up to 8 feet in thickness. In places it is almost an argillite, and breaks into rectangular blocks with slickened surfaces.

Near Boulder, however, the lower bed is replaced by a zone 20-25 feet wide, in which are six or seven thin, black-shale beds, alternating with rather thicker layers of sandstone; and north of Boulder for some distance this horizon appears to be represented by either an alternation of white, red, or green sandy clays or a very sandy white shale. In some localities the horizon has one of these sets of characters, and in others the other set. North of Ingleside, Larimer County, this zone consists of 5-10 feet of fine-looking, plastic, light-gray clay.

The upper of the two beds commonly found farther south is represented from Boulder northward by about 50 feet of black shale. It is more or less sandy, and may even contain thin, calcareous sandstone layers, but several feet of clean shale, with papery lamination much like the Graneros shale (see p. 134), is common at the base. In the northern part of the area this upper zone is thickened greatly by the presence of 100 feet, or more, of shale and brown, shaly sandstone in alternate layers. As the top is approached, the shale gets less plentiful and the sandstone loses its shaly nature, gradually merging into the massive Dakota sandstone (see p. 133). Whether these beds are Comanchian or Cretaceous, or represent a transition from one to the other, is unknown; but the total thickness of the Comanchian formation is so much greater than farther south, if they are included in it, and the Dakota must then be made so much thinner than usual, that it seems probable the upper shaly zone below the Dakota sandstone is largely, or entirely, of Dakota age. It was often found difficult, however, to distinguish the two zones with certainty in the field; so both have been classified in this report as Lower Dakota. That the lower zone is of that age there seems little doubt.

The following section, measured in a ditch along Dry Creek, near Loveland, is rather typical of the northern exposures:

Benton shales.

Dakota (30 feet).....	Sandstone	30 feet	
Lower Dakota (222 feet)....	Sandy, calcareous shale with some sandstone, especially near the top.	150 feet	Upper shale zone.
	Black shale with less sand	20 feet	Upper shale zone.
	Sandstone	2 feet	
	Varicolored shale with little sand.............	20 feet	Lower shale zone.
	Sandstone	30 feet	

Morrison marls.

Topography.—The hard Lower Dakota and Dakota sandstones are responsible for the presence of the second, and largest, hogback east of the mountains nearly everywhere. South of Boulder the top is usually marked by a single, sharp crest where either Lower Dakota or Dakota rocks outcrop, usually the former. North of Boulder, however, the shaly zones at the top of the Lower Dakota lie beneath a shallow, longitudinal trough or valley, and the Lower Dakota sandstone, below, and the Dakota sandstone, above, both develop into crests. In some localities, where the rocks between the two shale or clay zones are unusually thick or resistant, three crests are present. Near Boulder the main crest of this hogback is sometimes made up of Morrison limestone, as already mentioned (see p. 129), and the sandstone outcrops as one or more minor ridges on the eastern flank.

Clays and Shales.—South of Boulder the one or two shale or clay beds are noted for their highly refractory properties, and they are extensively used for the manufacture of fire-brick, muffles, crucibles, etc. They are usually too deficient in tensile strength, plasticity, and cohesion as mined to permit their use for high-grade wares, such as porcelain, but experiments show that good results may often be secured by washing or mixing them with a ball-clay. The beds are, however, often too thin to be profitably exploited.

It has been generally believed that there is no true fire-clay north of Boulder, but this investigation has proven this idea incorrect, since six miles northwest of Fort Collins there is a 7-foot bed that is fully as refractory as the material found farther south; and equally promising clays occur from the Wyoming line to a point six miles therefrom, and possibly farther. There the bed varies from 2 to 6 feet in thickness. All these refractory samples came from the lower zone and are much like the southern material in their deficient plasticity, tensile strength, and cohesion. They differ decidedly, however, in color from the southern fire-clays, being white, white and pinkish, or light bluish green. All are massive clays rather than shales, and are sandy. Many samples taken between the two districts mentioned are decidedly refractory, but not enough so to make them true fire-clays. It is possible, nevertheless, that such very refractory clays exist at places not visited.

The two shale zones north of Boulder are, outside of their possible decidedly refractory nature, very promising, since not a single sample taken failed to make good bricks, at least; and many seemed adapted to the manufacture of more valuable products. The lower zone proved to contain a better grade of clay or shale than the upper. The following table exhibits the properties of the material from each zone in terms of per cent of samples tested. The highly refractory portions of the lower zone have, however, been ignored in these calculations:

	Lower Zone	Upper Zone
Fusing above Cone 8	55%	15%
Average cone at which fusion occurs	12	8
Adapted to the manufacture of other products than bricks or earthenware	55%	35%
Possibly adapted to the manufacture of paving-bricks	50%	20%
Burning to colors other than pink or red	30%	5%
Deficient in tensile strength	75%	55%
Deficient in plasticity	30%	20%

The high percentage of samples deficient in tensile strength means that the products will often be very tender and the waste will be great, unless great care is used in handling the green ware. This does not apply, of course, to goods made by the dry or semi-dry pressed processes. Not only does a relatively high percentage of the samples seem to possess qualities required of paving-brick material, but a number are very promising in this respect. It is doubtful if any other horizon has as much material of probable value for such a purpose.

Dakota Formation

Character of the Rocks.—The name "Dakota," as here used, includes only the material between the upper clay or shale zone of the Lower Dakota formation and the black Graneros shales (see p. 134). As thus defined, the formation varies considerably in thickness from a maximum of about 220 feet south of Golden to a minimum of 25-30 feet near Loveland. It consists essentially of compact sandstones in massive beds, very similar to the Lower Dakota sandstones, but rarely of other colors than yellowish, light gray, or white. The change to the Graneros shales above may be sudden, but it is more apt to take place through a transition zone of 10-30 feet of hard, white and black, slaty shales which become increasingly sandy the farther they are from the upper contact.

In the vicinity of Golden and Colorado City a fire-clay bed, exactly like the Lower Dakota bed or beds, was sampled. It was not noticed at other points, but north of Boulder a gray, brown, or black, non-refractory shale is occasionally found at the same horizon.

Topography.—The topography resulting from the outcropping of Dakota beds has been described on page 132.

Clays and Shales.—No clay or shale occurs in the Dakota, except where the fire-clay bed near the top, or its northern equivalent, is present. At several points the fire-clay is of as high quality as the beds in the Lower Dakota formation, but it is not so easily mined near Golden, due to the overturning, faulting, and crushing of the bed. The northern equivalent of this bed fused at Cone 8 in all the samples taken. It burned pink or flesh-colored, and was too deficient in tensile strength to answer well for making anything but pressed or soft-mud bricks. All the samples vitrified well, however, and the bed is a promising source of paving-brick material.

Graneros Formation

Character of the Rocks.—In northern Colorado the Graneros, Greenhorn, and Carlile formations are usually together called the Benton formation. Each of the divisions is often recognizable, however, and the more specific names are occasionally utilized. As there is some difference in the quality of the shale found in the first and last-named divisions, it was thought best to use the threefold division in this report.

The thickness of the Graneros formation is rather uniformly about 200 feet, but it is more than this in some parts of the Denver Basin, and reaches about 525 feet east of Lyons. Everywhere the rocks are dark gray to black, thinly laminated clay-shales containing thin local sandstone and limestone beds. Several beds of white shale or plastic clay are often present near the base. Thin beds of oyster shells are common at several horizons.

In the Denver Basin there is a prominent zone of lime- and iron-carbonate concretions, from 1 to 3 feet in diameter, about 200 feet above the base.

Near the Wyoming line the lowest 20 feet is hard and siliceous, and lacks the usual fine lamination.

Topography.—Everywhere the Graneros shales outcrop on the barren eastern slope of the great Dakota hogback, or else underlie the western side and middle of the valley at the eastern base thereof.

Clays and Shales.—Much that was said relative to the quality of the Graneros shales in the southern area (see p. 110) is equally relevant here, but the beds of this area seem to average slightly better than farther south. This is shown in a higher average viscosity temperature (Cone 9), a greater proportion (45 per cent) of cream-, buff-, or flesh-burning clays, and a higher percentage (35) of samples showing good vitrifying qualities. Several of these may make good paving-bricks. Although a few beds seem adapted to the manufacture of higher-grade products, the Graneros is still distinctly a formation of attractive pink or light-tinted, brick-making material.

Greenhorn Formation

Character of the Rocks.—The Greenhorn formation is not usually so distinct and easily recognizable as in the southern area, but its nature is quite similar; i. e., thin limestone bands separated by thinner shales. The thickness varies from a few feet up to 25 feet or more. The limestones are apt to be light gray when fresh, and black when weathered, and they are often impure and shaly. The shales are dark gray.

Topography.—The Greenhorn formation forms a prominent ridge outside of the Gateway of the Garden of the Gods and east of Lyons; but it is usually concealed by wash in the valley between the Dakota and Niobrara hogbacks, lying somewhat nearer the latter than the former.

Clays and Shales.—No workable beds of shale were found.

Carlile Formation

Character of the Rocks.—The thickness of the Carlile formation averages somewhat less than half that of the Graneros (see p. 134) in this area, and contains a number of thin, non-persistent, bluish or grayish limestone beds that are often bituminous. Otherwise, it is very similar to the Graneros. In some places, however, a considerable thickness of the shales is bituminous, and the upper member is often a gray to greenish sandstone or sandy shale, 6-15 feet thick. The shales of the lower part are somewhat darker than those above.

Topography.—The Carlile shales underlie the eastern side of the valley west of the Niobrara (see p. 136) hogback, and they often outcrop on the barren western slope of that ridge. Where the Greenhorn limestones outcrop prominently, the shales fill the valley between that elevation and the Niobrara hogback.

Clays and Shales.—The shales have qualities very similar to those of the Graneros formation (see p. 135), but average somewhat poorer, the most notable differences being a greater tendency to burn red and a lower average viscosity temperature. There is not so much difference between the two horizons, however, as exists farther south. A very large proportion of the beds will make good and attractive building-bricks of one kind or another; but, at the great majority of points sampled, the formation is worthless for other purposes.

Niobrara Formation

Character of the Rocks.—Although the northern Niobrara beds are never subdivided into the Timpas and Apishapa formations, as is done in the southern area, it is as easy to do so in one place as in the other. The lower portion, ending in a hard, calcareous shale or limestone zone, would then be Timpas, and the remainder Apishapa. The upper Timpas so resembles the Apishapa lithologically, however, that there seems to be no reason, except custom, for using the two names anywhere.

The thickness of the formation is about 400 feet throughout the central part of the area, but it thickens to the south and thins to the north. At the base is a prominent zone of hard, compact, light-colored, dolomitic limestone in beds up to 3 feet thick, which are separated by thin clay seams. The bedding is very irregular, and the thickness of the zone varies from 15 to 50 feet or more. This limestone passes above through an alternation of thin shales and "blocky" limestone beds into marly shales. At the top of this second zone occur several thin, hard calcareous shale or limestone bands. This hard zone is somewhat below the middle of the formation. Most of the shales below are dark brown when fresh, but weather gray to white. The hard zone is even darker brown when fresh, and weathers yellowish. Above the hard, calcareous zone the remainder of the formation consists of calcareous sandy shales, which weather yellow or buff and contain several thin limestone bands. Several different species of bivalves, some sharks' teeth, and fish remains constitute the fossils found.

Topography.—The basal limestone forms a prominent hogback everywhere, but the height is much less than the great Dakota hogback to the west. It is the first ridge east of the Dakota hogback, unless a low ridge of Greenhorn limestone intervenes. The hard, calcareous layer below the middle of the formation sometimes makes a secondary ridge east of the main one; and a third limestone zone may develop into a minor ridge east of the last; but this is uncommon. The main hogback is often covered with a growth of pinon tress. These are wanting on immediately contiguous formations.

Clays and Shales.—The Niobrara shales are too calcareous to be of interest to ceramists, and were therefore not sampled.

Pierre Formation

Character of the Rocks.—The Pierre formation has a thickness of 7,900 feet south of Golden, but measures less than half this in many places. Its general nature is the same as in the southern area (see p. 114), but the tepee buttes disappear north of Colorado Springs; and, in the Denver Basin, a soft, yellowish-gray, fine-grained sandstone, 100-350 feet thick, occurs at the top of the lower third. The shales are nearly everywhere some shade of gray, often dark, when fresh; but they are apt to weather to a drab, buff, or yellowish-green gumbo soil that is very sticky when wet. The last-named color is rather characteristic of the northern part of the area. The shales become more sandy toward the top, and usually grade insensibly into the Fox Hills formation above. In some places this transitional zone is marked by the presence of thin limestone lenses and small ferruginous concretions. Soft sandstones and gray, fine-grained, concretionary limestone beds occur at several horizons; and the rusty zone mentioned in the description of the southern area is usually prominent. The fossils found include many varieties of invertebrates and some fish remains.

Four miles north of Boulder there is a 40-foot zone of limestone which closely resembles the basal Niobrara.

North of Boulder the lowest 75-100 feet is black and has a papery lamination which makes it look much like the Benton shales. There, also, occurs a light-gray to dark greenish-gray, gritty, calcareous sandstone which loses lime on weathering and assumes a lighter tint. It is hard and outcrops prominently in many places. As it is at the same horizon as the sandy zone in the Denver Basin, it is probably the northern equivalent of those beds. It is called the Hygiene sandstone; and, while thin near Boulder, its thickness increases to 300 feet or more farther north. Four miles north of Boulder a zone of shale separates the sandstone into two members. This shale thickens to the north and has a maximum of 200-300 feet three miles farther north. Calcareous concretions several feet in diameter are common in the upper part of the sandstone, and invertebrate fossils and carbonized wood occur at several horizons. North of Fort Collins the whole Pierre formation is more sandy than to the south, and the Hygiene sandstone is less distinct and is difficult to trace.

Topography.—The Pierre formation usually underlies a broad, flat or gently undulating valley occupying most of the space between Niobrara and Laramie hogbacks or outcrops. The Hygiene sandstone, however, often develops into a ridge or hogback.

Clays and Shales.—Almost everything said relative to the ceramic qualities of the Pierre shales in the southern area (see p. 115) is equally true of those rocks in northern Colorado. In fact, most of the percentages given are identical in the two regions. However, only half as large a proportion are deficient in tensile strength in the northern area, but this improvement is counteracted by a higher percentage (45), with a relatively high air shrinkage. Only 5 per cent of the northern shales seem utterly worthless; and the same low percentage may make paving-brick. The worthless samples were not taken wholly from the top of the formation, as was the case farther south.

While a careful exclusion of concretions and other impurities will usually yield material that will make fair to good red or pink bricks of some kind, different horizons of the formation in any district will commonly differ decidedly in their properties; and careful tests of a number of zones should always be made before locating a brick plant, since no general statement can be made as to which part of the formation is apt to be the best.

Fox Hills Formation

Character of the Rocks.—The Fox Hills is almost entirely yellowish, sandy shales, but contains a few beds of clay-shale, and is capped by about 50 feet of greenish or yellowish-gray, micaceous sandstone, which weathers light gray. The thickness is 1,400 feet near Niwot and 800-1,000 feet in the Denver Basin, but it may be much less elsewhere. The sandstone contains large, dark-brown, lime- and iron-carbonate concretions, which often have a fucoid in the center. Invertebrate fossils and plant remains are common, especially in the top layer of the capping sandstone, which is sometimes shaly.

Topography.—The capping sandstone combines with the basal Laramie sandstones above to form a prominent escarpment or hogback—the last east of the mountains, unless Tertiary formations are present. The hogback thus formed is remarkable at several points for the wall- or dyke-like appearance of the hard beds projecting from its summit. The soft, lower Fox Hills beds outcrop on the western slope of this hogback and in the valley at its base (or below the escarpment when the beds are not upturned). Just south of Clear Creek, at Golden, there is a hill of the soft shales.

Clays and Shales.—Most of the Fox Hills shales are altogether too sandy to be worthy of consideration. Where clayey beds are found, they are inferior to the Pierre shales in every way, except that they have a greater tendency to burn pink instead of red. Practically all of them will make fair to good soft-mud bricks, however, and two or three samples might make other products; none vitrified well.

Laramie Formation

Character of the Rocks.—The Laramie formation is everywhere divisible into two parts: a lower, composed of massive, gray or white sandstone, containing some dark-gray or brown, sandy shale or clay-shale, shaly sandstone, and workable beds of coal; and an upper, consisting of sandy shales and clay-shales, and massive clays of many colors interbedded with sandy shales and sandstones. This upper sandstone is often ferruginous. The lower division is 40-200 feet thick, and the upper, 250-1,000 feet thick. The sandstones contain very hard, concretionary masses, 30-40 feet long, of material similar to the surrounding rocks; and the upper beds yield many concretions of carbonate of lime and iron, 2 to 4 feet in diameter. The coal-beds vary in thickness from a few inches to 15-20 feet. A few lignitic bands and thin, unworkable coal seams may be found in the upper division. The basal sandstone usually forms a lithologic unit with the capping sandstone of the Fox Hills formation, but may be distinguished from the latter by the lack of mica and the white or gray color.

Near Fort Morgan and Sterling the upper division contains a characteristic bed, consisting of 30-40 feet of alternating laminae of sandstone and gray clay, each layer being not over one-half inch thick.

Topography.—The topography resulting from the outcropping of the Fox Hills-Laramie sandstone has already been described under the discussion of the former formation (see p. 139). The softer, upper division is exposed on the eastern side of the Fox Hills-Laramie hogback, or on the flat or undulating area above the escarpments or bluffs formed by the lower beds when the layers are not upturned.

Clays and Shales.—A great variety of clays and shales occur in the Laramie formation, and there is no special horizon that appears better or poorer than others. Neither does any bed retain its qualities for many miles. In spite of these variations, it can be said that the formation is of the greatest interest to ceramists, and has yielded enormous quantities of valuable clays, especially near Golden. This investigation proves, however, that equally good beds exist elsewhere. The general qualities of Laramie clays and shales are shown in the following table in terms of the percentage of samples tested:

Viscosity temperature above Cone 8	45%
Average cone at which viscosity occurs	9
Deficient in plasticity	20%
Excessive air shrinkage	65%
Deficient in tensile strength	30%
Burn to tints other than pink or red	60%
Burn pink	30%
Burn red	10%
Adapted to making other products than bricks or earthenware	35%
Possibly adapted to making paving-bricks	25%
Worthless	15%

The large proportion with a high air shrinkage indicates that the dry or semi-dry process must be used in many cases. This, together with the relatively high average viscosity temperature and the fact that a large percentage burn to white, cream, buff, or other light tints, makes the majority of the Laramie clays or shales especially useful for the manufacture of a very high grade of pressed face bricks. A considerable proportion of the samples will make other products, however, and these include practically everything made of clay, except highly refractory goods. Grogging is often necessary to secure the best results. Several very promising sources of material for paving-bricks were located, but the chances that they will make a high grade of this product would be better if a larger proportion burned to a darker color—contained more iron.

Arapahoe Formation

Character of the Rocks.—The Arapahoe formation not only is now known to be of the same age as the lowest part of the Dawson formation (see p. 142), but it is lithologically identical with, and may be traced into, the base of that formation. It has, however, a much more extensive distribution than the upper, and thicker, portion of the Dawson formation.

At the base of the Arapahoe formation there is 50-200 feet of conglomerate beds containing some coarse sandstones; while above this lies 400-600 feet of soft sandstone and sandy shale. The prevailing color is light gray or white, but the conglomerate often weathers dark brown. A conglomerate bed at the base is hard, and averages 40 feet thick. It is characterized by the presence of numerous pebbles of silicified limestone, called chert. These are black on the exterior and gray on freshly broken surfaces. One or two beds of clay lie just above the conglomerate zone at Golden.

Topography.—The Arapahoe beds outcrop on the eastern slope or at the base of the Laramie hogback; or, where the beds are not upturned, above Laramie bluffs or escarpments. The basal conglomerate, although very hard, often disintegrates readily when exposed to the air, and rarely projects more than 2 or 3 feet above the surface north of Platte Canon. South of that point, however, its outcrops are much more prominent; and, west of Sedalia, it forms the western portion of the most prominent hogback in the area. At many points both north and south of here it is not exposed at all, but may be traced readily by means of the numerous black "chert" pebbles in the soil.

Clays and Shales.—The Arapahoe formation is not known to contain any clay outside of the beds near Golden, and these are no longer worked.

Denver Formation

Character of the Rocks.—The Denver formation is also of the same age as the lower part of the Dawson formation (see p. 142), but is younger than the Arapahoe, and is lithologically distinct from both it and the Dawson.

The lower 400 feet is composed entirely of andesitic debris—sandstones, sandy shales, and conglomerates. Then come one to three flows of basaltic lava of various thicknesses up to 140 feet each. Above this occurs 800-900 feet of material which is identical with the lower beds immediately above the lava flows, but contains increasing proportions of orthoclase, quartz, and mica toward the top; and the highest beds are entirely made up of rather coarse granitic, gneissic, or schistose debris, consisting largely or entirely of the minerals just mentioned. Fossil leaves, palm stumps, and petrified wood are plentiful in the formation.

Topography.—The lower beds outcrop prominently on the steep slopes of the two basalt-capped mesas east of Golden, and in the lower part of Green Mountain south of Golden. Elsewhere they underlie an undulating or level surface. The upper beds are exposed only on the sides and top of Green Mountain.

Clays and Shales.—The upper beds are too coarse-grained, and the lower ones, where finer, are too basic, to interest ceramists; so they were not sampled.

Dawson Formation

Character of the Rocks.—The Dawson formation is the lower and thicker member of what was formerly called the Monument Creek formation. The latter is now known to contain rocks belonging to two different systems which are separated by an unconformity and which differ lithologically to some extent; so it is necessary to divide it into two formations.

The Dawson formation has a maximum thickness of about 2,000 feet, and covers a large area between Colorado Springs and Denver. It consists of a complex alternation of grits, sandstones, conglomerates, sandy shales, and clays. These often show bright yellow or red colors, and occur in beds 20-40 feet thick. Thin beds of siliceous limonite also occur at many horizons. The conglomerates are most numerous near the base, where the Dawson merges into the Arapahoe formation. The beds may be uncemented or of great hardness; they may be well bedded, or, as is more commonly the case, they may show little or no lamination and be irregularly stratified. Cross-bedding is very common, and the material often shows little evidence of sorting. Silicified wood is abundant. At, or very near, the top of the formation occur several layers of rhyolite tuff, some of which are silicified and resemble jasper.

Topography.—Near the mountains the basal beds have been upturned and form a prominent hogback or ridge. West of Sedalia the height of this topographic feature is greater than any of the lower sedimentary formations attain. Farther east there is a valley several miles wide, with a decidedly rolling surface, dotted with buttes and picturesque outcroppings of the harder beds. Still farther east the upper beds underlie high mesas capped with the rhyolite or overlying Castle Rock conglomerate.

Clays and Shales.—The clay-beds are usually decidedly lenticular, and the properties of different beds differ considerably, but, as a whole, the material is of very high grade. No samples taken proved worthless, all failed to fuse below Cone 12, and the average viscosity temperature is above Cone 24. Excluding the fire-clays, the average viscosity temperature is Cone 18. Forty-five per cent of the samples are true fire-clays, the same proportion will make products more valuable than bricks or earthenware, and an even larger number may yield paving-bricks. Fifty per cent burn white or light-tinted, practically all are very plastic, and none have an excessive air shrinkage. The only unfortunate feature is a deficiency in tensile strength exhibited by 50 per cent of the test-pieces. This limits their usefulness unless they are washed or mixed with other clays.

Castle Rock Formation

Character of the Rocks.—The Castle Rock formation is the upper member of what was formerly designated the Monument Creek formation. It is of lower White River or Chadron age; and the maximum thickness is 300 feet. It is composed of hard, massive conglomerates consisting of pebbles up to several inches in diameter, imbedded in finer-grained material. These grade in some places into a grit streaked with coarser fragments.

Topography.—The Castle Rock formation occurs as the capping of mesas and buttes.

Clays and Shales.—The Castle Rock formation contains no clays or shales.

Brule Formation

Character of the Rocks.—The Brule formation comprises a maximum of several hundred feet of pale-buff or flesh-colored, sandy clays containing thin sand or sandstone and brown, pink, or green clay beds of limited extent. Some conglomerate occurs near the top. Volcanic ash is also present at one or more horizons. The whole is calcareous.

Topography.—The Brule formation outcrops as bad-lands, mesas, or bluffs; and lies beneath somewhat hummocky plains. The bluffs often have a chalky appearance.

Clays and Shales.—Most of the material is too sandy to interest ceramists, and three-quarters of the more clayey beds sampled proved worthless. The average temperature of viscosity is at Cone 4, and most of the pieces burned red. The tensile strength is also low in nearly all cases, and no samples seemed likely to make anything but soft-mud or pressed bricks or earthenware, usually of doubtful quality.

Arikaree Formation

Character of the Rocks.—The Arikaree formation is composed of a maximum of a few hundred feet of fine, light-gray sands, containing layers of hard, dark-gray, irregularly cylindrical or pipe-shaped concretions. More or less sandy beds and volcanic ash are numerous, and some local lenses of conglomerate may be found.

Topography.—Arikaree beds usually outcrop on the steep slopes below Ogallala-capped (see below) bluffs or mesas.

Clays and Shales.—Practically no true clays or shales occur in the formation.

Ogallala Formation

Character of the Rocks.—The Ogallala formation appears to be of the same age as the Nussbaum formation (see p. 119) to the south. It is also very similar to that formation lithologically. In fact, the only appreciable difference noted is the cementation with calcium carbonate of the upper sandy beds as well as the basal gravels.

Topography.—The Ogallala beds usually cap mesas, buttes, or bluffs.

Clays and Shales.—The Ogallala formation contains no clay or shale.

Recent Formation

All that was said relative to this formation in Chapter I (see p. 119) is equally applicable to the northern area.

CHAPTER III

Area in Northwestern and Central-Western Colorado

GENERAL GEOLOGY AND TOPOGRAPHY OF THE AREA

All that was said under these headings in Chapter I (see pp. 101-103) applies equally well farther west.

Except around Glenwood Springs, there are no known workable clay beds older than the Jurassic period near centers of population in this area, although extensive deposits of all other kinds of sediments of greater age are common. The post-Permian sedimentary formations are usually so similar in general nature, although differing more or less in details, that anyone versed in the nature of the equivalent formations in eastern Colorado will ordinarily have little difficulty in determining the age of a clay or shale bed west of the mountains, or in locating a given horizon.

The following table shows the ages of the more important clay-bearing formations in the area under consideration, and indicates their probable equivalents east of the mountains:

<table>
<tr><th>Period and System</th><th>Formation</th><th colspan="2">Equivalent Formation in Eastern Areas</th></tr>
<tr><td rowspan="11">Cretaceous and Comanchean (?)</td><td>Laramie</td><td colspan="2">Laramie</td></tr>
<tr><td>Lewis</td><td colspan="2" rowspan="2">Fox Hills or Trinidad</td></tr>
<tr><td rowspan="2">Mesa Verde</td></tr>
<tr><td colspan="2">Pierre</td></tr>
<tr><td rowspan="5">Mancos</td><td rowspan="2">Niobrara or</td><td>Apishapa</td></tr>
<tr><td>Timpas</td></tr>
<tr><td rowspan="3">Benton or</td><td>Carlile</td></tr>
<tr><td>Greenhorn</td></tr>
<tr><td>Graneros</td></tr>
<tr><td rowspan="2">Dakota</td><td colspan="2">Dakota</td></tr>
<tr><td colspan="2">Lower Dakota or Purgatory</td></tr>
<tr><td>Jurassic</td><td>Flaming Gorge or McElmo</td><td colspan="2">Morrison</td></tr>
</table>

The base of the Flaming Gorge or McElmo formation consists of marine sediments and may be of Sundance age.

Comanchean rocks have not been recognized in western Colorado, but the Dakota formation commonly consists of two sandstone members separated by shales; and this strongly suggests its binary nature east of the mountains, where the lower member is known to be of Comanchean age.

The western equivalent of the Niobrara formation is difficult to identify, although portions of the Mancos formation are calcareous and contain characteristic Niobrara fossils.

The Mesa Verde shales contain Pierre fossils, while the sandstones yield Fox Hills types; so it cannot be considered the exact equivalent of either alone.

The brief descriptions of the formations that follow are very much generalized, yet will usually serve to locate the clay-bearing horizons when read in conjunction with the descriptive matter bearing on the eastern formations.

No attempt to discuss the topographic features has been made, since local hard members of the various formations often develop into ridges or benches, and a much more detailed description than is here desirable would be needed to cover such cases.

The properties of the clays and shales of each formation are not discussed, since an insufficient number of beds were sampled to permit generalizations of that kind. The tests made, however, indicate that the clays and shales are apt to be similar in quality to those of equivalent formations to the east, but that many horizons average more gypsiferous. This makes the western material rather less promising than the eastern beds.

Flaming Gorge or McElmo Formation

The western Jurassic beds of Morrison and, possibly, upper Sundance age are known as the Flaming Gorge formation in the northern, and the McElmo formation in the southern, part of the state. They consist of several hundred feet of marly shales of variegated colors, some harder beds of limestone and sandstone, and a dark-colored, jasper-bearing conglomerate near the top. The resemblance to the Morrison beds is marked, but there are more pink and red beds present in the west, and the sandstone is apt to contain flakes of green shale.

Dakota Formation

The Dakota formation consists of a few tens or hundreds of feet of hard, light-colored sandstone or quartzite, often separated into two or more members by layers of sandy or clay-shale. At the base is a hard conglomerate bed.

Mancos Formation

The Mancos formation includes all the rocks of Benton and Niobrara age and part of the Pierre sediments. At the base are often found alternate layers of sandstone, carbonaceous shale, and coal. These resemble the Dakota beds rather closely, and were long so designated, but are now known to contain characteristic Benton fossils. Above the coal horizon lie several hundred feet of typical black Benton (Graneros and Carlile) clay-shales, containing some limestone and sandstone near the top. Still higher are sometimes found calcareous shales of Niobrara age, and at the top are a few thousand feet of buff clay-shales that very closely resemble the Pierre shales of the eastern areas. Lenticular sandstone beds, some limestone, and concretions occur at several horizons.

Mesa Verde Formation

The Mesa Verde formation consists of a few thousand feet of alternating sandstones, sandy shales, and coal beds. The sandstones are usually gray, but frequently weather to bright shades of red and yellow. This formation may be the western equivalent of the Hygiene sandstone. There is nothing to indicate this, however, except its sandy character and stratigraphic position; and the presence of Fox Hills fossils along with those of Pierre age would seem to put it higher in the geological time-scale.

Lewis Formation

The Lewis formation comprises several hundred to one or two thousand feet of dark-gray to black clay-shale, with layers or lens-shaped masses of dark-colored, compact limestone, and some sandy shale. The absence of sandstones is its most prominent feature, since it is underlain and overlain by much of that rock. The Lewis shales may be of Pierre age, although, as already mentioned under the discussion of the Mesa Verde formation, Fox Hills fossils are found in rocks stratigraphically below it. It may be, however, that so-called typical Pierre and Fox Hills fossils were really living at the same time throughout a large part of the time consumed by the deposition of the Pierre and Fox Hills sediments, but that one type flourished under conditions that led to the accumulation of muds (shales), while the other preferred a sandy bottom. An alternation of conditions would, then, cause the formation of rocks which could not definitely be placed in either formation. This seems to be the case so far as the Mesa Verde and Lewis formations are concerned.

Laramie Formation

The Laramie formation consists of a few hundred to a thousand or more feet of rather soft, massive sandstones, usually light-colored, together with sandy or clay-shales that may be dark-colored, and many coal beds.

PARTIAL LIST OF THE SOURCES OF DATA CONSULTED IN COMPILING THE DESCRIPTIONS OF THE COLORADO CLAY-BEARING FORMATIONS

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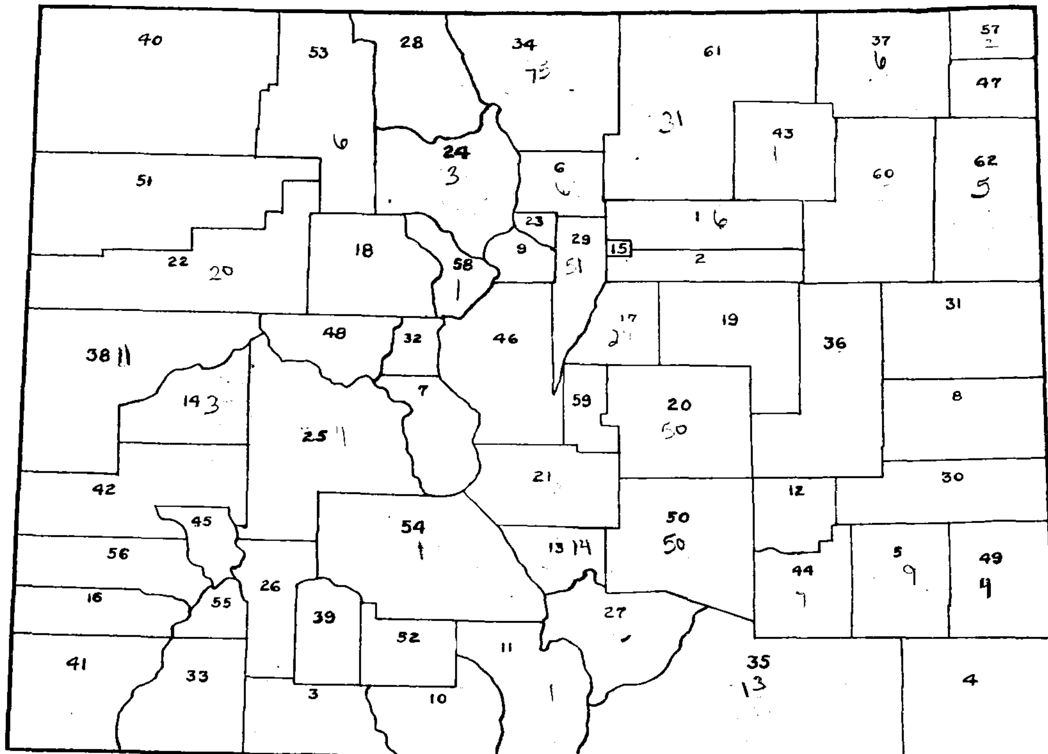
COUNTY MAP OF THE STATE OF COLORADO



NUMBER OF SAMPLES TAKEN IN EACH COUNTY

1.	Adams	6
2.	Arapahoe	0
3.	Archuleta	0
4.	Baca	0
5.	Bent	9
6.	Boulder	68
7.	Chaffee	0
8.	Cheyenne	0
9.	Clear Creek	0
10.	Conejos	0
11.	Costilla	1
12.	Crowley	0
13.	Custer	14
14.	Delta	3
15.	Denver	0
16.	Dolores	0
17.	Douglas	24
18.	Eagle	0
19.	Elbert	0
20.	El Paso	50
21.	Fremont	23
22.	Garfield	20
23.	Gilpin	0
24.	Grand	3
25.	Gunnison	4
26.	Hinsdale	0
27.	Huerfano	25
28.	Jackson	0
29.	Jefferson	51
30.	Kiowa	0
31.	Kit Carson	0
32.	Lake	0
33.	La Plata	0
34.	Larimer	75
35.	Las Animas	13
36.	Lincoln	0
37.	Logan	6
38.	Mesa	11
39.	Mineral	0
40.	Moffat	0
41.	Montezuma	0
42.	Montrose	0
43.	Morgan	13
44.	Otero	7
45.	Ouray	0
46.	Park	0
47.	Phillips	0
48.	Pitkin	0
49.	Prowers	4
50.	Pueblo	50
51.	Rio Blanco	0
52.	Rio Grande	0
53.	Routt	6
54.	Saguache	1
55.	San Juan	0
56.	San Miguel	0
57.	Sedgwick	2
58.	Summit	1
59.	Teller	0
60.	Washington	5
61.	Weld	31
62.	Yuma	5
	Total	535

NOTE—This list and the preceding map were prepared before the creation of Alamosa County.

PART III

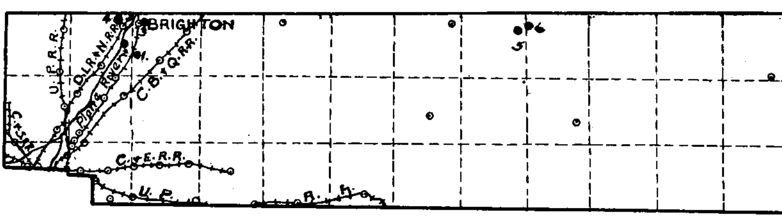
The Location, Occurrence, Field Characteristics, and Economic Value of the Samples Tested

CHAPTER I

Adams County

Geology of the County.—The eastern half of the county is en-entirely underlain with Laramie rocks; but there are extensive deposits of Arapahoe age in the northwestern corner, and a little Denver material to the southeast. A comparatively small area to the west of the center of the southern boundary is covered with Dawson beds.

ADAMS COUNTY



Sketch map showing the approximate locations of the beds sampled

1. *Location:* 3 miles[1] southeast of Brighton; the old brick-yard on Colby's place in Sec. 19.

Occurrence: 3-5 feet is exposed in a pit dug below a level surface on which there is no overburden.

Field Characteristics: Soft, yellowish-brown, massive, sandy clay typical of the soil of a large part of the district.

Economic Value: Should make first-class, red soft-mud bricks if burned to Cone 03.

[1] The distances mentioned in Part III are usually merely guesses and are apt to be more or less incorrect. Not much dependence should be placed upon them when they seem to conflict with other data.

2. *Location:* 2 miles south of Brighton and near the river; ¼ mile southwest of cemetery; just west of "river road."

Occurrence: A 10-foot, horizontal bed with no overburden in the bank of an arroyo in the bottom land near the river. In pockets in alluvial gravel.

Field Characteristics: Medium-hard, brownish-gray, gritty clay of irregular structure, spotted with alkali and sand.

Economic Value: Should make good, pink to red soft-mud bricks if burned above Cone 03.

3. *Location:* 1 mile east of Brighton in Sec. 5; 100 or 200 paces west of road.

Occurrence: A 3-foot exposure along a ditch beneath a gentle, westerly slope. There is no overburden where the sample was taken, but it is probably thick in most places.

Field Characteristics: Soft, yellowish-green, fine-grained, shaly material.

Economic Value: Should make red dry or semi-dry pressed bricks, with an absorption of about 12%, if burned to Cone 05.

4. *Location:* 1 mile west of Brighton, where the main road west of town across the river passes the U. P. track and a large ditch.

Occurrence: A 50-foot exposure with 1-2 feet overburden on a hill rising west of the railroad. The beds have a slight dip.

Field Characteristics: Medium-hard, yellow, brown, and greenish, fine-grained to sandy, thin to thick beds.

Economic Value: Should make good, pink dry-pressed bricks, but must be burned to Cone 01 to bring absorption below 12%. The air shrinkage is much too high (16%) and the tensile strength too low for other uses.

5. *Location:* N. ½ of Sec. 12, Tp. 1 S., R. 61 W.

Occurrence: A 25-foot horizontal bed beneath 8 feet of coal; 85 feet below surface.

Field Characteristics: A soft, greenish clay.

Economic Value: Might make fair, buff dry-pressed bricks, but the absorption would be high and the quality is doubtful.

6. *Location:* S. W. ¼, Sec. 6, Tp. 1 S., R. 60 W.

Occurrence: A 30-foot horizontal bed varying from nothing to over 60 feet from the surface.

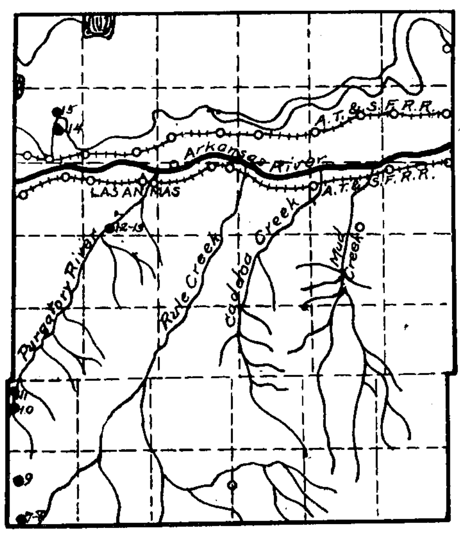
Field Characteristics: Soft, bluish clay.

Economic Value: Should make first-class, red pressed bricks, and might answer for soft-mud and stiff-mud bricks and earthenware if grogged.

Bent County

Geology of the County.—Most of the Arkansas River and the creeks south thereof flow over Dakota sediments. North of the Arkansas are extensive exposures of Benton and Niobrara rocks. Benton beds also form the highlands between the creeks south of the Arkanas. In the extreme southwest corner occur Purgatory and Morrison beds; while Niobrara and Tertiary rocks underlie the extreme southeast corner. A little Tertiary material also occurs along the northern boundary.

BENT COUNTY



Sketch map showing the approximate locations of the beds sampled

7. *Location:* Muddy Gap; 8 miles south of the J. J. Ranch and 3 miles east of Pealed Pine Creek.

Occurrence: A 6-foot horizontal bed underlying 35-50 feet of solid sandstone on a cliff below a high mesa. About 50 feet below the Dakota formation. This sample is the upper 6 feet of a 15-foot bed.

Field Characteristics: A hard, gray to black, medium coarse-grained, sandy, massive clay, with some sandstone seams.

Economic Value: Probably worthless, since burned products are very soft.

8. *Location:* Muddy Gap; 8 miles south of the J. J. Ranch and 3 miles east of Pealed Pine Creek.

Occurrence: A 6-foot horizontal bed underlying 35-50 feet of sandstone on a cliff below a high mesa. About 50 feet below the Dakota formation. This sample is the lower 9 feet of a 15-foot bed.

Field Characteristics: A hard, gray to black, medium coarse-grained, sandy, massive clay, with some sandstone seams.

Economic Value*:* Probably worthless, since burned products are very soft.

9. *Location:* Muddy Gap; 5 miles south of J. J. Ranch.

Occurrence: A 6-foot exposure of horizontal material, with 1-2 feet of overburden, exposed in an irrigation ditch on the side of a knoll. 100 feet below the top of the Morrison formation.

Field Characteristics: Soft, gray to brown, medium-fine to fine, massive clay.

Economic Value: Probably worthless, as the bricks, although attractive and of white color, have a very high absorption (23%).

10. *Location:* Richards Ranch (20 miles southeast of La Junta); ½ mile west of the Purgatory River.

Occurrence: A 9-foot horizontal bed exposed in a well 18-20 feet from the surface. 150 feet below the top of the Dakota formation.

Field Characteristics: A gray, hard, coarse-grained, sandy, massive clay.

Economic Value: Valueless, except for grog.

11. *Location:* J. J. Ranch (20 miles southeast of La Junta); 2 miles northeast of ranch house and ½ mile west of the Purgatory River.

Occurrence: An 8-foot exposure of horizontal material, with 2-6 feet of overburden, exposed on the side of a knoll above the road. 35 feet below the top of the Morrison formation.

Field Characteristics: A soft, greenish-gray, fine-grained, massive clay, exposed in many places along the Purgatory River.

Economic Value: Should make good, reddish-brown pressed bricks if burned to Cone 03, and will answer for soft- and stiff-mud bricks if grogged.

12. *Location:* 4 miles south of Las Animas on the Purgatory River.

Occurrence: A 5-foot exposure of horizontal material, with a foot or less of overburden, on the side of a low knoll along the river bank. Near the top of the Dakota formation.

Field Characteristics: A medium-hard, gray, medium-fine, sandy, massive clay.

Economic Value: Should answer spendidly for a wide variety of purposes, as shown on Table No. 1. Some grogging may be required, but the tensile strength and plasticity are so high as to permit this without injuring the quality of the clay.

13. *Location:* 4 miles south of Las Animas on the Purgatory River.

Occurrence: An 8-foot exposure of horizontal material on the bank of the river, 15 feet below No. 12.

Field Characteristics: A medium-hard, gray, medium-coarse, sandy, shaly clay, with some sandstone seams.

Economic Value: Should make fairly good, red soft-mud bricks, if burned to Cone 05. The cohesion is probably too weak to permit the manufacture of other products

14. *Location:* 8 miles northwest of Las Animas, on Adobe Creek.

Occurrence: An 8-foot exposure of horizontal material, with 3-6 feet of overburden, on the banks of Adobe Creek. Near the base of the Graneros formation.

Field Characteristics: A medium-hard, gray, medium fine-grained, sandy shale, containing sandstone seams.

Economic Value: May make rather soft, very absorbent earthenware, hollow structural materials, and drain tiles, but will wear the dies.

15. *Location:* 8½ miles northwest of Las Animas and ½ mile west of Adobe Creek, above the Fort Lyon Canal.

Occurrence: A 35-foot horizontal bed, with 6 feet or less of overburden, on the side of a knoll. Near the top of the Carlile formation.

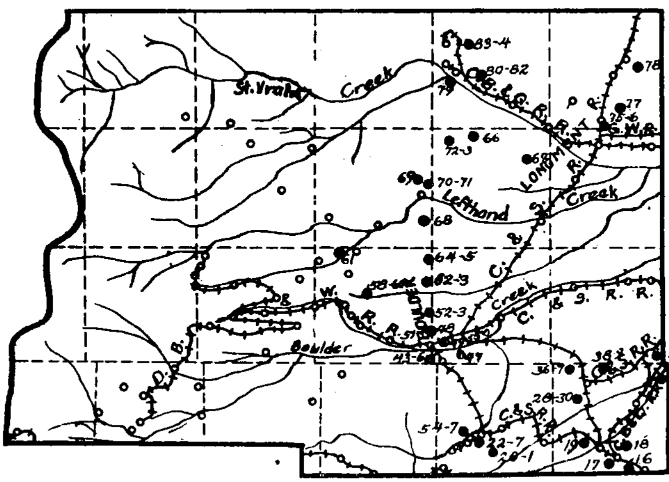
Field Characteristics: Medium-hard, gray to black, fine-grained shale and clay.

Economic Value: The clay has a number of possible uses, but the high absorption and air shrinkage and slightly deficient plasticity tend to lessen its probable value for anything but paving and flashed bricks.

Boulder County

Geology of the County.—The west half of the county is composed mostly of pre-Cambrian crystalline rocks. Bordering this area to the eastward are relatively narrow exposures of all the sedimentary formations, from the Fountain to the Niobrara; and farther east are broader bands of Pierre and Fox Hills rocks. An extensive area of Laramie beds and a small patch of Arapahoe rocks occur in the southeast corner of the county.

BOULDER COUNTY



Sketch map showing the approximate locations of the beds sampled

16. *Location:* In the Sunnyside mine at Louisville Junction.

Occurrence: A 6- to 8-foot bed forming the roof of a coal-seam, 360 feet below collar of the shaft.

Field Characteristics: A medium-hard, gray, fine-grained, massive clay.

Economic Value: High air shrinkage and absorption and somewhat deficient plasticity will probably prevent the use of this clay.

17. *Location:* Burns Junction; ¼ mile west of the station where the C. & S. track is about 8 feet lower than the electric track.

Occurrence: An 8-foot bed on the surface, exposed in the railroad cut.

Field Characteristics: A very hard, gray, finely gritty, thin-bedded clay.

Economic Value: If grogged, should make a fine, buff soft-mud brick or earthenware, and may answer for rather tender terra-cotta.

18. *Location:* North of Burns Junction, where the steam line turns away from the electric track in the first ravine crossed by a bridge.

Occurrence: A 10-foot, nearly level bed, with 2 feet or more of overburden, in the bank of a ravine. This sample is from a lower horizon than No. 17.

Field Characteristics: A very hard, light-gray to yellowish, finely gritty, thin-bedded clay.

Economic Value: Should make good, pink pressed bricks, if burned to Cone 1.

19. *Location:* Near Louisville Junction, in the railroad cut just west of the junction of the steam and electric lines.

Occurrence: A 30-foot exposure of thin beds which dip about 10° easterly and strike N. 30° E., and have 3-6 feet of overburden.

Field Characteristics: A medium-hard, yellowish-green, fine-grained, somewhat gritty, thin-bedded clay, containing a thin coal blossom.

Economic Value: May make good, flesh-colored soft-mud or pressed bricks, if burned carefully to Cone 3. The soft-mud bricks will require grogging. The clay vitrifies well, but would be more likely to make a valuable paver if it burned darker.

20. *Location:* Monarch; in the coal mine at working face of the fourth entry on May 31, 1910.

Occurrence: A 3-foot bed which dips from 5°-20° easterly (?) and strikes about N. 40° E. Below the coal.

Field Characteristics: A soft, light-gray, fine-grained, smooth-feeling, thin-bedded, slaty clay, containing coaly fossil plants.

Economic Value: Should make first-class, light flesh-tinted soft- or stiff-mud bricks, if slightly grogged and burned to Cone 03, and can be manufactured into very attractive pressed bricks, but the absorption will be rather high. Might make paving, fresco, or flashed bricks.

21. *Location:* Monarch; in the coal mine at the entrance of the fourth entry.

Occurrence: A 3-foot bed which dips from 5°-15° easterly (?) and strikes about N. 40° E. Above the coal.

Field Characteristics: Very hard, gray, fine-grained, massive clay, with thin sandy streaks.

Economic Value: Should make first-class, flesh-colored soft-mud or pressed bricks and earthenware; and may yield terra-cotta, hollow structural material, and drain tiles, if grogged. The bricks will have an excessive absorption unless burned almost to vitrification.

22. *Location:* Marshall; in the old Rosser Mine.

Occurrence: A 5-foot bed with a slight easterly dip, forming the roof of a coal-seam in an old coal entry.

Field Characteristics: A very hard, cream-colored, finely gritty clay.

Economic Value: Should make first-class, light-pink soft-mud bricks and, probably, paving-bricks. It may possibly be used for pressed bricks and vitrified or unvitrified floor tiles, but there will be much waste from breakage of the green ware. This clay has many good qualities, and might be very valuable if the plasticity and cohesion could be improved by fine grinding. The addition of a little very plastic clay might produce material of great worth.

23. *Location:* Marshall; old No. 5 slope at the east entrance.

Occurrence: A 6-foot bed with slight easterly dip, with 10 feet of overburden, which forms the roof of the coal-seam at the top of the hill.

Field Characteristics: Medium-hard, light to dark gray, finely gritty, thin-bedded clays.

Economic Value: May make yellow pressed bricks or unvitrified floor tiles, which will be tender before burning and must be heated to at least Cone 03.

24. *Location:* Marshall; above the ditch south of the railroad, half-way between the station and the Gorham mines.

Occurrence: Several 2- to 6-foot beds with a slight easterly dip; near the top of the Laramie escarpment.

Field Characteristics: Very hard, light brownish-gray, fine-grained, massive to thin-beddel clays.

Economic Value: A promising material for the manufacture of paving-bricks.

25. *Location:* Marshall; above the ditch south of the railroad, half-way between the station and the Gorham mines.

Occurrence: A 4-foot bed with a slight easterly dip, half-way up the Laramie escarpment.

Field Characteristics: A medium-hard, yellowish-brown, gritty, thin-bedded clay.

Economic Value: Very promising material for manufacturing paving-bricks, and might make flashed bricks.

26. *Location:* Marshall; above the ditch south of the railroad, half-way between the station and the Gorham mines.

Occurrence: A 15-foot bed with slight easterly dip. Near the base of the Laramie escarpment.

Field Characteristics: A medium-hard, yellowish-brown, gritty, thin-bedded clay.

Economic Value: Should make good, pink soft-mud bricks and, probably, paving or flashed bricks.

27. *Location:* Marshall; above the ditch south of the railroad, half-way between the station and the Gorham mines.

Occurrence: An 8-foot bed with slight easterly dip, near the bottom of the hill.

Field Characteristics: A medium-hard, light brownish-gray, fine-grained, thin-bedded clay.

Economic Value: Will make fair, pink soft-mud bricks if burned to Cone 01, but the air shrinkage will be a bit excessive.

28. *Location:* 1 mile south of Louisville, in the Centennial Mine.

Occurrence: 3 feet was sampled of what is said to be a 10-foot bed which dips 5° easterly and strikes N. 10° W., and underlies a coal-seam about 260 feet from the surface.

Field Characteristics: A very hard, gray, fine-grained, thick-bedded clay.

Economic Value: May make fair, buff soft-mud or pressed bricks or earthenware, but the absorption and air shrinkage are a little high.

29. *Location:* 1 mile south of Louisville, in the Centennial Mine.

Occurrence: A parting in a coal-seam, which varies from 6 inches to 3 feet in thickness, has a dip of 5° easterly, strikes N. 10° W., and lies 260 feet below the surface.

Field Characteristics: A medium-hard, gray, massive clay of variable texture.

Economic Value: Should make good, flesh-colored earthenware if grogged. The bricklets are attractive, but have an excessive air shrinkage. If this were reduced by grogging, the absorption would probably be high.

30. *Location:* 1 mile south of Louisville, in the Centennial Mine.

Occurrence: 4 feet was sampled of what is said to be a 30-foot bed which dips 5° easterly, strikes N. 10° W., and forms the roof of a coal-seam, 260 feet from the surface.

Field Characteristics: A soft, gray, fine-grained, soapy-feeling, thick-bedded clay.

Economic Value: Should make good, buff earthenware and attractive, but highly absorbent, bricks if grogged.

31. *Location:* Lafayette; in the Simpson Mine.

Occurrence: 3-4 feet is exposed of a bed which dips 5°-10° southeasterly, strikes N. 60° E., and forms the floor of a coal-seam, 240 feet below the surface.

Field Characteristics: A medium-hard, dark-gray, thin-bedded clay of variable texture, which contains stringers of coal.

Economic Value: Should make fine, red earthenware and soft-mud or pressed bricks, and, probably, vitrified and flashed bricks. It is possible that grogging will reduce the air shrinkage sufficiently to permit the manufacture of other products.

32. *Location:* Lafayette; in the Simpson Mine.

Occurrence: A 4-foot bed which dips 5°-10° southeasterly, strikes N. 60° E., and forms the roof of a coal-seam, 240 feet below the surface.

Field Characteristics: A very hard, gray, fine-grained, thick-bedded clay.

Economic Value: Should make fine, buff earthenware and flashed bricks. Heavy grogging may permit the manufacture of other bricks.

33. *Location:* Lafayette; in the Simpson Mine.

Occurrence: A parting, 1 foot or more thick, which dips 5°-10° southeasterly, strikes N. 60° E., and occurs in a coal-seam, 240 feet below the surface.

Field Characteristics: A soft, gray, fine-grained, massive clay which is much slickensided.

Economic Value: Should make fine, pink earthenware, flashed bricks, and, possibly, paving-bricks. Heavy grogging may yield other products.

34. *Location:* South of Lafayette, in the Vulcan Mine.

Occurrence: 8 feet is exposed of a nearly level bed which forms the roof of a coal-seam, 180 feet below the collar of a shaft not far from the creek.

Field Characteristics: A medium-hard, gray, fine-grained, massive clay, containing a streak of "soapstone."

Economic Value: Should make good, light-pink earthenware and flashed bricks, and, probably, paving-bricks.

35. *Location:* South of Lafayette, in the Vulcan Mine.

Occurrence: 4 feet is exposed of a nearly level bed which forms the floor of a coal-seam, 180 feet below the collar of a shaft not far from the creek.

Field Characteristics: A medium-hard, gray, finely gritty, massive clay.

Economic Value: Should make fine, buff pressed bricks, and earthenware, flashed bricks, and, probably, paving-bricks. Grogging may yield other products.

36. *Location:* About a mile northwest of Louisville, in a ditch 250 paces west of the electric track.

Occurrence: 30 feet of material, with 3 feet of overburden, which dips 10° northeasterly, strikes N. 35° W., and is exposed in the ditch.

Field Characteristics: Very hard, gray to yellowish, fine-grained, thick-bedded clays.

Economic Value: Grogging is required for any product, and even then the value is doubtful, although good, red soft-mud bricks or earthenware could doubtless be made.

37. *Location:* About a mile northwest of Louisville, in a ditch 250 paces west of the electric track.

Occurrence: The two most promising beds in the 30 feet of material mentioned in No. 36; each bed is about 6 feet thick.

Field Characteristics: Very hard, gray, fine-grained, massive clays.

Economic Value: Grogging is required for any product, and even then the value is doubtful, although good, red soft-mud bricks or earthenware could doubtless be made.

38. *Location:* About a mile northeast of Louisville, at the Summit Mine.

Occurrence: A bed said to be 3 feet thick which has a slight easterly dip, strikes N. 60° East, and occurs 200 feet below the surface.

Field Characteristics: A soft, dark-gray, fine-grained shale.

Economic Value: Should make good, buff earthenware, and will yield attractive pressed bricks of fine quality if burned to Cone 2. Grogging should yield stoneware, drain tiles, and other products.

39. *Location:* About a mile northeast of Louisville, at the Summit Mine.

Occurrence: 2 feet is exposed of what is said to be a 10-foot bed which has a slight easterly dip, strikes N. 60° E., and occurs 200 feet below the surface.

Field Characteristics: A very hard, dark-gray, fine-grained, massive clay, containing thin streaks of sand.

Economic Value: May make light-buff earthenware if grogged, and, possibly, paving-bricks, but the quality of the latter is doubtful.

40. *Location:* Lafayette; Independent Mine.

Occurrence: A 1-4-foot bed which dips 10° northerly, strikes N. 80° W., and occurs between two coal-seams, 120 feet from the collar of a shaft sunk in the creek bottom.

Field Characteristics: A soft, dark-gray, fine-grained, soapy-feeling, massive clay, which is much slickensided.

Economic Value: Will make good, pink soft-mud bricks if burned to Cone 2, and may yield paving-bricks.

41. *Location:* Lafayette; Independent Mine.

Occurrence: A 4-foot bed which dips 10° northerly, strikes N. 80° W., and occurs as the roof of the upper of three coal-seams, 120 feet from the collar of a shaft in the creek bottom.

Field Characteristics: A medium-hard, gray, fine-grained, thin-bedded clay.

Economic Value: Should make exceptionally fine, pink soft-mud and pressed bricks, earthenware, terra-cotta, and floor tiles. Will also probably yield stiff-mud bricks, hollow structural materials, and conduits.

42. *Location:* Lafayette; Independent Mine.

Occurrence: A 4-5-foot bed which dips 10° northerly, strikes N. 80° W., and occurs between the two lower coal-seams in a group of three, 120 feet below the collar of a shaft in the creek bottom.

Field Characteristics: A medium-hard, light-gray, somewhat gritty, massive clay.

Economic Value: Should make fine, pink pressed bricks and unvitrified floor tiles if burned to Cone 3. Heavy grogging may yield other products.

43. *Location:* The Adamant Brick Company's tunnel in Polecat Canon near Boulder.

Occurrence: A 20-foot bed, with 3-4 feet of overburden, which dips 80° easterly, strikes N. 20° W., and occurs on the eastern slope of the Dakota hogback. Near the base of the Graneros formation.

Field Characteristics: Medium-hard, gray, fine-grained, massive clay, which is locally, but erroneously, called "fire-clay."

Economic Value: The plasticity is too low, and the cohesion and absorption too high, to yield a very satisfactory product of any kind.

44. *Location:* Test pit opened by Adamant Brick Company in Polecat Canon near Boulder.

Occurrence: A 2-foot exposure of material, with 2-3 feet of overburden, on the eastern slope of the Dakota hogback. May be a Recent bed.

Field Characteristics: Soft, gray, very fine clay of irregular structure, streaked with brown.

Economic Value: Should make attractive pink pressed and soft-mud bricks, vitrified or unvitrified floor tiles, and, probably, earthenware and stiff-mud bricks. Although fine-grained, it should be tested for paving-bricks.

45. *Location:* In Polecat Canon near Boulder.

Occurrence: A 5-foot bed which dips 75° easterly, strikes N. 20° W., and occurs at the crest of the north end of the Dakota hogback.

Field Characteristics: Very hard, gray, medium-grained, massive clay.

Economic Value: May make red pressed bricks of fair quality, but they will be tender before burning.

46. *Location:* Opening made by the Adamant Brick Company in Polecat Canon near Boulder.

Occurrence: 20-foot bed, with 2 feet of overburden, of obscure dip and strike, near the foot of the hill below the fork in the small stream.

Field Characteristics: A hard, black, medium-grained shale, with streaks of yellow on the weathered surface.

Economic Value: Should make fair, pink building-bricks of any kind.

47. *Location:* The Adamant Brick Company's pit near Boulder.

Occurrence: 40 feet of material, with 1-3 feet of overburden, which dips 15° easterly, strikes N. 10° W., and occurs on the north side of a broad knoll.

Field Characteristics: Medium-hard to soft, yellowish-green and gray, medium-grained, thin beds of shale.

Economic Value: Should make fair, buff to brown building-bricks of any kind, but some grogging will be needed for other than pressed bricks.

48. *Location:* 1,500 feet north and 1,200 feet west of the S.E. Cor., Sec. 25, T. 1 N., R. 71 W.

Occurrence: 25-foot laccolitic cap of igneous rocks, forming the top of small mounds east of the Dakota hogback.

Field Characteristics: Very hard, cream-white, porphyritic, much-jointed, weathered igneous rock.

Economic Value: Should make good, buff pressed bricks and, if slightly grogged, soft- and stiff-mud bricks if burned to Cone 03.

49. *Location:* Boulder Pressed Brick Company's pit on N. 12th Street.

Occurrence: 50 feet of material, with 3-10 feet of overburden, which dips 30° easterly, strikes N. 15° E., and occurs on a low, broad mound. About 1,500 feet above the base of the Pierre formation.

Field Characteristics: Soft (except at bottom), yellowish-green (with dark gray at bottom), medium-fine shales, containing bands and concretions of carbonate of lime and iron.

Economic Value: Should make fine, pink building-bricks of any kind.

50. *Location:* Austin Pressed Brick Company's yard at Boulder

Occurrence: 30 feet of material, with 2 feet of overburden, which dips 15° easterly, strikes N. 10° E., and occurs on the south bank of Boulder Creek, some distance back from the stream. 1,200 feet above the base of the Pierre formation.

Field Characteristics: Medium-hard, yellowish-green, medium-fine shales, which are more or less gritty and contain numerous fossils and concretions and much gypsum.

Economic Value: Should make fair, pink soft-mud or pressed bricks and, possibly, stiff-mud bricks, but burning troubles seem unavoidable.

51. *Location:* Northwest of Boulder, where Seventh Avenue reaches the hogback.

Occurrence: Several 1-2-foot vertical layers, interbedded with 20 feet of sandstone with a north and south strike.

Field Characteristics: Very hard, black, fine-grained, compact clay.

Economic Value: Should make red soft-mud and paving-bricks, and might be used for pressed bricks and vitrified and unvitrified floor tiles, but there is apt to be much waste, due to breakage of the green ware.

52. *Location:* 600 feet north and 1,200 feet west of the S.E. Cor. Sec. 24, T. 1 N., R. 71 W.; north of Boulder in Speer's tunnel.

Occurrence: A sample was taken from the entrance and dump of a 150-foot tunnel on the eastern slope of the Dakota hogback. Near the base of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained, very thin-bedded shales.

Economic Value: Should make fair, pink soft- and stiff-mud bricks with high absorption; also good coated terra-cotta, and, probably, earthenware, hollow structural materials and drain tiles.

53. *Location:* In ravine on Seventh Avenue, where it reaches the foothills north of Boulder.

Occurrence: A 6-foot bed that dips 75° east and strikes N. and S. in a ravine cut in a notch in the Dakota hogback.

Field Characteristics: Very hard, gray-green, fine-grained, compact, marly shales.

Economic Value: May make good, flesh-tinted soft- and stiff-mud bricks if burned above Cone 03; also, possibly, paving-bricks and pressed bricks with high absorption.

54. *Location:* The S.E. ¼ of S.E. ¼ of Sec. 20, T. 1 S., R. 70 W.; on the Thomas Jones ranch.

Occurrence: A 40-foot exposure of material, with 2 feet of overburden, which dips 50° easterly and strikes N. 25° W., on the south side of a gully at the end of a long mesa. Three-fourths of the way up from the base of the Pierre formation.

Field Characteristics: Hard, yellowish-green, medium-grained shales, containing a little grit and narrow bands of concretions.

Economic Value: Should make good, pink soft- or stiff-mud bricks, and probably pressed bricks, with rather high absorption.

55. *Location:* N.W. ¼ of Sec. 29, T. 1 S., R. 70 W.; in cuts on the electric road.

Occurrence: A 15-foot exposure beneath 2-6 feet of overburden at the north end of two long mesas. Near the middle of the Pierre formation.

Field Characteristics: Soft, yellowish-green, somewhat gritty shales, which are coarsely granular on the weathered surface.

Economic Value: Should make good, pink soft-mud bricks and earthenware, and pressed bricks with relatively high absorption. May answer for stiff-mud bricks, but these are apt to be laminated.

56. *Location:* 1,600 feet north and 100 feet west of the S.E. Cor. Sec. 30, T. 1 S., R. 70 W.; at the water's edge on south side of South Boulder Creek.

Occurrence: A 50-foot exposure of beds, with 3 feet of overburden, which dip 60° easterly, strike N. 10° E., and outcrop at the creek level. One-fourth of the way up from the base of the Pierre formation.

Field Characteristics: Medium-hard, blue-gray, fine-grained shales.

Economic Value: May make pink soft- or stiff-mud bricks, but the absorption will be high.

57. *Location:* About 400 feet north and 1,800 feet west of the S.E. Cor. Sec. 19, T. 1 S., R. 70 W.; on the farm of John Dunn.

Occurrence: A 20-foot exposure of material which dips 65° easterly, strikes N. 10° W., and occurs on a tributary to South Boulder Creek. Near the top of the Graneros formation.

Field Characteristics: Soft, gray (with white streaks), very fine-grained shales.

Economic Value: Will make fair, buff soft- or stiff-mud bricks and earthenware.

58. *Location:* In the Sunshine District northwest of Boulder, in a tunnel 1,500 feet north and 400 feet west of the S.E. Cor. Sec. 16, T. 1 N., R. 71 W.

Occurrence: A vertical dyke, 17 feet thick, which strikes N. 70° W. and outcrops on the eastern face of a hill, not far above the bottom of a ravine running northeasterly.

Field Characteristics: Very soft, white, fine-grained, decomposed igneous rock.

Economic Value: Should make good, white soft- or stiff-mud bricks if burned to Cone 03, and pressed bricks if burned to Cone 3.

59. *Location:* Northwest of Boulder in the Sunshine District; 1,900 feet north and 1,100 feet west of the S.E. Cor. Sec. 16, T. 1 N., R. 71 W.

Occurrence: A vertical dyke, 10-15 feet thick, which strikes N. 70° W., and occurs on the hill west from No. 58. Sample comes from the dump of a tunnel.

Field Characteristics: A very hard, white, fine-grained, somewhat altered igneous rock.

Economic Value: Should make fine, flesh-tinted soft-mud and pressed bricks.

60. *Location:* In the Sunshine District northwest of Boulder, in a tunnel 900 feet north and 1,400 feet west of the S. E. Cor. Sec. 15, T. 1 N., R. 71 W.

Occurrence: A vertical dyke, 15 feet thick, which strikes N. 70° W., and outcrops near the bottom of the northwestern face of a hill.

Field Characteristics: A very hard, white, fine-grained, somewhat altered igneous rock.

Economic Value: Should make fine, flesh-tinted soft-mud and pressed bricks, if burned to Cone 1.

61. *Location:* West of Altona on the south side of the road just west of the fork.

Occurrence: A 40-foot exposure, containing several different beds, with 1 foot of overburden, which dip 35° east, strike about N. 40° W., and underlie a low mound.

Field Characteristics: Hard, green and brown, fine-grained, marly shales, containing some limestone and sandstone layers not included in the sample.

Economic Value: Should make attractive, buff to flesh-colored bricks and earthenware, but these must be burned to Cone 1, and there is danger of overburning part of the kiln, as they vitrify at Cone 3.

62. *Location:* 500 feet north and 1,000 feet west of the S.E. Cor. Sec. 12, T. 1 N., R. 71 W.; north of Boulder.

Occurrence: A 300-400-foot exposure of beds which dip 50° east, strike N. 20° E., and occur on the slope east of the Niobrara hogback. Base of the Pierre formation.

Field Characteristics: Medium-hard, yellowish-green, fine-grained shale that weathers black.

Economic Value: Should make fine, red soft-mud bricks and, possibly, pressed bricks if these are not too fragile before burning.

63. *Location:* 200 feet north and 1,200 feet west of the S.E. Cor. Sec. 12, T. 1 N., R. 71 W.; north of Boulder.

Occurrence: A 100-foot exposure of beds which dip 60° easterly, strike north and south, and occur high on the eastern slope of the Dakota hogback. Base of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained shales.

Economic Value: Should make good, pink soft-mud, pressed, and flashed bricks, and terra-cotta. May answer for stiff-mud bricks, earthenware, hollow structural materials, conduits, and fire bricks.

64. *Location:* 300 feet north and 1,800 feet west of the S.E. Cor. Sec. 1, T. 1 N., R. 71 W.; north of Boulder in a stone quarry east of the road; about half-way up the Dakota hogback.

Occurrence: A 20-foot exposure of beds which dip 60° easterly, strike north and south, and occur on the western slope of the Dakota hogback.

Field Characteristics: Hard to soft, red, green, and other colors, fine-grained to gritty, marly shales and clays, containing sandstone and limestone beds not included in the sample.

Economic Value: Should make flesh-tinted soft-mud bricks and, possibly, pressed bricks, but the latter will be fragile before burning. As the clay must be ground, its value is doubtful.

65. *Location:* 400 feet north and 400 feet west of the S.E. Cor. Sec. 1, T. 1 N., R. 71 W.; north of Boulder.

Occurrence: A 50-foot exposure of beds, with 10 feet of overburden, which dip easterly, strike north and south, and outcrop on the western slope of a mesa. In the lower part of the Pierre formation.

Field Characteristics: Medium-hard, brown, fine-grained shales that are somewhat gritty.

Economic Value: Should make beautiful, red soft-mud bricks, but requires grinding. May be made into attractive pressed bricks, but these will be fragile before burning.

66. *Location:* On the east side of a hill in the W. ½ Sec. 4, T. 2 N.; west of Longmont.

Occurrence: An 80-foot exposure of material which dips slightly to the southeast, strikes N. 30° E., and underlies a small, steep-sided knoll. Just below the Hygiene sandstone.

Field Characteristics: Soft, dark-gray, very fine-grained shales, containing some large concretions of carbonate of lime and iron.

Economic Value: Should make good, red soft- and stiff-mud and pressed bricks, but there is apt to be considerable waste due to the fact that the incipient vitrification and vitrification temperatures are separated by but two cones.

67. *Location:* 1,000 feet north and 1,200 feet west of the S.E. Cor. Sec. 11, T. 2 N., R. 70 W.; west of Longmont.

Occurrence: A 20-foot exposure of material, with about 3 feet of overburden, which has a slight easterly dip, strikes N. 30° E., and outcrops in a ditch beside the road. About the middle of the Pierre formation.

Field Characteristics: Medium-hard, yellowish-green, fine-grained shales, containing a little sand and showing an efflorescence of alkali.

Economic Value: Should make fine, red soft-mud bricks and fair pressed bricks which will be fragile before burning.

68. *Location:* 500 feet north and 300 feet west of the S.E. Cor. Sec. 25, T. 2 N., R. 71 W.; north of Boulder.

Occurrence: An exposure of over 100 feet of material that dips 30° E., strikes north and south, and occurs in a ravine in a hill capped with porphyry.

Field Characteristics: Medium-hard, black, fine-grained shales.

Economic Value: Should make fine, red soft-mud bricks and fair pressed bricks which will be fragile before burning.

69. *Location:* One-fourth of a mile northwest of Altona, and north of the fork in the road.

Occurrence: This sample was taken from material dumped on the bank of a ditch and may be a Recent deposit.

Field Characteristics: Soft, yellowish-gray, fine-grained, gritty or chalk-like clay.

Economic Value: Should make a fine, dark-scarlet coloring agent, and may be used for making pressed bricks, or vitrified or unvitrified floor tiles.

70. *Location:* Just north of the blacksmith shop at Altona, along a ditch around the hill.

Occurrence: A bed about 3 feet thick which dips 25° E., strikes N. 5° W., and occurs on the western slope of the Dakota hogback. It is probably of Morrison age, although Mr. Grout was inclined to classify it as Lower Dakota.

Field Characteristics: Medium-hard, green, sandy shale.

Economic Value: Should make good soft-mud bricks, but must be ground and burned to Cone 1. May answer for pressed bricks, unvitrified floor tiles, and earthenware.

71. *Location:* One-fourth of a mile north of Altona, where a ditch from a reservoir crosses a divide in the Dakota hogback.

Occurrence: 10-12-foot exposure of material which dips 25° easterly, strikes N. 5° W., and occurs in a small valley between harder beds in the Dakota hogback. Probably of Dakota age, but is close to the Graneros shales.

Field Characteristics: Medium-hard, black, fine-grained shale with sandstone streaks.

Economic Value: Should make good, flesh-tinted soft-mud bricks and pressed bricks which will be fragile before burning.

72. *Location:* 600 feet north and 700 feet west of the S.E. Cor. Sec. 6, T. 2 N., R. 70 W.; south of Lyons.

Occurrence: The sample includes 10 feet of the less sandy material in a thicker exposure of beds which dip 15° easterly, strike N. 20° E., and occur on the bank of a ditch that crosses a ravine just east of the road.

Field Characteristics: Medium-hard, black and brown, sandy shales, containing streaks of sandstone.

Economic Value: Should make fair, red soft-mud bricks, but must be burned to Cone 1.

73. *Location:* 1,800 feet north and 1,500 feet west of the S.E. Cor. Sec. 7, T. 2 N., R. 70 W.; south of Lyons.

Occurrence: A 5-foot bed, with a foot or more of overburden, which dips 15° easterly, strikes N. 20° E., and occurs at the side of the road which follows the longitudinal valley or glade along the Dakota hogback.

Field Characteristics: Very hard, gray, sandy clay.

Economic Value: This should make fine grog, and might make paving-bricks if it can be handled.

74. *Location:* 1,500 feet north and 500 feet west of the S.E. Cor. Sec. 25, T. 10 N., R. 70 W.; about 2 miles east and 1 mile north of Forks Hotel; in Larimer County. (A mistake was made in locating this clay on the map from which the samples were numbered. This accounts for the fact that it is described here with the Boulder County samples.)

Occurrence: A 4-foot bed which dips 30° N., strikes N. 75° W., and occurs at the head of a short arroyo which drains into the North Poudre ditch where it leaves the Dakota hogback. There are a series of ripple-marked beds a few feet above this one.

Field Characteristics: Medium-hard, light-gray, very fine-grained shale.

Economic Value: Should make fine, pink soft-mud and pressed bricks and earthenware; also, possibly, terra-cotta, hollow structural materials, and conduits, but these will be fragile before burning and may warp.

75. *Location:* 200 feet north and 200 feet west of the S.E. Cor. Sec. 32, T. 3 N., R. 69 W.; in the Brick Company's pit at Longmont.

Occurrence: A 15-foot exposure of beds, with 1 foot of overburden, which dip slightly to the east, strike N. 30° E., and occur on a gentle westerly slope. Near the top of the Pierre formation. This sample includes only the lowest 4 feet.

Field Characteristics: Medium-hard, yellowish-green, fine-grained, thick and thin beds of clay, containing a little grit.

Economic Value: Should make good, salmon-pink soft-mud or pressed bricks and fair earthenware. It has been used for making drain tiles as well as bricks, but the shrinkage is too high, the absorption too low, and the plasticity deficient for the manufacture of a good grade of tiles. Grog is used in the bricks and reduces the air shrinkage.

76. *Location:* 200 feet north and 200 feet west of the S.E. Cor. Sec. 32, T. 3 N., R. 69 W.; in the Brick Company's pit at Longmont.

Occurrence: A 15-foot exposure of beds, with 1 foot of overburden, which dip slightly to the east, strike N. 30° E., and occur on a gentle westerly slope. Near the top of the Pierre formation. This sample comprises the 11 feet of clay at the top of the exposure.

Field Characteristics: Medium-hard, yellowish-green, fine-grained, thick and thin beds of clay, containing a little grit.

Economic Value: Should make good, salmon-pink soft-mud or pressed bricks and fair earthenware. It has been used for making drain tiles as well as bricks, but the shrinkage is too high, the absorption too low, and the plasticity deficient for the manufacture of a good grade of tiles. Grog is used in the bricks and reduces the air shrinkage.

77. *Location:* On the Longmont Water Supply Pipe Line; just north of McCall Lake.

Occurrence: A 200-foot exposure of material, with 1 foot of overburden, which dips 75° easterly, strikes N. 30° E., and occurs on the gentle slope north of the lake. Near the base of the Pierre formation.

Field Characteristics: Soft, yellowish-green, slightly gritty shales.

Economic Value: Should make good, pink soft-mud and pressed bricks, terra-cotta, and, probably, stiff-mud bricks, earthenware, hollow structural materials, and drain tiles, although the plasticity is a little low for some of these. It may possibly answer for unvitrified roofing-tiles if the air shrinkage is not too high or grogging does not lower the plasticity too much.

78. *Location:* 400 feet north and 2,000 feet west of the S.E. Cor. Sec. 23, T. 3 N., R. 69 W.; in the C. & S. railroad cut; north of Longmont.

Occurrence: A 10-foot exposure of material, with 2 feet of overburden, which is nearly horizontal and underlies gentle slopes. Near the top of the Pierre formation.

Field Characteristics: Soft, yellowish-green, fine-grained shales, which contain some grit and sandy streaks.

Economic Value: Should make good, pink soft-mud and pressed bricks and terra-cotta; also, probably, stiff-mud bricks, earthenware, hollow structural materials, and conduits, although the plasticity is somewhat deficient for some of these.

79. *Location:* About the middle of the south side of Sec. 17, T. 3 N., R. 70 W.; south of Lyons.

Occurrence: A 6-foot bed which dips 30° easterly, strikes N. 20° E., and occurs about half-way up the western side of the Dakota hogback.

Field Characteristics: Hard, green, medium-grained shales and clays. Interbedded with 6- to 12-inch layers of "lithographic" limestone.

Economic Value: Probably worthless.

80. *Location:* S.W. Cor. Sec. 21, T. 3 N., R. 70 W.; east of Lyons.

Occurrence: A 10-foot exposure of material, with 1 foot of overburden, which dips 15° easterly, strikes N. 25° E., and occurs in a ditch at base of a hill.

Field Characteristics: Soft, black, fine-grained shales.

Economic Value: Should make fair, pink building-bricks and earthenware, but the stiff-mud bricks may be laminated.

81. *Location:* A little south of the middle of the south side of Sec. 20, T. 3 N., R. 70 W.; east of Lyons.

Occurrence: Sample includes 8 feet of the less sandy material in a wider exposure of beds which dip 80° easterly, strike

N. 40° W., and outcrop on the northeastern bank of a ravine back of the hogback. May be of Dakota age, since there appears to be not over 15 feet of hard sandstone above it.

Field Characteristics: Medium-hard, black, fine-grained shale, containing streaks of sandy shale.

Economic Value: Good for nothing but red soft-mud bricks.

82. *Location:* 800 feet north and 1,400 feet west of the S.E. Cor. Sec. 20, T. 3 N., R. 70 W.; along a ditch.

Occurrence: A 6-foot exposure of material that dips 25° easterly, strikes N. 5° W., and occurs half-way down the gentle slope east of the main Dakota hogback.

Field Characteristics: Soft, blue to light-gray, sandy shales and clays.

Economic Value: Should make attractive, light-pink, non-vitrified floor tiles and building-bricks of all kinds, but the soft- and stiff-mud bricks will be fragile before burning.

83. *Location:* 1,500 feet north and 1,200 feet west of the S.E. Cor. Sec. 9, T. 3 N., R. 70 W.; northeast of Lyons.

Occurrence: Sample comes from the dump of a 60-foot shaft on the slope of the Dakota hogback. Near the middle of the Graneros formation.

Field Characteristics: Rather hard, black, fine-grained shales.

Economic Value: Probably worthless.

84. *Location:* 1,500 feet north and 1,000 feet west of S.E. Cor. Sec. 10, T. 3 N., R. 70 W.; northeast of Lyons.

Occurrence: A 10-foot exposure of material, with 2 feet of overburden, that dips 70° westerly, strikes N. 20° W., and outcrops in a transverse valley, crossing the hogback.

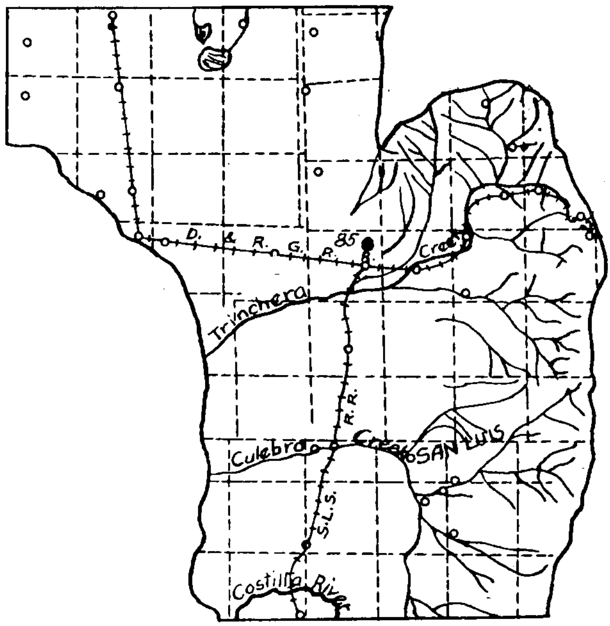
Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Should make good, red soft-mud and pressed bricks and, probably, earthenware, terra-cotta, and stiff-mud bricks, but the last may be laminated.

Costilla County

Geology of the County.—The geology of Costilla County is too complex to be described without the aid of a detailed map. Most of the rocks near centers of population, however, are Tertiary lake deposits.

COSTILLA COUNTY



Sketch map showing the approximate locations of the beds sampled

85. *Location:* At the south base of Mount Blanca.

Occurrence: The sample was collected and sent in by J. C. Ross and F. L. Beckwith, who furnished no information concerning its occurrence.

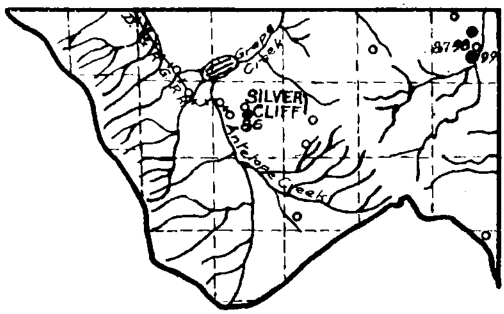
Field Characteristics: Hard, varicolored, fine-grained, massive clay, which is more or less sandy and conglomeritic.

Economic Value: Might make red pressed bricks, but these would have to be burned to Cone 03, and would vitrify at Cone 01.

Custer County

Geology of the County.—The only sedimentary rocks of the formations described in this report occur in the northeast corner of the county, where all the systems from the Fountain to the Pierre are represented.

CUSTER COUNTY



Sketch map showing the approximate locations of the beds sampled

86. *Location:* Near Silver Cliff.

Occurrence: The sample was collected and sent in by Mr. J. T. Stroehlke, who claims to own 60 acres of this material, but gives no further details concerning its occurrence.

Field Characteristics: Hard, white, medium-fine clay.

Economic Value: Should make fair, somewhat soft, cream-colored soft-mud bricks if burned to Cone 08.

87. *Location:* About 12 miles south of Florence.

Occurrence: A 4-foot bed which dips 45° northeasterly, strikes N. 45° W., and occurs near the top of the Dakota hogback.

Field Characteristics: Medium-hard, brown, coarse-grained, rather nodular clay.

Economic Value: Should make very nice, pink soft-mud and pressed bricks, earthenware, and unvitrified floor tiles; also, possibly, stiff-mud bricks, terra-cotta, hollow structural materials, and conduits, but the first will probably be laminated, and grog will have to be used for the others.

88. *Location:* 12 miles south of Florence.

Occurrence: 3-foot bed which dips 45° northeasterly, strikes N. 45° W., and occurs near the top of the Dakota hogback.

Field Characteristics: A hard, green, coarse-grained clay.

Economic Value: Should make soft, red soft-mud bricks.

89. *Location:* 12 miles south of Florence.

Occurrence: A 3-foot bed which dips 45° northeasterly, strikes N. 45° W., and occurs 60 feet below the top of the Dakota hogback.

Field Characteristics: A medium-hard, lavender and green, fine-grained, compact clay.

Economic Value: Should make good, buff-colored building-bricks of any kind.

90. *Location:* 12 miles south of Florence.

Occurrence: A 10-foot bed which dips 45° northeasterly, strikes N. 45° W., and outcrops in the bottom of the gulch, 100 feet below the top of the Dakota hogback.

Field Characteristics: Hard, lavender and green, coarse-grained, gritty clay.

Economic Value: Should make first-class, buff to brown pressed bricks and earthenware; and soft-mud bricks if grogged. Heavy grogging may yield terra-cotta, hollow structural materials, and conduits. It may also make paving-bricks.

91. *Location:* 12 miles south of Florence.

Occurrence: A bed of unstated thickness which dips 45° northeasterly, strikes N. 45° W., and occurs 150 feet below the top of the Dakota hogback.

Field Characteristics: Medium-hard, lavender and green, coarse, gritty clay.

Economic Value: Will make only fine, buff soft-mud bricks and, possibly, paving-bricks.

92. *Location:* 12 miles south of Florence.

Occurrence: A 30-foot bed which dips 45° northeasterly, strikes N. 45° W.; and occurs in the bottom of a gulch 150 feet below the top of the Dakota hogback.

Field Characteristics: A hard, lavender and green, coarse-grained clay.

Economic Value: Should make fine, buff to red pressed bricks. Grogging should yield earthenware, soft- and stiff-mud bricks, and, possibly, other products.

93. *Location:* 12 miles south of Florence.

Occurrence: A 12-foot bed in the bottom of the gulch below the Dakota hogback.

Field Characteristics: A soft, brown, coarse-grained clay.

Economic Value: May make buff pressed bricks, but is apt to swell badly on burning.

94. *Location:* 12 miles south of Florence.

Occurrence: A 10-foot bed 50 yards up the gulch from No. 93.

Field Characteristics: A medium-hard, gray and red, fine-grained clay.

Economic Value: Should make good, buff soft-mud bricks if burned to Cone 1.

95. *Location:* 12 miles south of Florence.

Occurrence: A 30-foot bed in the bottom of the gulch at the base of the Dakota hogback.

Field Characteristics: A soft, white, fine-grained, marly clay, containing some grit.

Economic Value: Should make rather soft, drab earthenware if grogged. The absorption is much too high for bricks.

96. *Location:* 12 miles south of Florence.

Occurrence: A 5-foot bed; occurrence otherwise unstated.

Field Characteristics: A hard, red, fine-grained clay.

Economic Value: Should make good, red soft-mud bricks, especially if grogged slightly; and, probably, flashed bricks.

97. *Location:* 12 miles south of Florence.

Occurrence: A 12-15-foot bed which dips 45° northeasterly, and strikes N. 45° W.; probably at the top of the Morrison formation.

Feld Characteristics: A soft, white, fine-grained clay.

Economic Value: An extraordinarily high absorption probably makes this material worthless, except, possibly, for earthenware if grogged.

98. *Location:* 12 miles south of Florence.

Occurrence: A 2-foot bed which dips 45° northeasterly and strikes N. 45° W.

Field Characteristics: A hard, green, fine-grained clay.

Economic Value: Should make good, buff bressed bricks and unvitrified floor tiles.

99. *Location:* 14 miles south of Florence.

Occurrence: A 5-6-foot bed which dips 75° westerly, and occurs near the top of the Dakota hogback.

Field Characteristics: A hard, black, fine-grained clay.

Economic Value: This is a first-class fire-clay.

Delta County

Geology of the County.—The only locality visited in Delta County was the city of Delta itself and the surrounding district. A number of samples were there taken, but were lost by the railroad in transit to Golden, and press of other duties prevented another trip to the locality. It may be said, however, that the Mancos formation is the only one represented within many miles of town. The city itself is on beds of Benton age, and this material is being used by the Delta Brick and Tile Company on the western side of the Gunnison River, opposite the town. The bricks are hard and are said to resist alkali, but to check on the surface. The fact that they burn to a yellow color in the interior of the stack, and pink on the exterior, indicates that the atmosphere is not sufficiently oxidizing and that changed burning conditions would be beneficial. There seems no reason why a good brick cannot be made, if the proper methods are employed. Several miles north and east of Delta occurs a great expanse of material of Pierre age, which is highly gypsiferous. It resembles No. 400 very closely, so far as appearance is concerned, and is probably of no greater value.

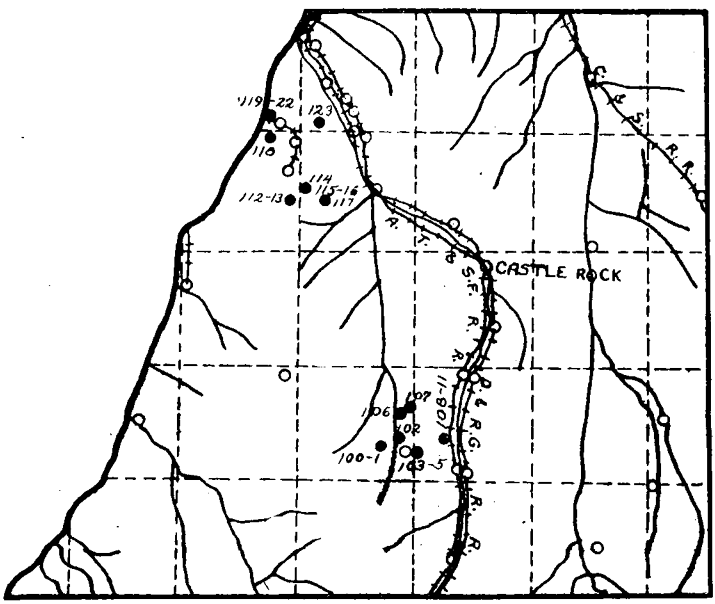
Denver County

No samples were taken in Denver or Arapahoe County, as the clay resources of both have been fairly well investigated, and it was thought best to confine this report to areas concerning which less was known. It was planned, however, to do a little work in these counties, if time permitted, but the sudden removal of the author to Oregon prevented the consummation of these plans.

Douglas County

Geology of the County.—The western half of the county is almost entirely pre-Cambrian crystalline rocks, although some sediments, of Fountain age and older, occur along Trout Creek on the southern boundary. The eastern half of the county is largely underlain by rocks of Dawson age, with numerous exposures of Castle Rock conglomerates capping the higher elevations. Between these two areas occur upturned sediments of all ages from the Fountain to the Laramie, but these pinch out near the center of the county and near the southern boundary.

DOUGLAS COUNTY



Sketch map showing the approximate locations of the beds sampled

100. *Location:* In Perry Park; 1 mile north of the store and ¼ mile west of the road.

Occurrence: A 6-foot bed, with 3 feet of overburden, which dips 21° N., strikes N. 18° W., and occurs two-thirds of the way up the southwestern slope of the Dakota hogback. 100 feet below the "spotted sandstone."

Field Characteristics: Soft to medium-soft, red, gray and spotted, medium-fine, marly clays.

Economic Value: This clay burns pink and has a wide variety of uses, as shown on Table No. 1. Possibly the best features are its high fusion point and low air shrinkage, while its comparatively low tensile strength detracts from the value of what would otherwise be a very valuable clay.

101. *Location:* Perry Park; ¼ mile north of the Park lake and 200 feet west of the public road.

Occurrence: An 8-foot exposure of material, with 2 feet of overburden, that dips 21° N., strikes N. 80° W., and occurs along the base of the Dakota hogback. 100 feet above the base of the Graneros formation.

Field Characteristics: Medium-soft, black, fine-grained shale.

Economic Value: Should make good, red pressed bricks, and, possibly, if grogged, soft- and stiff-mud bricks.

102. *Location:* Perry Park; ½ mile north of the store, beside the road, on "Adobe Hill."

Occurrence: A 2-foot bed, with 1 foot of overburden, which dips 20° northerly, strikes N. 80° W., and occurs on the western side of the Dakota hogback, near the brook.

Field Characteristics: Soft, gray, fine-grained, marly clay.

Economic Value: Should make fair, buff bricks and earthenware if care is used in burning.

103. *Location:* Perry Park; ¾ of a mile east of the store.

Occurrence: An 8-foot bed, with 2 feet of overburden, which dips 56° northeasterly, strikes N. 34° W., and occurs on the western side of a hogback. 100 feet above the base of the Morrison formation.

Field Characteristics: Soft to medium-hard, black, gray, and yellow, medium-coarse to fine-grained shales and clays, part of which are sandy.

Economic Value: Should make fine, light flesh-tinted soft-mud and pressed bricks, earthenware, and, possibly, terra-cotta, providing the air shrinkage, which was not tested, is not excessive.

104. *Location:* Perry Park; ¾ of a mile east of the store.

Occurrence: A 4-foot bed, with 8 feet of overburden, which dips 56° northeasterly, strikes N. 34° W., and occurs on the western side of a hogback. 80 feet above the base of the Morrison formation.

Field Characteristics: A soft, gray, very fine-grained, waxy shale, which contains 2 inches of crystalline gypsum.

Economic Value: Should make good, pink pressed bricks, and heavy grogging may yield soft- and stiff-mud bricks.

105. *Location:* Perry Park; ½ mile east of the store.

Occurrence: An 8-foot bed with 2 feet of overburden, which dips 20° northeasterly, strikes N. 65° W., and occurs on the eastern side of the Lykins-Lyons hogback. 10 feet below the "crinkled limestone."

Field Characteristics: Soft, red, medium coarse-grained, sandy shales.

Economic Value: Should make good, pink soft-mud bricks and earthenware.

106. *Location:* Perry Park; 2 miles north of the store in Kerr's pasture.

Occurrence: A 1-foot exposure of material, with 1 foot of overburden, which occurs on the side of a small knoll, back of Mr. Kerr's ranch-house. About 800 feet above the basal limestone member of the Niobrara formation, and may belong to the Pierre formation.

Field Characteristics: A soft, gray, medium coarse-grained, sandy clay.

Economic Value: Probably worthless.

107. *Location:* Perry Park; 2½ miles north of the store, near a wire fence, and 600 feet below the Laramie sandstone outcrop.

Occurrence: A 2-foot bed, with 1 foot of overburden, which dips 41° northeasterly, strikes N. 46° W., and occurs on the northern side of an arroya, on the western side of the Laramie hogback. Several such beds alternate with sandstone layers. About 250 feet above the basal sandstone of the Laramie formation.

Field Characteristics: A soft, gray to yellow, fine-grained sandy shale.

Economic Value: Might make paving-bricks, but the color is not such as to make this very probable.

108. *Location:* 2½ miles north of Larkspur; 500 feet west of the D. & R. G. R. R. Owned by Mr. Ware and leased by the Denver Sewer Pipe and Clay Company.

Occurrence: A 4-foot, lens-shaped bed, with 16 feet of overburden, at the base of a large knoll. 600 feet below the top of the Dawson formation.

Field Characteristics: Medium-hard, red and gray, medium coarse-grained, sandy clay.

Economic Value: Should make good, red building-bricks, but those made by the stiff-mud process are apt to be tender. Should also make paving-bricks. It is said that this material is shipped for the manufacture of tiles, but these would certainly be fragile before burning, and would probably warp somewhat.

109. *Location:* 2½ miles north of Larkspur; 500 feet west of the D. & R. G. R. R. Owned by Mr. Ware and leased by the Denver Sewer Pipe and Clay Company.

Occurrence: A 7-foot, lens-shaped bed, with 11 feet of overburden, at the base of a large knoll. 600 feet below the top of the Dawson formation.

Field Characteristics: Medium-hard, red and gray, medium coarse-grained, sandy clay.

Economic Value: Should make good, red building-bricks, but those made by the stiff-mud process are apt to be tender. Should also make paving-bricks. It is said that this material is shipped for the manufacture of tiles, but these would certainly be fragile before burning.

110. *Location:* 2½ miles north of Larkspur; 500 feet west of the D. & R. G. R. R. Owned by the Denver Sewer Pipe and Clay Company.

Occurrence A 4-foot, lens-shaped bed, with 30 feet of overburden, on the western side of a knob-shaped hill.

Field Characteristics: Hard, gray and red, medium coarse-grained, sandy clay.

Economic Value: Should make good, red soft-mud and pressed bricks and, probably, paving-bricks. Tiles made from this clay would be fragile before burning, and might have other imperfections resulting from the weak cohesion.

111. *Location:* 2½ miles northwest of Larkspur; ½ mile west of the D. & R. G. R. R.

Occurrence: A 5-foot horizontal bed, probably lens-shaped, with 1 foot of overburden, which occurs on the side of a knoll in Mr. Ware's pasture. 400 feet below the top of the Dawson formation.

Field Characteristics: A soft, yellow, medium coarse-grained, sandy clay.

Economic Value: Should make good, red soft-mud and pressed bricks and, probably, paving-bricks.

112. *Location:* 6 miles west of Sedalia; 1½ miles west of the large hogback formed by the basal Dawson beds.

Occurrence: 2-4-foot bed which dips 51° northeasterly, strikes N. 53° W., and occurs on the eastern side of the Lykins-Lyons hogback, 40 feet from an arroya containing a brook. 10 feet above the "crinkled limestone."

Field Characteristics: Medium-hard to medium-soft, red, medium fine-grained, sandy clay.

Economic Value: Probably worthless.

113. *Location:* 6 miles west of Sedalia; 1 mile west of the large hogback formed by the basal Dawson beds.

Occurrence: A 7-foot bed, with 6-18 feet of overburden, that has an indeterminate dip, strikes N. 57° W., and occurs near the western base of the Dakota hogback. 100 feet below the top of the Morrison formation.

Field Characteristics: A soft, gray, fine-grained, marly clay.

Economic Value: Might make fair, brownish pressed bricks, but these would have to be burned to Cone 05, and would vitrify and fuse at Cone 03.

114. *Location:* 5 miles west of Sedalia; ½ mile northwest of the large hogback formed by the basal Dawson beds.

Occurrence: A 2-foot exposure, with 4 feet of overburden, which has indeterminate dip and strike, and occurs in an arroya containing a brook.

Field Characteristics: A soft, yellowish-drab, fine-grained, sandy clay.

Economic Value: Probably worthless, but might make attractive, red pressed bricks if burned to a low temperature.

115. *Location:* 4 miles west of Sedalia, near an old coal mine.

Occurrence: A 4-foot bed, with 3 feet of overburden, which dips 70° northeasterly, strikes N. 42° W., and occurs in an arroya on the western side of the Laramie knoll near a group of abandoned buildings. 75 feet above the coal-bed.

Field Characteristics: A soft, dark-brown, fine-grained shale.

Economic Value: May make attractive, white or cream-tinted pressed bricks, vitrified or unvitrified floor tiles, or wall tiles, but these will be fragile before burning.

116. *Location:* 4 miles west of Sedalia, near a group of abandoned buildings.

Occurrence: An 8-foot bed, with 3 feet of overburden, which dips 70° northeasterly, strikes N. 42° W., and occurs in the western side of the Laramie knoll, 65 feet above the coal-bed.

Field Characteristics: A medium-soft, black, medium fine-grained clay.

Economic Value: Should make good, cream-colored to white soft-mud bricks, and may answer for pressed bricks, vitrified and unvitrified floor tiles, and wall tiles, but these may be fragile before burning.

117. *Location:* 4 miles west of town in an arroya; 400 feet from an old windmill.

Occurrence: A 15-foot bed, with 1 foot of overburden, which occurs near the western base of the Laramie hogback. 50 feet below the top of the Fox Hills formation.

Field Characteristics: A soft, gray, fine-grained, sandy shale.

Economic Value: Should make fine, red pressed bricks.

118. *Location:* 1 mile southeast of the railroad station at Platte Canon.

Occurrence: A 1-foot bed, with 8 feet of overburden, which dips 51° E., strikes N. 20° W., and is exposed in an abandoned tunnel on the eastern side of the Dakota hogback. About 50 feet below the top of the Dakota formation.

Field Characteristics: A hard, black, fine-grained clay.

Economic Value: One of the best fire-clays tested, and should make fine, white pressed bricks, wall tiles, and, possibly, vitrified or unvitrified floor tiles, although the absorption is a little high for the latter.

119. *Location:* ¾ of a mile east of the railroad station at Platte Canon.

Occurrence: A 5-foot bed, with 1½ to 10 feet of overburden, which dips 51° easterly, strikes N. 20° W., and occurs near the eastern base of the Dakota hogback. Near the base of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained shales.

Economic Value: Should make good, flesh-colored building-bricks of all kinds, but the stiff-mud bricks may be laminated.

120. *Location:* ¾ of a mile east of the railroad station at Platte Canon.

Occurrence: A 5-foot bed which dips 51° easterly, strikes N. 20° W., and is exposed in a tunnel at the north end of the Dakota hogback. 100 feet below the top of the Dakota formation.

Field Characteristics: Hard, black to dark-gray, fine-grained clay, containing more or less sand.

Economic Value: Should make fine, white soft-mud bricks and, probably, pressed bricks and vitrified and unvitrified floor tiles, but these will be fragile before burning. This clay has been used for manufacturing white pressed face bricks.

121. *Location:* 1 mile east of the railroad station at Platte Canon.

Occurrence: A 9-foot bed, with 3 feet of overburden, which dips 67° northeasterly, strikes N. 55° W., and occurs on the western side of the Niobrara hogback in a cut leading to the limestone quarry. At the top of the Carlile formation.

Field Characteristics: Medium-hard, gray, medium fine-grained, sandy shales and clays.

Economic Value: Should make fine, dark flesh-tinted soft-mud bricks and, possibly, pressed bricks which will be fragile before burning.

122. *Location:* 1 mile east of the railroad station at Platte Canon.

Occurrence: 12 feet was sampled of a larger exposure of material, with 3 feet of overburden, which dips 67° northeasterly, strikes N. 55° W., and occurs on the western side of the Niobrara hogback in a cut leading to the limestone quarry. 10 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard, yellow, medium fine grained clay, which is calcareous and contains four thin seams of crystalline gypsum in the 12 feet sampled.

Economic Value: May make good, pink earthenware, and has been used for manufacturing deep-yellow bricks, but the absorption is above 20%. The yellow color resulted from burning in a reducing atmosphere.

123. *Location:* 3 miles east of the railroad station at Platte Canon.

Occurrence: 10 feet was sampled of a thicker exposure of material, with 10 feet of overburden, which occurs on the northern side of an arroya in gently rolling country. 1,500 feet above the coal in the Laramie formation.

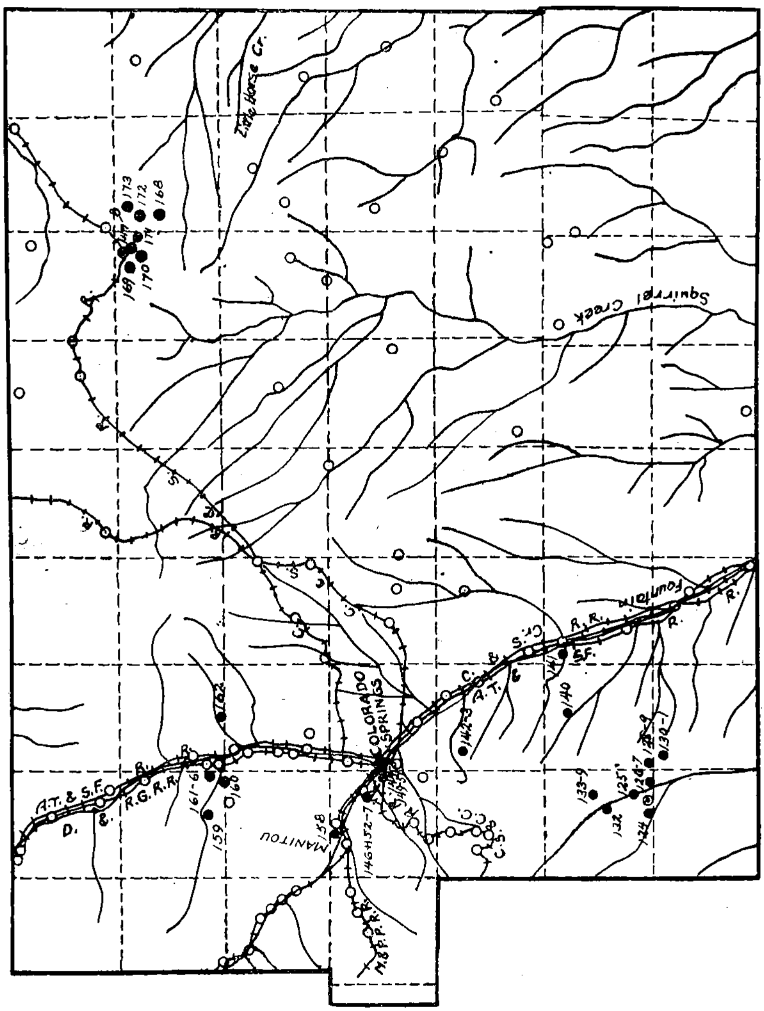
Field Characteristics: Soft, dark-gray, medium fine-grained shales and clays.

Economic Value: Should make good, buff pressed bricks.

El Paso County

Geology of the County.—The eastern quarter of the county is covered with sediments of Miocene or Pliocene age, while a considerable area of pre-Cambrian crystalline rocks lies along all but the southern end of the west boundary. Between these two areas lie extensive deposits of Pierre sediments to the south, and

Dawson sediments to the north, separated by narrower exposures of Fox Hills and Laramie age. Northwest of Colorado Springs and in the extreme southwest corner of the county are also found upturned exposures of all the formations from the Niobrara to the Fountain, and even some earlier ones not described in this report.



EL PASO COUNTY

Sketch map showing the approximate locations of the beds sampled

124. *Location:* 200 yards west of the Lytle post-office, across the road.

Occurrence: 20 feet was sampled of a more extensive exposure of material which dips 4° easterly, strikes N. 18° W., and occurs in the eastern side of a knoll. 150 feet below the top of the Morrison formation.

Field Characteristics: Soft, drab, medium fine-grained shales and clays.

Economic Value: Should make good, buff building-bricks of any kind, but may need some grogging.

125. *Location:* ¼ of a mile northeast of the Lytle post-office.

Occurrence: An 8-foot bed, with 65 feet of overburden, which dips 4° easterly, strikes N. 18° W., and outcrops on the western side of an arroya in the Dakota hogback. 60 feet below the top of the Morrison formation.

Field Characteristics: Medium-hard, gray, medium coarse-grained, sandy clay.

Economic Value: Probably worthless.

126. *Location:* ¾ of a mile east of the Lytle post-office.

Occurrence: A 2½-foot bed, with 25 feet of overburden, which dips 4° easterly, strikes N. 18° W., and occurs in a cut on the public road near Turkey Creek. 80 feet below the top of the Morrison formation.

Field Characteristics: A hard, dark-gray, fine-grained shale.

Economic Value: Should make good, pink pressed bricks, probably paving-bricks, and, possibly, soft-mud bricks, but the last will be fragile before burning.

127. *Location:* 1 mile east of the Lytle post-office, on Thurston's ranch.

Occurrence: A 4-foot exposure of material, with 14 feet of overburden, which dips 4° easterly, strikes N. 18° W., and occurs in a well in the level valley on the eastern side of the Dakota hogback. At the top of the Carlile formation.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Should make good, dark-red pressed bricks if burned to Cone 03.

128. *Location:* In Crooked Canon; 1 mile east of Thurston's ranch, and 2 miles east of the Lytle post-office.

Occurrence: A 25-foot exposure of material, with 35 feet of overburden, which dips 4° easterly, strikes N. 18° W., and occurs above the road. Above the material sampled occur 10 feet of concretionary limestone and 25 feet of Fox Hills shales.

Field Characteristics: Medium-hard, gray to black, medium fine-grained shales, containing much gypsum and some carbonate of calcium and iron concretions.

Economic Value: Probably worthless.

129. *Location:* In Crooked Canon; 1 mile east of Thurston's ranch, and 2 miles east of the Lytle post-office.

Occurrence: This sample came from the 15-foot exposure of Fox Hills shales mentioned in the description of No. 128.

Field Characteristics: Hard, yellow, medium fine-grained shales.

Economic Value: Should make good, white grog of medium fusing point, but is otherwise worthless.

130. *Location:* 7½ miles southwest of Fountain on Giles' ranch.

Occurrence: A 30-foot exposure of material, with 12 feet of overburden, which dips 8° E., has an indeterminate strike, and occurs on the north bank of Little Fountain Creek. Just below the top of the Pierre formation.

Field Characteristics: Hard, dark-gray, medium coarse-grained, fossiliferous clay.

Economic Value: Probably worthless.

131. *Location:* 8 miles southwest of Fountain on Giles' ranch.

Occurrence: A 30-foot exposure of material, with 12 feet of overburden, which dips 8° E., has an indeterminate strike, and occurs on the bank of Little Fountain Creek. Just below the top of the Pierre formation.

Field Characteristics: Hard, brown to black, medium coarse-grained, fossiliferous clay.

Economic Value: Probably worthless.

132. *Location:* 9 miles west of Fountain, 200 feet west of the State Road, and 300 yards south of Little Fountain Creek.

Occurrence: A 4-foot bed, with 2 feet of overburden, which dips 28° easterly, strikes N. 18° W., and occurs on the eastern side of a small ridge. Just below the limestone beds in the Lykins formation.

Field Characteristics: A medium-soft, red, medium fine-grained, sandy shale.

Economic Value: Probably worthless.

133. *Location:* 9 miles west of Fountain and 200 feet north of Little Fountain Creek; at the side of the State Road.

Occurrence: A 20-foot exposure of material, with 4 feet of overburden, which dips 54° E., strikes N. 18° W., and occurs on the bank at the side of a road. 200 feet above the base of the Morrison formation.

Field Characteristics: Medium-hard, gray to pink, medium coarse-grained, sandy shale and clay.

Economic Value: Probably worthless.

134. *Location:* 9 miles west of Fountain and 200 feet north of Little Fountain Creek; at the side of the State Road.

Occurrence: 15 feet was sampled in a thicker exposure of material, which dips 54° E., strikes N. 18° W., and occurs on the western side of Dakota hogback. 300 feet above the base of the Morrison formation.

Field Characteristics: A soft, greenish-gray, fine-grained, marly clay containing a little sand.

Economic Value: Might make light-brown bricks of any kind, if burned above Cone 2.

135. *Location:* 8¾ miles west of Fountain; beside the State Road.

Occurrence: A 7-foot bed, with 5 feet of overburden, which dips 44° E., strikes N. 18° W., and occurs on the south end of the Dakota hogback, on the north shore of Little Fountain Creek. Near the top of the Dakota formation, between walls of solid sandstone.

Field Characteristics: A hard, black, very fine-grained clay.

Economic Value: Should make good, cream-colored soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware, but the former may be laminated and the latter fragile before burning.

136. *Location:* 8¾ miles west of Fountain; beside the State Road.

Occurrence: A 6-foot bed, with 6 feet of overburden, which dips 44° E., strikes N. 18° W., and occurs at the southern end of the Dakota hogback, on the northern shore of Little Fountain Creek. Near the top of the Dakota formation, and above No. 135.

Field Characteristics: Hard, dark-gray, medium coarse-grained shales and clays.

Economic Value: A splendid fire-clay of unusually high plasticity and cohesion.

137. *Location:* 8¾ miles west of Fountain; beside the State Road.

Occurrence: A 40-foot exposure of material, with 4 feet of overburden, which dips 18° easterly, strikes N. 18° E., and occurs at the south end of the Dakota hogback on the northern side of Little Fountain Creek. 50 feet above the base of the Graneros formation.

Field Characteristics: Hard, gray, medium-fine- to medium-coarse-grained shales, containing a 6-inch seam of fine white clay near the top.

Economic Value: Should make fair, pink soft-mud, and, possibly, stiff-mud bricks, with rather high absorption.

138. *Location:* 8½ miles west of Fountain on the northern side of State Road. 200 feet from Little Fountain Creek.

Occurrence: A 55-foot exposure of material, with 4 feet of overburden, which dips 40° easterly, strikes N. 18° W., and occurs on a bank at the side of the road above the creek. 100 feet above the base of the Graneros formation.

Field Characteristics: Hard, gray to yellow, fine-grained shales containing streaks of very pure, light-colored clay at intervals.

Economic Value: Probably worthless, as the bricks are very soft and the absorption is rather high.

139. *Location:* 8½ miles west of Fountain on the northern side of State Road. 200 feet from Little Fountain Creek.

Occurrence: A 30-foot exposure of material, with 3 feet of overburden, which dips 18° easterly, strikes N. 18° W., and occurs on the western side, at the south end of the Niobrara hogback. 50 feet below the top of the Carlile formation.

Field Characteristics: Hard, black, brown and gray, medium fine-grained shales and clays, containing a little sand and some carbonate of lime, and iron concretions.

Economic Value: Should make good, red building bricks of all kinds, but the stiff-mud bricks may be laminated.

140. *Location:* 4 miles west of Fountain; ½ mile southeast of Townsend's ranch.

Occurrence: A 15-foot exposure of material, with 8 feet of overburden, which dips 5° easterly, has an indeterminate strike, and occurs in the bank of a dry creek. At the top of the Pierre formation.

Field Characteristics: Medium-hard, yellow to dark-gray, medium fine-grained, sandy shales, containing carbonate of lime and iron concretions and some gypsum.

Economic Value: Should make fine, pink soft-mud bricks, and, probably, stiff-mud bricks which may be laminated.

141. *Location:* ¼ mile west of Fountain; 100 feet from a public road; on Stephen's ranch.

Occurrence: A 12-foot exposure of material, with 4 feet of overburden, which dips 3° easterly, has an indeterminate strike, and is exposed on the bank of Fountain Creek.

Field Characteristics: Medium-soft, brown, fine-grained, sandy shales and clays, containing gypsum, especially near the bottom of the exposure.

Economic Value: Should make good, red pressed bricks, and grogging may yield good soft-mud bricks and earthenware.

142. *Location:* 5 miles south of Colorado Springs and 1 mile east of the foothills; on John J. Curr's ranch.

Occurrence: A 1-foot bed, with 2 feet of overburden, on the south side of an east-west valley; near the Star ranch.

Field Characteristics: A medium-hard, drab, fine-grained, sandy clay, containing much gypsum.

Economic Value: Should make good, red pressed bricks and, if grogged, other building-bricks and earthenware, but these must be burned to Cone 05, and vitrify and fuse at Cone 03.

143. *Location:* 5 miles south of town; ¾ of a mile east of the foothills; on John Y. Curr's ranch.

Occurrence: An 8-foot exposure of material, with 3-6 feet of overburden, on the side of a ditch washed out by a cloudburst.

Field Characteristics: Medium-soft, drab, medium fine-grained, sandy clay containing gypsum.

Economic Value: Should make good, red pressed bricks and, if grogged, other building-bricks and earthenware.

144. *Location:* Nineteenth Street and Manitou Boulevard, Colorado Springs. Schleshinger Bros.' brick-yard.

Occurrence: 50 feet was sampled of a thicker exposure of material, with 6 inches to 8 feet of overburden, which dips 8° N., has an indeterminate strike, and occurs in a pit at the western end of a ridge. 50 feet below the top of the Pierre formation.

Field Characteristics: Medium-hard, gray to brown, fine-grained, sandy shales and clays with some concretions.

Economic Value: Should make good, red soft-mud and pressed bricks and, probably, earthenware and stiff-mud bricks, but the last may be laminated.

145. *Location:* South Fifth and Broadway Streets, Colorado City; at the Ben Brewer Brick Company's yard.

Occurrence: 20 feet was sampled of a much thicker exposure of material, with 6 inches to 10 feet of overburden, which dips 78° easterly, strikes N. 1° W., and occurs in a cut on the northern side of a knoll.

Field Characteristics: Hard, gray, black and brown, fine-grained, sandy shales and clays.

Economic Value: Should make fine, red pressed bricks and, possibly, if grogged, soft- and stiff-mud bricks and earthenware.

146. *Location:* South Fifth and Broadway Streets, Colorado City; at the Ben Brewer Brick Company's yard.

Occurrence: 30 feet of material below Sample No. 145.

Field Characteristics: Hard, bluish-black, medium-fine to fine-grained shale and clay.

Economic Value: Should make fair, red soft-mud bricks and, possibly, stiff-mud and pressed bricks, but the former may be laminated, and the latter will have high absorption.

147. *Location:* At Calhan. Exact locality and other data unknown, as sample was furnished by the Standard Fire Brick Company of Pueblo.

Economic Value: A first-class fire-clay, and will make good, brown pressed bricks if burned to Cone 1. It might make flashed bricks, but the color is unpromising.

148. *Location:* At Calhan. Exact locality and other data unknown, as sample was furnised by the Standard Fire Brick Company of Pueblo.

Economic Value: First-class fire-clay.

149. *Location:* Colorado Springs. Pressed Brick and Fire Brick Company's yard.

Occurrence: 18 feet was sampled of a much thicker exposure of material which dips 60° easterly, has an indeterminate strike, and occurs on the southern side of a knoll. At the top of the Pierre formation.

Field Characteristics: Medium-hard, gray to black, medium fine-grained, sandy shales and clays, which contain bacculite fossils and other impurities.

Economic Value: Said to be the best clay at the plant, but is used only when it is weathered, as it is too hard to plow when fresh. Should make good, red pressed bricks, and soft- and stiff-mud bricks if grogged.

150. *Location:* Colorado Springs Pressed Brick and Fire Brick Company's yard.

Occurrence: 45 feet of material above Sample No. 149. At the base of the Fox Hills formation.

Field Characteristics: Medium-hard, yellow, fine-grained, sandy shales and clays containing concretions.

Economic Value: This material is commonly used at the plant for red pressed bricks. Should make good, red pressed bricks, and, possibly, soft- and stiff-mud bricks and earthenware if grogged.

151. *Location:* Colorado Springs Pressed Brick and Fire Brick Company's yard.

Occurrence and *Field Characteristics:* Same as No. 149, but this sample is from a different part of the pit and is said by the manager to differ from No. 149.

Economic Value: Should make good, red pressed bricks and, probably, soft- and stiff-mud bricks and earthenware if grogged. It differs from No. 149 in being more plastic and possessing 1 per cent lower air shrinkage and a lower tensile strength.

152. *Location:* 200 yards west of the Standard Mill at Colorado City, in the pit owned by Mr. Morrison.

Occurrence: 60 feet of material, with 1 foot of overburden, which dips 86° easterly, strikes N. 1° W., and occurs on the eastern side of the Dakota hogback. 150 feet above the base of the Graneros formation.

Field Characteristics: A medium-hard, dark-gray to black, medium fine-grained shale.

Economic Value: Should make fair, pink soft-mud or pressed bricks and, probably, stiff-mud bricks which may be laminated.

153. *Location:* 300 yards northwest of the Standard Mill at Colorado City, in the pit owned by Mr. Morrison.

Occurrence: 20 feet of material, with 1-2 feet of overburden, which dips 86° easterly, strikes N. 1° W., and occurs in the eastern side of the Dakota hogback. 100 feet above the base of the Graneros formation.

Field Characteristics: Hard, dark-gray to black, medium fine-grained shales.

Economic Value: Should make fair, flesh-colored soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware, but the former may be laminated.

154. *Location:* 300 yards northwest of the Standard Mill at Colorado City, in the pit owned by Mr. Morrison.

Occurrence: 15 feet of material, with 3 feet of overburden, which dips 86° E., strikes N. 1° W., and occurs on the eastern side of the Dakota hogback. It is about 60 feet above the base of the Graneros formation, and is separated from No. 153 by sand and shale-beds.

Field Characteristics: Medium-soft to hard, brown, gray and black, fine to medium fine-grained, sandy shales, containing sandy, brown, bituminous streaks, and 3 feet of soft sandstone in the center.

Economic Value: Should make fine, cream-colored soft-mud and pressed bricks; also, probably, laminated stiff-mud bricks and, possibly, paving-bricks.

155. *Location:* 300 yards northwest of the Standard Mill at Colorado City, in the pit owned by Mr. Morrison.

Occurrence: 15-foot bed, with 3 feet of overburden, which dips 86° E., strikes N. 1° W., and occurs in the eastern side of the Dakota hogback west of No. 154. At the base of the Graneros formation.

Field Characteristics: Medium-hard, brown, gray, yellow, and black, medium fine-grained, sandy shales, containing thin seams of hard sandstone.

Economic Value: Should make good, red pressed bricks and, possibly, if grogged, soft- and stiff-mud bricks and earthenware.

156. *Location:* 400 yards northwest of the Standard Mill at Colorado City.

Occurrence: A 10-foot bed, with 3 feet of overburden, which dips 86° E., strikes N. 1° W., and occurs near the top of the western slope of the Dakota hogback and underlies hard sandstone. May be of Lower Dakota age.

Field Characteristics: Soft to medium-hard, gray to black, fine-grained shale.

Economic Value: A fine fire-clay.

157. *Location:* 400 yards northwest of the Standard Mill at Colorado City.

Occurrence: A 30-foot bed, with 2 feet of overburden, which dips 86° E., strikes N. 1° W., and occurs 35 feet below the top of the western slope of the Dakota hogback.

Field Characteristics: Medium-hard, gray, medium fine-grained, sandy shale.

Economic Value: Should make good, red pressed brick, or other kinds of building-bricks and earthenware if burned to Cone 01.

158. *Location:* ¼ mile west of Balanced Rock in the Garden of the Gods, on the western side of Black Canon.

Occurrence: A 2-foot bed, with 3-8 feet of overburden, which dips 12° southerly, strikes N. 80° W., and occurs on a ridge between Black Canon and a small canon to the west. Near the base of the Fountain formation.

Field Characteristics: Medium-soft, red and green, medium fine-grained shales.

Economic Value: Was once used by the Van Briggle Pottery Company at Colorado Springs. Should make fine, flesh-colored soft-mud and pressed bricks and, probably, paving, flashed, and stiff-mud bricks, but the last may be laminated.

159. *Location:* 3 miles west of Edgerton; 150 feet east of a road running through a field.

Occurrence: 14½ feet of horizontal material, with 15 feet of overburden, which occurs on the northern side of a sharp ridge just above some coal. Probably of Laramie age.

Field Characteristics: Soft, light-gray, fine-grained shales and clays, part of which are sandy. 4½ feet from the bottom occurs a 4-foot layer of sandstone, which is not included in the sample.

Economic Value: Should make fine, cream-colored soft-mud bricks, and probably paving, flashed, and pressed bricks and earthenware, but the last two will be fragile before burning.

160. *Location:* ½ mile west of Edgerton siding, and 400 yards west of the D. & R. G. R. R.

Occurrence: A 3-foot, horizontal bed, with 10 feet of overburden, exposed in an abandoned pit in the side of a ridge.

Field Characteristics: Hard, gray, coarse-grained clay containing quartz pebbles.

Economic Value: Should make first-class, cream-colored to white soft-mud and pressed bricks, vitrified and unvitrified floor tiles, wall tiles, and, possibly, paving-bricks.

161. *Location:* ½ mile north of Pike View, near Edgerton.

Occurrence: A 6-foot, nearly horizontal bed, with 1 foot of overburden, in the side of a small arroya beside the public road; 400 feet above the coal.

Field Characteristics: Medium-soft, gray, medium fine-grained, sandy clay.

Economic Value: Probably worthless.

162. *Location:* ¾ of a mile north of Pike View; on the bank of Monument Creek, near a bridge; 300 feet east of the D. & R. G. R. R.

Occurrence: A 7-foot, horizontal bed, with 2 feet of overburden, exposed on the bank of a creek; 400 feet above the coal.

Field Characteristics: Medium-soft, yellow and gray, medium coarse-grained, sandy clay with half-inch seams of limestone every 2 or 3 feet.

Economic Value: Probably worthless.

163. *Location:* ¾ of a mile north of Pike View; on the bank of Monument Creek; 300 feet north of a bridge on a public road; 300 feet east of the D. & R. G. R. R.

Occurrence: 15 feet was sampled of a thicker exposure of nearly horizontal material, with 2-3 feet of overburden, which seems to overlie No. 162.

Field Characteristics: Soft, blue-gray, purple and yellow, fine to coarse-grained, sandy clays.

Economic Value: Probably worthless.

164. *Location:* ¼ of a mile north of Edgerton siding; 300 yards west of D. & R. G. R. R.; in an old coal-pit.

Occurrence: 5 feet was sampled of horizontal material on the eastern side of a ridge.

Field Characteristics: Hard, gray to pinkish-gray, medium coarse-grained clays. At the top of the Dawson formation.

Economic Value: A valuable, cream- or white-burning clay, which may be used for a wide variety of products, as shown in Table No. 1.

165. *Location:* ¼ mile north of Edgerton siding; 300 yards west of D. & R. G. R. R.; in an old coal-pit.

Occurrence: 5 feet was sampled below No. 164.

Field Characteristics: Hard, gray and red, medium coarse-grained, sandy clays.

Economic Value: Very similar to No. 164, but burns pink and is not quite so refractory.

166. *Location:* ¼ mile north of Edgerton siding; 300 yards west of D. & R. G. R. R.; in an old coal-pit.

Occurrence: 3 feet was sampled above No. 164.

Field Characteristics: Hard, gray, coarse-grained clay containing quartz pebbles.

Economic Value: Very similar to No. 164, but a somewhat lower tensile strength tends to lessen its usefulness slightly.

167. *Location:* 2½ miles east of Edgerton siding; 150 yards east of a road through a field.

Occurrence: A 4-foot, horizontal bed, with no to 36 feet of overburden, on the north side of a knoll. Just above the coal.

Field Characteristics: A medium-soft, dark-gray, fine-grained, sandy clay.

Economic Value: Should make fine, cream building-bricks, vitrified and unvitrified floor tiles, wall tiles, and, probably, earthenware and paving-bricks.

168. *Location:* 3 miles southeast of Calhan.

Occurrence: 8 feet was sampled of horizontal material, with 30 feet of overburden, on the northern side of a ridge.

Field Characteristics: A hard, red and gray, medium coarse-grained, sandy clay.

Economic Value: Should make first-class, light flesh-tinted pressed bricks, earthenware, terra-cotta, stoneware, and refractory goods, and, probably, hollow structural materials.

169. *Location:* ¾ of a mile southwest of Calhan.

Occurrence: 5 feet was sampled of horizontal material, with 10 feet of overburden, which occurs on the southern side of a small knoll.

Field Characteristics: A hard, light-brown, fine-grained, sandy clay.

Economic Value: Very similar to No. 168, but will burn red, will probably not answer for hollow structural material, and the quality of the terra-cotta is doubtful, even if grogged, due to the 7% air shrinkage.

170. *Location:* 1 mile south of Calhan.

Occurrence: 4 feet was sampled of horizontal material, with 10-28 feet of overburden, on the northern side of a ridge; in a cut.

Field Characteristics: A hard, grayish-red, fine-grained, sandy clay.

Economic Value: Should make good, vitrified floor tiles and fine red pressed bricks if burned to Cone 5. May answer for paving-bricks.

171. *Location:* 1 mile southeast of Calhan on Joe Bigsby's homestead.

Occurrence: 9 feet was sampled of horizontal material, with 10-25 feet of overburden, on the northern side of a long ridge.

Field Characteristics: Hard, grayish-red, fine-grained clay containing a little sand.

Economic Value: Should make fine vitrified floor tiles, refractory goods, wall tiles, and white earthenware; also, probably, terra-cotta, hollow structural materials, and drain tiles. Will answer for very attractive pressed bricks, but these will have relatively high absorption.

172. *Location:* 2½ miles southeast of Calhan; in a prospect hole.

Occurrence: 6 feet was sampled of horizontal material, with 8 feet of overburden, on a prominent knoll.

Field Characteristics: Hard, gray, brown and red, fine-grained, sandy clay.

Economic Value: One of the most valuable clays tested, and may be used for a variety of products, as shown on Table No. 1.

173. *Location:* 3 miles east of Calhan.

Occurrence: 6 feet of horizontal material, with 10 feet of overburden, on the side of a knoll.

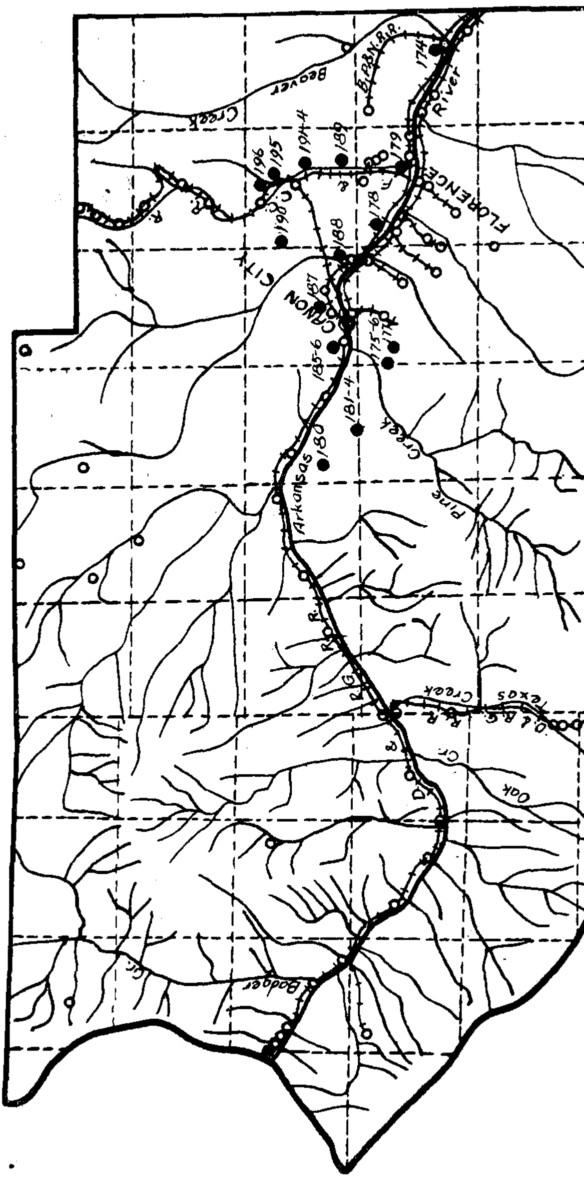
Field Characteristics: A hard, white, brown and red, fine-grained, sandy clay.

Economic Value: Should make fine, nearly white pressed bricks, vitrified and unvitrified floor tiles, wall tiles, and refractory materials. This clay is shipped to the Standard Fire Brick Company at Pueblo, but is not identical with either No. 147 or No. 148.

Fremont County

Geology of the County.—The geology of this county is very complicated and could hardly be set forth in detail without the aid of a geological map. It may be said, however, that the eastern one-third, with the exception of the extreme northeast corner,

FREMONT COUNTY



Sketch map showing the approximate locations of the beds sampled

is underlain by all the sediments described in Part III, Chapter I, as well as some of greater age. Rocks of Morrison to Niobrara age also occur in a relatively narrow north-south zone, six or seven miles long, south of Parkdale station. A similar zone, including beds of Pierre age, extends in a northwesterly direction for five or six miles from the same point.

174. *Location:* Beaver; 300 yards north of the railroad.

Occurrence: 15 feet was sampled of horizontal material on the side of a slope, 50 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard, dark-gray, fine-grained shales.

Economic Value: Probably worthless.

175. *Location:* 3 miles southwest of Canon City.

Occurrence: A bed of unstated thickness, which dips 43° southeasterly, strikes N. 35° E., and occurs on the southwestern side of the Dakota hogback. 20 to 40 feet below the top of the Dakota formation. May be of Purgatory age.

Field Characteristics: A hard, dark-gray, medium coarse-grained clay.

Economic Value: First-class fire-clay. This is from the so-called "Diamond Vein," owned by the Diamond Fire Brick Company.

176. This seems to be from exactly the same locality as No. 175, and probably under- or overlies that sample. It differs from No. 175 in being black in color and somewhat sandy.

177. *Location:* 3 miles south of Canon City, on the property of the Diamond Fire Brick Company.

Occurrence: A bed of unstated thickness, which dips 43° southeasterly, strikes N. 35° E., and occurs on the southwestern side of the Dakota hogback, below No. 176. 100 feet below the top of the Morrison formation.

Field Characteristics: A hard, very light-gray, medium coarse-grained, sandy clay.

Economic Value: May make buff pressed bricks, but these will be fragile before burning.

178. *Location:* 3 miles west of Florence. 1/8 mile west of the Arkansas River.

Occurrence: A 4-foot horizontal bed, with 3 feet of overburden, on the southern side of an arroya; just below a coal-seam. May be of Carlile age.

Field Characteristics: A medium-soft, gray and yellow, medium fine-grained, sandy clay containing bituminous material.

Economic Value: Should make good, pink pressed bricks.

179. *Location:* Florence; 100 yards north of the Arkansas River and ⅛ mile from the town bridge.

Occurrence: 20 feet was sampled of nearly horizontal material, with 2-3 feet of overburden, which occurs on the steep bank on the northern side of the road. 100 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard, gray, coarse-grained, sandy clay, containing many gypsum seams and some concretions.

Economic Value: Should make fair, somewhat soft, red soft-mud bricks and, possibly, stiff-mud and pressed bricks.

180. *Location:* 2 miles southeast of Parkdale station.

Occurrence: 8 feet was sampled of material, with 6-10 feet of overburden, which dips 30° W., has an indeterminate strike, and occurs in an abandoned tunnel on the eastern side of the Dakota hogback. 40 feet below the top of the Morrison formation.

Field Characteristics: Hard, light-gray, medium fine-grained clay.

Economic Value: Should make good, pink building and flashed bricks, terra-cotta, hollow structural materials, conduits, and vitrified floor tiles; also, possibly, vitrified bricks and unvitrified floor tiles .

181. Probably from the same locality as Nos. 175 and 176, and overlies one or both of these samples. Although field blanks state erroneously that the sample is from near Parkdale, it is on property owned by the Adamant Fire Brick Company of Canon City, and differs from Nos. 175 and 176 only in being pinkish-gray in color.

182. *Location:* 5 miles southeast of Parkdale station; near the road, in a prospect hole.

Occurrence: 5 feet was sampled of horizontal material, with 2 feet of overburden, on a low knoll. At the base of the Graneros formation.

Field Characteristics: Medium-hard, brown, black and gray, fine-grained shales with thin interbedded sandstone seams.

Economic Value: May possibly be used for a variety of products, as shown on Table No. 1, but will probably answer best for pink pressed and soft-mud bricks, earthenware, and paving-bricks.

183. *Location:* 5 miles southeast of Parkdale station; near the road.

Occurrence: 20 feet was sampled of material, with 3 feet of overburden, which dips 70° N., strikes N. 87° W., and occurs on the side of a knoll above the dry bed of a stream. 300 feet below the top of the Morrison formation.

Field Characteristics: Hard, greenish-gray, medium coarse-grained, sandy shales and marly clays.

Economic Value: Should make good, buff soft-mud bricks and earthenware, and also, possibly, other building-bricks and paving-bricks, but the pressed bricks will have rather high absorption.

184. *Location:* 5 miles southeast of Parkdale station.

Occurrence: An 8-foot bed with no to 20 feet of overburden, which dips 70° northerly, strikes 87° W., and occurs on the south side of the Dakota hogback. At the base of the Purgatory formation.

Field Characteristics: Hard, black, medium fine-grained, sandy clay.

Economic Value: A first-class fire-clay.

185. *Location:* 100 yards north of the Prison quarry at Canon City.

Occurrence: 15 feet was sampled of material, with 20 feet of overburden, which dips 66° E., strikes N. 30° W., and occurs on the western side of the Niobrara hogback. 20 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard to hard, gray to brown, medium fine-grained shales.

Economic Value: Should make good, red pressed bricks and, possibly, other varieties of bricks if grogged.

186. *Location:* 100 yards north of the Prison quarry at Canon City; at side of a tunnel for a water main through the Dakota hogback.

Occurrence: 50-foot exposure of material, with 1-2 feet of overburden, which dips 66° easterly, strikes N. 30° W., and occurs on the eastern side of the Dakota hogback.

Field Characteristics: Medium-hard, black and brown, fine to medium fine-grained shales.

Economic Value: Should make first-class, red pressed and soft-mud bricks.

187. *Location:* 1 mile northeast of Canon City; on the property of the Canon Brick and Tile Company.

Occurrence: A 6-11-foot bed of surface adobe.

Field Characteristics: Soft, yellowish-gray, fine-grained adobe.

Economic Value: Should make fine, pink soft-mud and pressed bricks, earthenware, terra-cotta, hollow structural materials and drain tiles; also, possibly, conduits.

188. *Location:* 5 miles northwest of Florence; near Oil Creek.

Occurrence: 25 feet was sampled of material, with 2 feet of overburden, that occurs in a round knoll. At the top of the Carlile formation.

Field Characteristics: Medium-hard, brown to black, fine-grained shales.

Economic Value: Should make fine, pink pressed and, possibly, soft-mud bricks. The latter would be somewhat fragile before burning.

189. *Location:* 3½ miles north of Florence; 300 yards east of the F. & C. C. R. R.

Occurrence: 25 feet was sampled of material, with 2 feet of overburden, which occurs on the side of a wide north-and-south valley. May be of Carlile age.

Field Characteristics: Medium-soft, brown to gray, fine-grained shales and clays, containing narrow seams of sandstone.

Economic Value: Should make fine, pink pressed face-bricks.

190. *Location:* 5 miles northeast of Canon City, on the property of the Canon Brick and Tile Company; near Menzie's ranch.

Occurrence: A 11-foot bed which dips 12° S., strikes N. 40° W., and occurs on the eastern slope of the Dakota hogback. May be of Dakota age.

Field Characteristics: A hard, black, medium coarse-grained clay.

Economic Value: This clay cracks so badly on drying that it is probably worthless. Grogging hardly seems possible, since the plasticity and cohesion are already very low; but if the cracking can be remedied, it will make a first-rate fire-clay.

191. *Location:* Oro Junta; 5 miles north of Florence; 100 feet from the F. & C. C. R. R.

Occurrence: 8 feet was sampled of material, with 2 feet of overburden, which dips 9° southwesterly, strikes N. 65° W., and occurs on the southern side of the Dakota hogback, near the base. At the base of the Graneros formation.

Field Characteristics: A medium-hard, gray and yellow, fine-grained shale, containing an excessive amount of gypsum.

Economic Value: Should make fine, pink pressed face-bricks, soft-mud bricks, and, possibly, paving-bricks.

192. *Location:* 5⅛ miles north of Florence; 150 feet west of the F. & C. C. R. R.

Occurrence: A 3-foot bed, with 27 feet of sandstone overburden, which dips 9° southwesterly, strikes N. 65° W., and occurs on the western side of a gully made by a stream in the Dakota hogback. 30 feet below the top of the Dakota formation.

Field Characteristics: Hard, black, fine-grained shales and clays.

Economic Value: Should make good, white soft-mud and pressed bricks, and vitrified and unvitrified floor tiles.

193. *Location:* 5⅛ miles north of Florence; 150 feet west of the F. & C. C. R. R.

Occurrence: A 2½-foot bed that dips 9° southwesterly, strikes N. 65° W., and occurs on the western side of a gully made by a stream in the Dakota hogback. 75 feet below the top of the Dakota formation.

Field Characteristics: Hard, dark-gray to black, fine-grained, sandy shale. It contains a 6-inch seam of very hard, sandy clay that is said to be fire-clay. All was sampled together.

Economic Value: Should make good, white pressed and soft-mud bricks, and vitrified and unvitrified floor tiles; also, probably, earthenware.

194. *Location:* 5¼ miles north of Florence, in a cut on the F. & C. C. R. R.

Occurrence: 25 to 30 feet was sampled of material, with 2 feet of overburden, that dips 9° southwesterly and strikes N. 65° W. 150 feet below the top of the Morrison formation.

Field Characteristics: A hard, bluish-gray, fine-grained, sandy marl.

Economic Value: Probably worthless.

195. *Location:* 7 miles northwest of Florence and 100 yards east of the F. & C. C. R. R.

Occurrence: 35 feet was sampled of material that dips 47° southeasterly and strikes N. 65° E. May be of Carlile age.

Field Characteristics: Medium-soft, gray to black, medium fine-grained shales, containing numerous concretions.

Economic Value: Probably worthless.

196. *Location:* 8 miles northwest of Florence.

Occurrence: 7 feet was sampled of material that dips 12° southerly, strikes N. 45° W., and occurs in a north-south gully made by a stream in the Dakota hogback. 200 feet below the top of the Dakota formation.

Field Characteristics: A hard, dark-gray, medium coarse-grained, sandy clay.

Economic Value: Probably good for nothing but grog.

Garfield County

Geology of the County.—The geology of this county is altogether too complicated to be presented without the aid of a geological map.

197. *Location:* 5 miles west of Wheeler station; 18 miles south of Glenwood Springs, on the C. M. R. R.

Occurrence: A 3-foot horizontal bed which is said by Mr. C. H. Harris, who furnished the sample, to be interbedded with "lava."

Field Characteristics: A soft, red, fine-grained clay.

Economic Value: Should make odd-colored, brownish-red pressed bricks, and, also, probably, soft-mud bricks if slightly grogged.

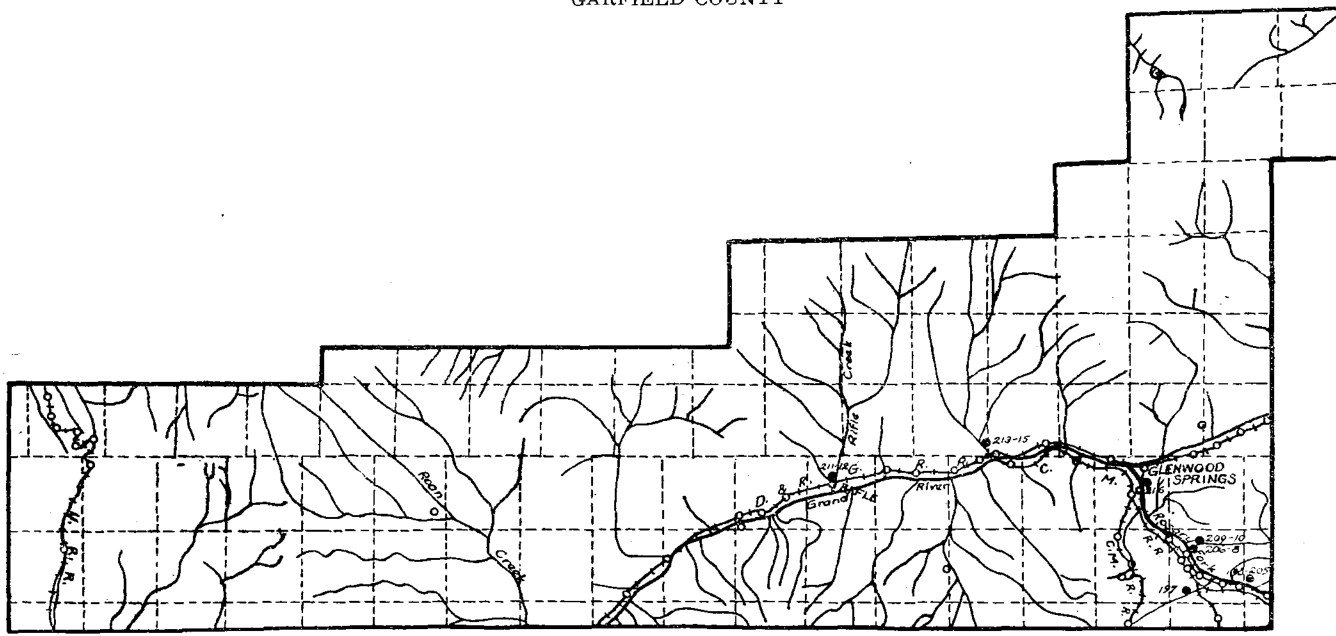
198. *Location:* On the C. H. Harris ranch near Wheeler station; 18 miles south of Glenwood Springs, on the C. M. R. R.; 900 feet north of the house.

Occurrence: 50 feet was sampled at the base of an exposure of 200 or more feet, of material which dips 25° northerly, strikes S. 30° W., and occurs 300 feet above the bottom of a steep hillside. The sample was taken on the floor of a 75-foot tunnel. The beds are probably of Flaming Gorge age, but differ in color from rocks of this horizon seen elsewhere.

Field Characteristics: Soft, cream to yellow and brown, fine-grained shales that are slightly sandy and calcareous.

Economic Value: Probably worthless, although Mr. Harris reports that the American Clay Machinery Company, of Bucyrus, Ohio, pronounces this to be a fire-clay, with no shrinkage when burned to Cone 2 after being dry-pressed. The statement relative to the shrinkage was found to be correct, and, when burned to this temperature, the clay certainly resembles fire-clay, but it fuses rather suddenly at Cone 5.

GARFIELD COUNTY



Sketch map showing the approximate locations of the beds sampled

199. This sample is from the same locality as No. 198 and is similar to that material, but is from a 2-foot non-sandy bed at the mouth of the tunnel.

200. This sample is from the same locality as No. 198 and is similar to that sample, but is non-sandy, and was taken from a point 100 feet higher up the hill than No. 198.

201. This sample is from the same locality as No. 198 and is similar to that sample, but was taken from a point 6 feet above No. 200 and is brown in color. It differs from the three preceding samples in that it should make good, flesh-colored pressed bricks and unvitrified floor tiles.

202. This sample is from the same locality as No. 198 and is similar to that sample, but was taken from a point 50 feet above No. 200.

203. *Location:* On the C. H. Harris ranch near Wheeler station; 18 miles south of Glenwood Springs, on the C. M. R. R. ⅛ of a mile northeast of the house; in a tunnel.

Occurrence: 20 feet was sampled of a much thicker exposure of material which dips 25° northerly, strikes south 30° W., and occurs at the breast of a 25-foot tunnel, 400 feet up the hillside.

Field Characteristics: Soft, gray, fine-grained shales and clays of the same age as the preceding five samples.

Economic Value: Should make good, buff pressed bricks and unvitrified floor tiles.

204. This sample is from the same locality as No. 203 and is similar to that sample, but was taken at the mouth of the tunnel. The color varies from brown to yellow and gray, and the texture varies from very fine to medium coarse.

205. This sample is from the same locality as No. 203, but was taken half-way to the breast of the tunnel, and the color is brown. It also differs from the two preceding samples in that it should make good soft-mud bricks and earthenware, as well as pressed bricks and unvitrified floor tiles.

206. *Location:* Glenwood Pressed Brick and Plaster Company's plant at Cattle Creek; 7 miles south of Glenwood Springs, on the D. & R. G. R. R.

Occurrence: A 15-foot bed which dips 67° northeasterly, strikes N. 45° W., and occurs on the side of a hill 100 feet above the bottom of the valley.

Field Characteristics: A medium-hard, gray to brown, medium-fine, finely gritty shale.

Economic Value: It is claimed that the pressed bricks burn unevenly and slake quickly, and the tests indicate that not only is a high temperature (Cone 5) necessary in burning these bricks, but the point of fusion is Cone 8; so great care must be used in burning. Also, the burned product has a high absorption and would not do for face-bricks, although of a rather attractive white or cream color.

207. *Location:* Glenwood Pressed Brick and Plaster Company's plant at Cattle Creek; 7 miles south of Glenwood Springs, on the D. & R. G. R. R.

Occurrence: A 4-foot bed which dips 70° northeasterly, strikes S. 60° E., and occurs 100 feet above the bottom of the valley and 500 feet east of No. 206.

Field Characteristics: A medium-hard, gray, medium fine-grained, finely gritty shale.

Economic Value: Similar to No. 206, except that the material is easier to burn, the absorption is higher, and the cohesion is stronger.

208. *Location:* Glenwood Pressed Brick and Plaster Company's plant at Cattle Creek; 7 miles south of Glenwood Springs, on the D. & R. G. R. R.

Occurrence: A 4-foot bed which dips 35° northeasterly, strikes S. 60° E., and occurs on the side of a hill 100 feet above the bottom of the valley and 800 feet east of No. 206.

Field Characteristics: Medium-hard, white, medium fine-grained, sandy shale.

Economic Value: Similar to No. 207, but the cohesion is weaker.

209. *Location:* 1¼ miles above the mouth of Cattle Creek; 7 miles south of Glenwood Springs, on the D. & R. G. R. R.

Occurrence: A 15-foot bed which dips 35° northerly, strikes S. 75° E., and occurs on the side of a hill 300 feet above the bottom of the valley.

Field Characteristics: A medium-hard, bright-red, fine-grained shale.

Economic Value: May make brownish-red pressed bricks, but the unburned ware will be fragile, and there is apt to be considerable loss, due to over- and underburning of a portion of the product.

210. *Location:* 1¼ miles above the mouth of Cattle Creek; 7 miles south of Glenwood Springs, on the D. & R. G. R. R.

Occurrence: Adjoining No. 209 on the east.

Field Characteristics: A hard to medium-soft, grayish-green to red, fine-grained shale, which is more or less micaceous and schistose.

Economic Value: This should make dark-buff pressed bricks, without the unfavorable qualities of the preceding four samples, but with their high absorption.

211. *Location:* I. T. Buckle's Brick Yard; 1 mile north of Rifle.

Occurrence: 15 feet was sampled of material, with 4 feet of overburden, that dips 5° westerly, strikes south 30° W., and occurs in the side of a small gulch.

Field Characteristics: A medium-soft, purplish, medium coarse-grained, gritty, shaly marl.

Economic Value: Should make first-class, pink soft-mud or pressed bricks and, probably, stiff-mud bricks. The material is now mixed with No. 212, but would make a better product by itself.

212. *Location:* I. T. Buckle's Brick Yard; 1 mile north of Rifle.

Occurrence: 15 feet was sampled of material occurring on the side of a small gulch.

Field Characteristics: A soft, brown, sandy soil.

Economic Value: Should make soft, sandy, pink bricks. Is now used to grog No. 211, but this seems unnecessary.

213. *Location:* New Castle; 1½ miles from the railroad and 500 feet beyond the Cement Mill on the road up the gulch.

Occurrence: A 3-foot bed, with 6 inches of overburden, that dips 45° southerly, strikes S. 60° E., and occurs on the hillside near the bottom of the gulch just below the road. This bed is of Benton age.

Field Characteristics: A soft, buff-colored, very fine-grained clay.

Economic Value: Should make first-class, light-brown pressed and, possibly, soft-mud bricks if carefully burned. The latter would require grogging, however. It is claimed that good pottery has been made from this clay, but it shows no indication that it is adapted to the manufacture of a good quality of such ware.

214. *Location:* New Castle; 1½ miles from the railroad and 500 feet beyond the Cement Mill on the road up the gulch.

Occurrence: A 10-foot bed adjoining No. 213 to the north.

Field Characteristics: A hard, black, fine-grained clay.

Economic Value: Should make good, dark flesh-colored soft-mud bricks and, possibly, pressed bricks, but the latter will be fragile before burning.

215. *Location:* New Castle; 1½ miles from the railroad; directly behind the Cement Mill on the road.

Occurrence: 5 feet was sampled of material that dips 70° southerly, strikes east and west, and occurs on the side of a hill. This material is of Pierre age.

Field Characteristics: Soft, brown, fine-grained, slightly gritty shales.

Economic Value: Should make good, buff earthenware, terra-cotta, and, possibly, hollow structural materials and drain tiles.

216. *Location:* Glenwood Springs; in a brick-yard just south of town.

Occurrence: A 4-foot exposure of horizontal material occurring on the surface of a flat valley.

Field Characteristics: Soft, brown, medium coarse-grained, sandy soil.

Economic Value: This material is worthless.

Grand County

Geology of the County.—The geology of Grand County is too complicated to be presented without the aid of a geological map.

217. *Location:* Hot Sulphur Springs; on the south bank of the Grand River; in the town.

Occurrence: A 6-foot exposure of material, with 4 feet of overburden, that dips 40° N., strikes N. 70° W., and occurs 5 feet above the water on the river bank. This bed is of Benton age and lies about 100 feet above the base of the Mancos formation.

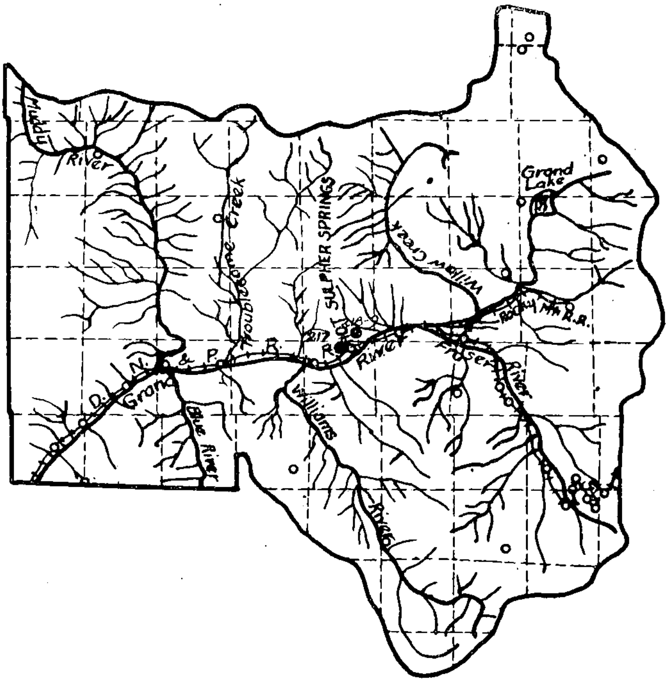
Field Characteristics: A soft, black, very fine-grained shale with white, plastic streaks.

Economic Value: Should make good, light-red pressed bricks.

218. *Location:* Hot Sulphur Springs; 2 miles north of town; opposite the Roundhouse; on the western end of the southern slope of a low hill between high sedimentary and high igneous hills.

Occurrence: Hundreds of feet are exposed, and were sampled at intervals, of material that dips 70° northeasterly, strikes N.

GRAND COUNTY



Sketch map showing the approximate locations of the beds sampled

55° W., and was sampled 100 feet or more above the base of the hill. This material is of Benton age and is 500 feet above the base of the Mancos formation.

Field Characteristics: Medium-hard, black, very fine-grained shales.

Economic Value: Probably worthless, due to high absorption and low tensile strength.

219. *Location:* Hot Sulphur Springs; ¼ mile northeast of No. 218.

Occurrence: Hundreds of feet are exposed, and were sampled at intervals, of material which dips 35° northeasterly, strikes N. 55° W., and occurs under a capping of sandstone. This material is of Pierre age, and occurs 800 feet above the black Benton shales.

Field Characteristics: Soft, brownish-gray, fine-grained shales which are more or less gritty.

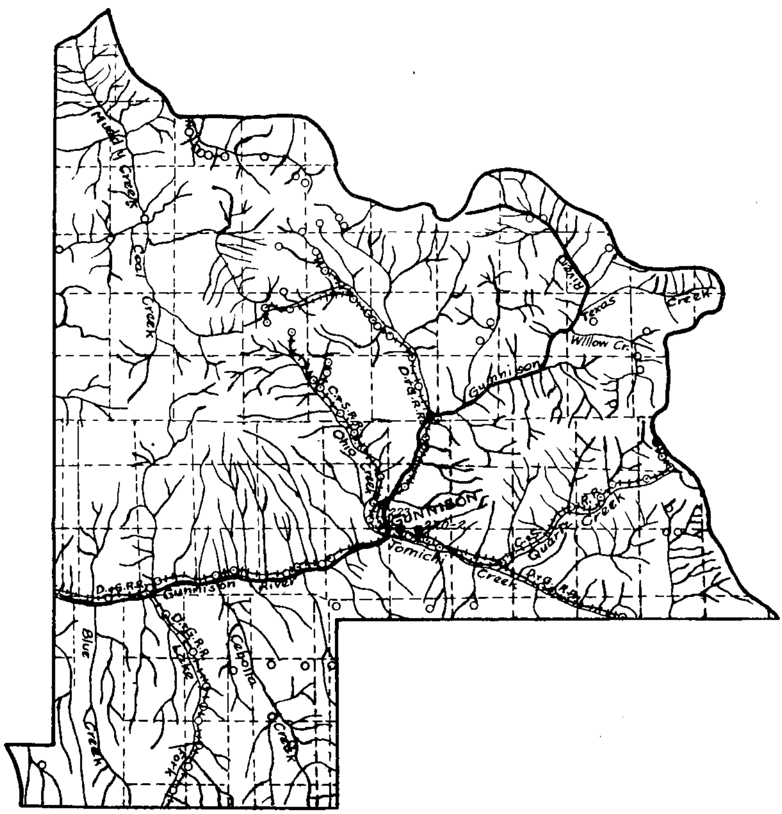
Economic Value: Should make good, red pressed bricks.

Gunnison County

Geology of the County.—The geology of this county is too complex to be presented without the aid of a geological map.

220. *Location:* Gunnison; 2½ miles east of town; on land owned by F. W. Harper.

GUNNISON COUNTY



Sketch map showing the approximate locations of the beds sampled

Occurrence: A 6-foot exposure of a bed said to be 8-10 feet thick, underlying 10 feet of sandstone, which dips 5° northerly, strikes east-west, and occurs at the top of a 250-foot hogback.

Field Characteristics: A hard, dark-gray and dark-brown, very fine-grained clay.

Economic Value: It is claimed that this material has been tested and was pronounced a fire-clay, but it fuses at Cone 8. It is probably worthless except for very light-colored pressed bricks which will be fragile before burning.

221. *Location:* Gunnison; 2½ miles east of town; on land owned by F. W. Harper.

Occurrence: 5 feet was sampled of a much thicker exposure of material which dips 5° northerly, strikes east-west, and occurs a short distance below No. 220.

Field Characteristics: Very hard, brownish-red, very fine-grained clay.

Economic Value: May make red pressed bricks, but they will be fragile before burning. Should be tested for paving and flashed bricks.

222. *Location:* Gunnison; 2½ miles east of town; on land owned by F. W. Harper.

Occurrence: 100 feet or more of material which dips 5° northerly, strikes east-west, and occurs 100 feet down the hill from No. 221.

Field Characteristics: Soft, light-green, very fine-grained, marly clay.

Economic Value: Should make fair, buff pressed bricks and, possibly, soft-mud bricks and earthenware if grogged with Nos. 220 and 221. This should yield a good product if carefully burned.

223. *Location:* Gunnison; on the Normal School grounds

Occurrence: 3 feet was sampled of horizontal material occurring on the surface of a gently sloping hill.

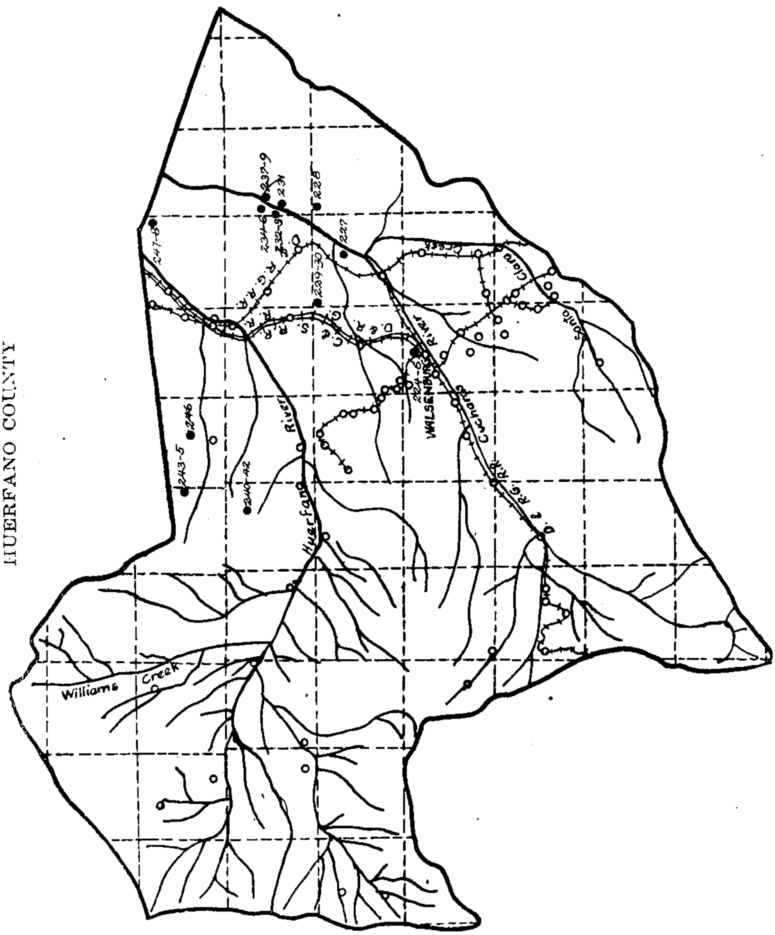
Field Characteristics: Soft, brown, coarse-grained, gritty soil.

Economic Value: Bricks made from this material were used in the interior work of the new Normal School, and this seems to be all that they are good for, since the absorption is too high and they are much too soft for first-class face-bricks.

Huerfano County

Geology of the County.—Although the geology of this county is much too complicated to be completely presented without the aid of a geological map, it may be said that the far-eastern corner of the county is largely covered by rocks of Dakota age, while the canon of the Cuchara River cuts down below the Morrison formation. To the westward, zones of Graneros, Greenhorn, Carlile, Timpas, and Apishapa age border the Dakota areas and have general northwesterly-southeasterly strikes. These are followed to the west by a thick zone of Montana material, which turns at right angles to the westward 10 miles north of Walsenburg—situated near the western edge of this zone. Northwest of this Montana zone occur relatively thin strips of all ages from Apishapa to Morrison, while west of Walsenburg are extensive deposits of rocks of Raton age.

HUERFANO COUNTY



Sketch map showing the approximate locations of the beds sampled

224. *Location:* At Walsenburg; one block north of the D. & R. G. R. R. depot.

Occurrence: A 5-foot exposure in a pit.

Field Characteristics: Soft, sandy soil.

Economic Value: Should make fair, red soft-mud bricks with 15% or more absorption.

225. *Location:* Walsenburg; near the North Walsenburg school; ¼ mile north of the river.

Occurrence and *Field Characteristics* unstated.

Economic Value: Should make fine, red soft-mud bricks and, probably, pressed bricks and earthenware.

226. *Location:* Walsenburg; north of the dyke north of town.

Occurrence and *Field Characteristics* unstated.

Economic Value: Should make good soft-mud bricks and, probably, stiff-mud bricks, earthenware, terra-cotta, hollow structural materials, and drain tiles. Some grogging may be needed, and this may seriously decrease the plasticity.

227. *Location:* 3 miles northeast of Cuchara Junction, on the most northerly of three hills capped with Niobrara material.

Occurrence: A 35-foot bed which dips 5° southwesterly, strikes N. 45° W., and occurs part way up the slope of a butte. Near the center of the Carlile formation.

Field Characteristics: Medium-hard, brownish-black, fine-grained shales.

Economic Value: Should make fine, flesh-tinted soft-mud, pressed, and flashed bricks, and, possibly, stiff-mud bricks, earthenware, terra-cotta, hollow structural materials, conduits, and paving-bricks; but grogging will be necessary in the cases of some of these, and this may seriously decrease the plasticity.

228. *Location:* 6 miles northeast of Cuchara Junction, near Cuchara Creek, in an arroya entering the creek from the southeast; just at the beginning of the rock-walled canon.

Occurrence: A 2-foot bed below 10-50 feet of sandstone which dips 10° southwesterly, strikes N. 45° W., and occurs in the bank of an arroya. May be of Dakota age.

Field Characteristics: Very hard, bluish-gray, coarsely granular clay.

Economic Value: Should make fine, almost white pressed bricks, earthenware, and Rockingham ware; also, probably, terra-cotta, hollow structural materials, conduits, and flashed bricks, but for some of these it must be grogged.

229. *Location:* 3 miles west and a little south of Apache station, on the northeastern point of a hill just southwest of Bradford Lake.

Occurrence: 5 feet was sampled of nearly horizontal material beneath 10-15 feet of lava. Near the base of the Pierre formation.

Field Characteristics: Very hard, gray to black, fine-grained shales, containing more or less grit.

Economic Value: Probably worthless, although it might make red pressed bricks which would be very fragile before burning.

230. *Location:* 3 miles west and a little south of Apache station, on the northeastern point of a hill just southwest of Bradford Lake.

Occurrence: An exposure of 40 feet or more of nearly horizontal material below No. 229.

Field Characteristics: Medium-hard, brownish-gray, fine-grained shales, containing more or less grit.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, terra-cotta, hollow structural materials, conduits, vitrified and unvitrified floor tiles, and, probably, stiff-mud and paving-bricks.

231. *Location:* Somewhat over 6 miles northeast of Cuchara Junction, in the canon near J. G. Abercrombie's north line.

Occurrence: An 8-foot bed which dips 10° southwesterly, strikes N. 45° W., and occurs near the bottom of the canon.

Field Characteristics: Medium-hard, dark-gray with white streaks, fine-grained shale in thin beds, interbedded with somewhat thicker sandy layers.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, hollow structural materials, and unvitrified floor tiles, and, probably, terra-cotta and conduits if slightly grogged.

232. *Location:* 6 miles northeast of Cuchara Junction; ¼ mile northwest of the beginning of the rock-walled Cuchara Canon.

Occurrence: A 3-6-foot bed, with about 1 foot of overburden, which dips 15° southwesterly, strikes N. 45° W., and occurs in several arroyas in slopes capped with Dakota sandstone.

Field Characteristics: Very hard, black, coarsely granular clay.

Economic Value: This is one of the most valuable clays located, and is well adapted for a wide variety of uses, as shown on Table No. 1.

233. *Location:* 6 miles northeast of Cuchara Junction; ¼ mile northwest of the beginning of the rock-walled Cuchara Canon.

Occurrence: 20-foot bed, with 3-4 feet of overburden, which dips 10° southwesterly, strikes N. 45° W., and occurs in the low mound on the slope of the Dakota-capped hill. At the base of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained shales.

Economic Value: Should make good, yellowish soft-mud, paving, and flashed bricks, and, possibly, stiff-mud and pressed bricks, terra-cotta, hollow structural materials, conduits, and sewer pipes.

234. *Location:* About 9 miles due east of the mouth of Apache Creek, where Cuchara Creek turns to the north.

Occurrence: A 3½-foot, nearly horizontal bed, which occurs high in the western wall of the Cuchara River canon. Base of the shaly zone. At the top of the Purgatory formation.

Field Characteristics: A medium-hard, black, fine-grained shale containing several white, plastic streaks.

Economic Value: Should make nearly white soft-mud and pressed bricks, earthenware, vitrified and unvitrified floor tiles and wall tiles, and, possibly, stiff-mud bricks and terra-cotta.

235. *Location:* About 9 miles due east of the mouth of Apache Creek, where Cuchara Creek turns to the north.

Occurrence: Several plastic streaks, 2-6 inches wide, mentioned as forming part of No. 234.

Field Characteristics: Very soft, white, very fine-grained clay.

Economic Value: Should make fine, white pressed bricks, earthenware, vitrified and unvitrified floor tiles, stoneware, wall tiles, and refractory wares; and may be classified as a fair ball-clay.

236. *Location:* About 9 miles due east of the mouth of Apache Creek, where Cuchara Creek turns to the north.

Occurrence: 10-foot bed overlying No. 234.

Field Characteristics: Medium-hard, brownish-gray, sandy shale, containing thin streaks of sandstone.

Economic Value: Should make flesh-tinted soft-mud bricks.

237. *Location:* 7 miles northeast of Cuchara Junction; about a mile down Cuchara Canon from the first rock walls; near the site of a proposed dam for a big reservoir.

Occurrence: 25-30-foot exposure of material which dips 10° southwesterly, strikes N. 45° W., and is exposed in an excavation at the base of the canon wall to determine the nature of the material on which the dam would rest.

Field Characteristics: Medium-hard to very hard, green and red, fine-grained, alternating marls and sandstones in 2-foot beds.

Economic Value: Should make pink soft-mud bricks if burned to Cone 01.

238. *Location:* 7 miles northeast of Cuchara Junction; about a mile down Cuchara Canon from the first rock walls; near the site of a proposed dam for a big reservoir.

Occurrence: A 2-6-foot bed which dips 10° southwesterly, strikes N. 45° W., and occurs just below the shaly zone; at the top of the Purgatory formation.

Field Characteristics: Very hard, white, fine-grained clay.

Economic Value: First-class fire-clay.

239. *Location:* 7 miles northeast of Cuchara Junction; about a mile down Cuchara Canon from the first rock walls; near the site of a proposed dam for a big reservoir.

Occurrence: An 8-foot bed which dips 10° southwesterly, strikes N. 45° W., and occurs part way up the canon wall under an overhanging ledge of sandstone.

Field Characteristics: A very hard, grayish-green, somewhat gritty clay.

Economic Value: May make fair, pink soft-mud bricks, but these will be fragile before burning.

240. *Location:* 5 miles northwest of St. Mary in an outlier of Dakota rock west of the main hogback.

Occurrence 5-foot bed which dips 25° easterly, strikes N. 10° E., and is exposed in the walls of the canon cut into the hogback. At the top of the Purgatory formation.

Field Characteristics: Medium-hard, gray to black, fine-grained, thin-bedded clay with gritty streaks.

Economic Value: Should make fine, flesh-colored pressed and flashed bricks, earthenware, vitrified and unvitrified floor tiles, and, probably, terra-cotta, hollow structural materials, conduits, paving-bricks, unvitrified roofing-tiles, and sewer pipes; but most of these are apt to be fragile before burning.

241. *Location:* 5 miles northwest of St. Mary in an outlier of Dakota rock west of the main hogback.

Occurrence: A 2-foot bed which dips 25° easterly, strikes N. 10° E., and is exposed in a canon through the Dakota hogback. 30 feet above No. 240. Near the base of the Dakota formation.

Field Characteristics: Very hard, light-gray, fine-grained clay and shale.

Economic Value: First-class fire-clay.

242. *Location:* 5 miles northwest of St. Mary in an outlier of Dakota rock west of the main hogback.

Occurrence: A 40-foot exposure of material which dips 25° easterly, strikes N. 10° E., and is exposed in a canon cutting the Dakota hogback. Near the top of the Morrison formation.

Field Characteristics: Very hard, green, fine-grained, compact marl.

Economic Value: Probably worthless.

243. *Location:* About 1 mile north of Apache Creek and west of Huerfano station; in the second notch crosing the Dakota hogback.

Occurrence: A 5-foot bed, with 3-4 feet of overburden, which dips 85° easterly, strikes N. 10° E., and is exposed on the northern slope of a Dakota hogback. Possibly of Purgatory age.

Field Characteristics: A medium-hard, iron-stained, sandy shale.

Economic Value: Should make first-class, pink soft-mud and pressed bricks, earthenware, terra-cotta, and unvitrified floor tiles, and, probably, stiff-mud bricks, hollow structural materials, and drain tiles.

244. *Location:* About 1 mile north of Apache Creek and west of Huerfano station; in the second notch crossing the Dakota hogback.

Occurrence: A 5-foot bed, with 3-4 feet of overburden, which dips 85° easterly, strikes N. 10° E., and occurs 100 feet up the northern slope of a hogback. A short distance below No. 243.

Field Characteristics: Medium-hard, black, fine-grained clays and shales, containing a white streak.

Economic Value: Should make first-class refractory wares, vitrified floor tiles, and wall tiles.

245. This sample was taken from the 6-inch white streak mentioned in No. 244.

Economic Value: First-class fire-clay.

246. *Location:* West of Huerfano station on the eastern slope of Hayden Butte.

Occurrence: A 75-80-foot exposure of material, with a slight easterly dip, occurring in arroyas about half-way up the side of the butte.

Field Characteristics: Medium-hard, yellowish-gray, slightly gritty shales.

Economic Value: Should make good, pink soft-mud bricks, earthenware, and terra-cotta; also, probably, stiff-mud and pressed bricks, hollow structural materials, drain tiles, unvitrified and vitrified roofing-tiles, and sewer pipes.

247. *Location:* 5 miles southeast of Graneros in Huerfano Canon, opposite the "Bull Corral," and 1 mile southeast of the stone in the canon which marks the angle in the county boundary.

Occurrence: A 5-foot bed, with 3 feet of overburden, which dips 15° northerly, strikes N. 75° E., and is exposed in several small arroyas.

Field Characteristics: Very hard, black, coarsely granular clay.

Economic Value: First-class fire-clay.

248. *Location:* 5 miles southeast of Graneros, in Huerfano Canon; about 1½ miles up the Huerfano River from the stone in the canon which marks the angle in the county boundary.

Occurrence: A lens-shaped bed, 500 or 600 feet long, with a maximum thickness of 3½ feet, which dips 5° easterly, strikes N. 40° E., and occurs beneath an overhanging bluff of sandstone on the northern side of the canon.

Field Characteristics: A medium-hard, dark-gray, fine-grained shale.

Economic Value: A first-class fire-clay.

Jefferson County

Geology of the County.—The western half of the county is covered with pre-Cambrian crystalline rocks, while over the eastern half occurs material of Denver and Arapahoe age, except at the extreme north, where there is a considerable exposure of Laramie rocks. Separating the eastern and western areas is a relatively narrow zone of more or less steeply upturned beds, which, when all are present, include all horizons from the Fountain to the Laramie. This zone extends in a nearly straight line from Platte Canon station to Eldorado Springs.

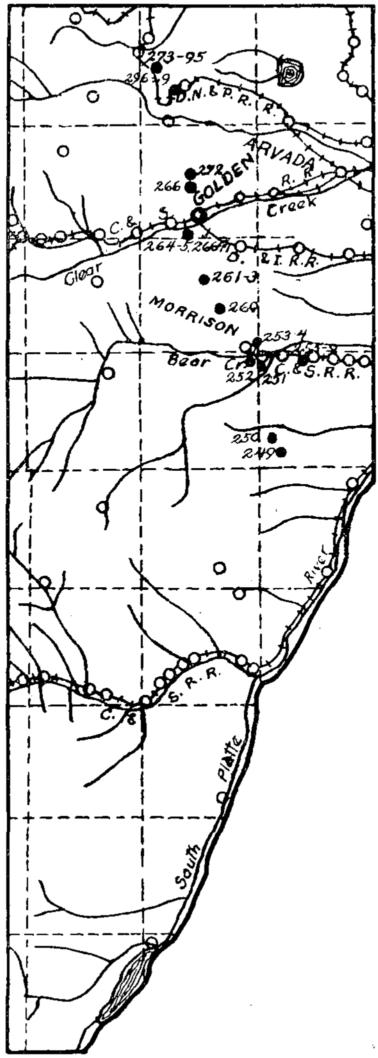
249. *Location:* 5½ miles south of Morrison.

Occurrence: 1 foot was sampled of a thick exposure of material with 18 inches of overburden, about half-way up the gentle slope capped with Laramie material. Near the center of the Fox Hills formation.

Field Characteristics: A soft, yellow, medium fine-grained shale.

Economic Value: Might make fair, red pressed bricks which will be fragile before burning, or soft-mud bricks after grogging.

JEFFERSON COUNTY



Sketch map showing the approximate locations of the beds sampled

250. *Location:* 5 miles south of Morrison.

Occurrence: 15 feet was sampled of a much thicker exposure of material, with 5 feet of overburden, which dips 40° easterly, strikes N. 33° W., and occurs at the eastern base of the Dakota hogback. 100 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Probably worthless, although it might make an attractive, light-gray or nearly white pressed brick if the loss from breakage before burning is not too excessive.

251. *Location:* South of Morrison at the edge of town.

Occurrence: 4 feet was sampled of a much thicker exposure of material, with 5 feet of overburden, which dips 37° easterly, strikes N. 37° W., and occurs in the eastern side of the Dakota hogback. At the base of the Graneros formation.

Field Characteristics: A hard, black, fine-grained shale.

Economic Value: Probably worthless, although it might make an attractive, light-gray or nearly white pressed brick if the loss from breakage before burning is not too excessive. Might have a wide variety of uses if mixed with a fatter clay.

252. *Location:* 100 yards southeast of the Cliff House at Morrison; beside the public road.

Occurrence: 6 feet was sampled of a thicker exposure of material, with 6 feet of cemented overburden, which dips 43° easterly, strikes N. 18° W., and occurs on the western side of the Dakota hogback. 100 feet below the top of the Morrison formation.

Field Characteristics: Medium-hard, gray, red, and yellow, fine-grained, sandy shales.

Economic Value: Should make good, pink soft-mud bricks.

253. *Location:* 200 yards north of Bear Creek at Morrison.

Occurrence: 6 feet was sampled of a thicker exposure of material which dips 49° easterly, strikes N. 18° W., and occurs in the eastern side of a small Lykins ridge, 10 feet above the "crinkled limestone."

Field Characteristics: Medium-soft, red, medium fine-grained, sandy shales, containing streaks of limestone.

Economic Value: Should make extra-fine, pink soft-mud and pressed bricks if burned to Cone 2; also earthenware and, probably, stiff-mud bricks and terra-cotta.

254. *Location:* Southeast of Morrison, on an irrigation ditch at the northern end of the Dakota hogback; south of Bear Creek.

Occurrence: 5 feet was sampled of a thicker exposure of material, with 6 feet of overburden, which dips 37° northeasterly and strikes N. 35° W.

Field Characteristics: A medium-soft, black, fine-grained shale containing a 3-inch bed of crystalline gypsum.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, terra-cotta, vitrified and unvitrified floor tiles, and, probably, stiff-mud bricks, hollow structural materials, conduits, vitrified and unvitrified roofing-tiles, and sewer pipes.

255. *Location:* 2½ miles east of Morrison, on a bluff on the southern shore of Bear Creek.

Occurrence: 20 feet was sampled of a thicker exposure of material, with 2-3 feet of overburden, which dips 80° westerly, strikes N. 78° W., and occurs near the top of the bluff. Near the top of the Pierre formation.

Field Characteristics: Medium-hard, gray, medium fine-grained, sandy shales.

Economic Value: May make pink building-bricks, but those made by the stiff- and soft-mud processes will require heavy grogging, and there will probably be considerable loss due to over- and underburning.

256. *Location:* 3 miles east of Morrison; just south of the C. & S. R. R., on Carbon Hill.

Occurrence: A 10-foot bed, with 3 feet of overburden, which dips 76° easterly, strikes N. 40° E., and occurs at the northern base of the hill in an abandoned pit. Near the top of the Laramie formation.

Field Characteristics: Soft, gray, red, and yellow, medium fine-grained clays and shales.

Economic Value: Should make fine, yellowish pressed, paving, and flashed bricks, earthenware, and vitrified and unvitrified floor tiles; also, probably, soft- and stiff-mud bricks if grogged.

257. *Location:* 3 miles east of Morrison; just south of the C. & S. R. R., on Carbon Hill.

Occurrence: 15 feet was sampled of a thicker exposure of material, with 1 foot of overburden, which dips 76° easterly, strikes N. 40° W., and occurs at the northern base of the hill in an abandoned pit. 50 feet below No. 256.

Field Characteristics: Soft-gray, medium fine-grained shale.

Economic Value: Should make fine, cream-colored soft-mud and pressed bricks, earthenware, vitrified and unvitrified floor tiles; also, probably, stiff-mud, paving, and flashed bricks, stone ware, and yellow-ware.

258. *Location:* 3 miles east of Morrison; just south of the C. & S. R. R., on Carbon Hill.

Occurrence: 12 feet was sampled of a thicker exposure of material, with 2 feet of overburden, which dips 76° easterly, strikes N. 40° W., and occurs at the northern base of the hill in an abandoned pit. 100 feet below No. 257.

Field Characteristics: A hard, gray, medium fine-grained shale.

Economic Value: Should make fine, cream-colored pressed bricks, earthenware, vitrified and unvitrified floor tiles, and, probably, soft-mud, stiff-mud, and flashed bricks.

259. *Location:* 3 miles east of Morrison; just south of the C. & S. R. R., on Carbon Hill.

Occurrence: 12 feet was sampled of a thicker exposure of material, with 18 inches of overburden, which dips 76° easterly, strikes N. 40° W., and occurs at the northern base of the hill in an abandoned pit. 300 feet below No. 258 and 100 feet above the coal.

Field Characteristics: A hard, gray, medium fine-grained shale, with sandy streaks.

Economic Value: Should make good, cream-colored soft-mud and pressed bricks, earthenware, and vitrified and unvitrified floor tiles; also, probably, stiff-mud and flashed bricks, and, possibly, paving-bricks.

260. *Location:* 5 miles south of Golden and one mile west of Green Mountain; in a drift off Gehman's tunnel.

Occurrence: A 15-foot bed which dips 45° easterly, strikes N. 27° W., and occurs 150 feet below the surface in the Dakota hogback.

Field Characteristics: A hard, black, very fine-grained clay.

Economic Value: First-class fire-brick.

261. *Location:* 3½ miles south of Golden.

Occurrence: A 20-foot bed on the western side of Dakota hogback. At the top of the Morrison formation.

Field Characteristics: A soft, red, greenish-yellow, fine-grained, sandy shale.

Economic Value: Should make fine, flesh-colored soft-mud and pressed bricks and earthenware.

262. *Location:* 3½ miles south of Golden and ½ mile west of Green Mountain.

Occurrence: 20 feet was sampled of a thicker exposure of vertical material, with 18 inches of overburden, which strikes N.

40° W., and occurs 30 feet up the northern end of the Laramie hogback. 50 feet above basal sandstone of the Laramie formation.

Field Characteristics: Soft, light-gray and yellow, fine-grained shale, containing sandstone layers not included in the sample.

Economic Value: Should make fine, flesh-colored soft-mud and pressed bricks, earthenware, vitrified and unvitrified floor tiles, and, probably, stoneware and Rockingham ware.

263. *Location:* 3½ miles south of Golden and 500 feet west of the Laramie hogback.

Occurrence: 1 foot was sampled of a much thicker occurrence of vertical material, with 1 foot of overburden, which strikes N. 40° W., and underlies soil on the southern side of a gently sloping knoll. No outcrops are visible. 500 feet below the top of the Fox Hills formation.

Field Characteristics: Medium-soft, yellowish-brown, fine-grained shale.

Economic Value: If there is not too much waste from over- and underburning, should make attractive, light-red soft-mud bricks if grogged; and, also, pressed bricks.

264. *Location:* West of Golden.

Occurrence: 25 feet was sampled of a thicker exposure of material which dips 65° westerly, strikes S. 88° E., and occurs halfway up the steep slope of a 75-foot hill. 350 feet below the top of the Fox Hills formation.

Field Characacteristics: Medium-soft, gray, fine-grained, sandy shales.

Economic Value: Should make red soft- and stiff-mud bricks with high absorption, and may answer for paving-bricks.

265. *Location:* West of Golden.

Occurrence: 5 feet was sampled of a thicker exposure of material, with 8 inches of overburden, which dips 38° westerly, strikes S. 88° E., and occurs half way up the side of the Laramie hogback. 100 feet below the top of the Fox Hills formation.

Field Characteristics: Soft, drab, very fine-grained shales.

Economic Value: Should make fair, dark flesh-colored soft- and stiff-mud bricks.

266. *Location:* West of the brick-yard north of Golden.

Occurrence: A 50-foot exposure of material, with 3 feet of overburden, which dips 76° easterly, strikes S. 20° E., and occurs on the eastern slope of the Lyons hogback. 75 feet above the base of the Lykins formation.

Field Characteristics: A hard, red, medium-grained, sandy shale, containing greenish-white streaks.

Econome Value: Probably worthless.

267. *Location:* West of Golden.

Occurrence: A 50-foot, nearly vertical bed exposed in a pit. 50 feet below the top of the Laramie formation.

Field Characteristics: Unstated, except that it is a clay containing sandy layers.

Economic Value: Should make fine, nearly white soft-mud and pressed bricks and vitrified floor tiles; also, probably, stiff-mud bricks.

268. *Location:* West of Golden.

Occurrence: A 25-foot bed in a pit in the Laramie hogback. 100 feet below the top of the formation.

Field Characteristics: Unstated, except that the clay is very pure.

Economic Value: Should make good, nearly white soft-mud bricks and, possibly, pressed bricks and earthenware, but these will be fragile before burning.

269. *Location:* West of Golden.

Occurrence: A 12-foot bed in a pit in the Laramie hogback. 200 feet below the top of the formation.

Field Characteristics: Unstated.

Economic Value: Should make good, light flesh-colored soft-mud bricks and, possibly, pressed bricks and earthenware, but these will be fragile before burning.

270. *Location:* West of Golden.

Occurrence: A 15-foot bed in a pit in the Laramie hogback. 250 feet below the top of the formation.

Field Characteristics: Unstated, except that much coarse, carbonaceous material is present.

Economic Value: Should make good, nearly white soft-mud bricks.

271. *Location:* West of Golden.

Occurrence: A 10-foot bed in a pit in the Laramie hogback; adjoining No. 270 on the west.

Field Characteristics: Unstated.

Economic Value: May make grayish soft-mud or pressed bricks; both will be fragile before burning.

272. *Location:* ¾ mile north of the brick-yard; north of Golden.

Occurrence: 8 feet was sampled of a thicker exposure of material which dips 65° easterly, strikes S. 37° E., and is exposed in a tunnel on the eastern side of the Dakota hogback; 130 feet from the mouth. 25 feet above the base of the Graneros formation.

Field Characteristics: A hard, black, very fine-grained shale.

Economic Value: Should make good, cream-colored soft-mud and pressed bricks, earthenware, and vitrified and unvitrified floor tiles; also, probably, stiff-mud bricks and, possibly, paving-bricks.

273. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, very fine-grained clay.

Economic Value: Might make red soft-mud bricks if grogged, but the absorption would then be excessive.

274. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, coarse-grained, sandy clay.

Economic Value: Should make fair, red soft-mud and pressed bricks and earthenware; also, probably, stiff-mud bricks.

275. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-hard, white, medium fine-grained clay.

Economic Value: Should make fine, nearly white soft-mud and pressed bricks, earthenware, terra-cotta, hollow structural materials, and drain tiles.

276. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, light-drab, medium coarse-grained, sandy shale.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware; probably, also, stiff-mud bricks.

277. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Soft, cream-colored, fine-grained shales and clays.

Economic Value: May make pink soft- and stiff-mud bricks and earthenware if grogged. The absorption will be high, and a considerable proportion are apt to be over- and underburned.

278. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, fine-grained, sandy shale.

Economic Value: May make red building-bricks, but grogging will be required if the soft- or stiff-mud process is used, and the absorption will be high. There is apt, also, to be a considerable portion of over- and underburned material.

279. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, fine-grained, sandy shale.

Economic Value: Probably worthless.

280. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, drab, medium fine-grained clay.

Economic Value: Worthless.

281. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, drab, fine-grained clay.

Economic Value: Should make good, buff pressed bricks and earthenware, but a considerable portion are apt to be over- and underburned. Heavy grogging might yield soft-mud bricks.

282. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, coarse-grained, sandy clay.

Economic Value: May make pink soft-mud or pressed bricks, but the former will require grogging.

283. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: A hard, yellowish-drab, medium coarse-grained, sandy clay.

Economic Value: Probably worthless.

284. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, drab, medium coarse-grained, sandy clay.

Economic Value: May make pink earthenware and soft-mud and pressed bricks, but the first two will require grogging, and there is apt to be a considerable portion of over- and underburned material.

285. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, medium fine-grained, sandy clay.

Economic Value: Probably worthless, although it will yield buff pressed bricks of high absorption, and might answer for soft- and stiff-mud bricks and earthenware after heavy grogging.

286. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-soft, drab, medium coarse-grained sandy clay.

Economic Value: Should make good, pink soft-mud bricks, and, probably, pressed and stiff-mud bricks.

287. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, yellowish-drab, medium fine-grained, sandy clay.

Economic Value: May make pink pressed, soft-mud, and stiff-mud bricks, but the last two will need heavy grogging.

288. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Soft, drab, fine-grained clay.

Economic Value: May make pink pressed, soft-mud, and stiff-mud bricks, but the last two will require grogging, and over- and underburning is apt to cause considerable waste.

289. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Soft, drab, coarse-grained, sandy clay.

Economic Value: Should make good, red soft-mud bricks and, possibly, pressed bricks.

290. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, drab, fine to coarse-grained sandy clays.

Economic Value: May make red pressed bricks with high absorption, and soft- and stiff-mud bricks if heavily grogged.

291. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Hard, brown, coarse-grained, sandy clay.

Economic Value: Should make good, red soft-mud bricks and, possibly, stiff-mud and pressed bricks.

292. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Soft, drab, fine-grained clay.

Economic Value: Worthless.

293. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated, except that it is in the Dakota hogback.

Field Characteristics: Soft, drab, coarse to fine-grained clays and shales.

Economic Value: Should make good, white soft-mud bricks and, possibly, stiff-mud and pressed bricks.

294. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Soft, yellowish-drab, medium-grained, sandy clay.

Economic Value: May make pink soft-mud, stiff-mud, and pressed bricks, but the first two will require grogging, and all are subject to waste due to over- and underburning.

295. *Location:* Near Coal Creek, on D. & N. W. R. R.

Occurrence: Unstated.

Field Characteristics: Medium-hard, yellowish, medium coarse-grained, sandy shale.

Economic Value: May make a paving-brick.

296. *Location:* In a cut on D. & N. W. R. R., opposite Coal Creek canon; on the Loveland property. The so-called "No. 2" bed.

Occurrence: A 60-foot exposure of material, with 4 feet of overburden, which dips 82° easterly, strikes S. 16° E., and occurs in a low hogback. Immediately above the basal Laramie sandstone.

Field Characteristics: Soft to medium-soft, light to dark-drab, yellow and brown, fine-grained clays and shales, with some sandy streaks.

Economic Value: Should make good, pink pressed bricks. It is reported that earthenware and roofing-tiles have been made from this clay, but the air shrinkage is much too high and the cohesion too low to permit of the manufacture of these products on a large scale.

297. *Location:* In a cut on D. & N. W. R. R., opposite Coal Creek canon; on the Loveland property. The so-called "No. 1" bed.

Occurrence: 60 feet of material, with 4 feet of overburden. which dips 82° easterly, strikes S. 16° E., and occurs on the eastern slope of a low hogback. 100 feet above the basal Laramie sandstone.

Field Characteristics: Soft to medium soft, light-drab and yellowish, fine-grained clays and shales, with some sandy streaks. Called locally "yellow clay."

Economic Value: Should make fine, pink pressed bricks and, probably, soft- and stiff-mud bricks if grogged.

298. *Location:* In a cut on D. & N. W. R. R., opposite Coal Creek canon; on the Loveland property. The so-called "B" bed.

Occurrence: A 25-foot bed, with 5 feet of overburden, which dips 82° easterly, strikes S. 16° E., and occurs at the eastern base of a low hogback.

Field Characteristics: A very soft, yellow, very sandy clay with drab streaks and a few plastic, non-sandy layers.

Economic Value: Should make good, red soft-mud bricks, and may be used to grog the nearby clays.

299. *Location:* In a cut on D. & N. W. R. R., opposite Coal Creek canon; on the Loveland property. The so-called "A" bed.

Occurrence: A 20-foot bed, with 4 feet of overburden, which dips 82° easterly, strikes S. 16° E., and occurs on the eastern slope of a low hogback. 200 feet above the basal Laramie sandstone.

Field Characteristics: Soft, drab and yellow, medium fine-grained, somewhat sandy clays and shales.

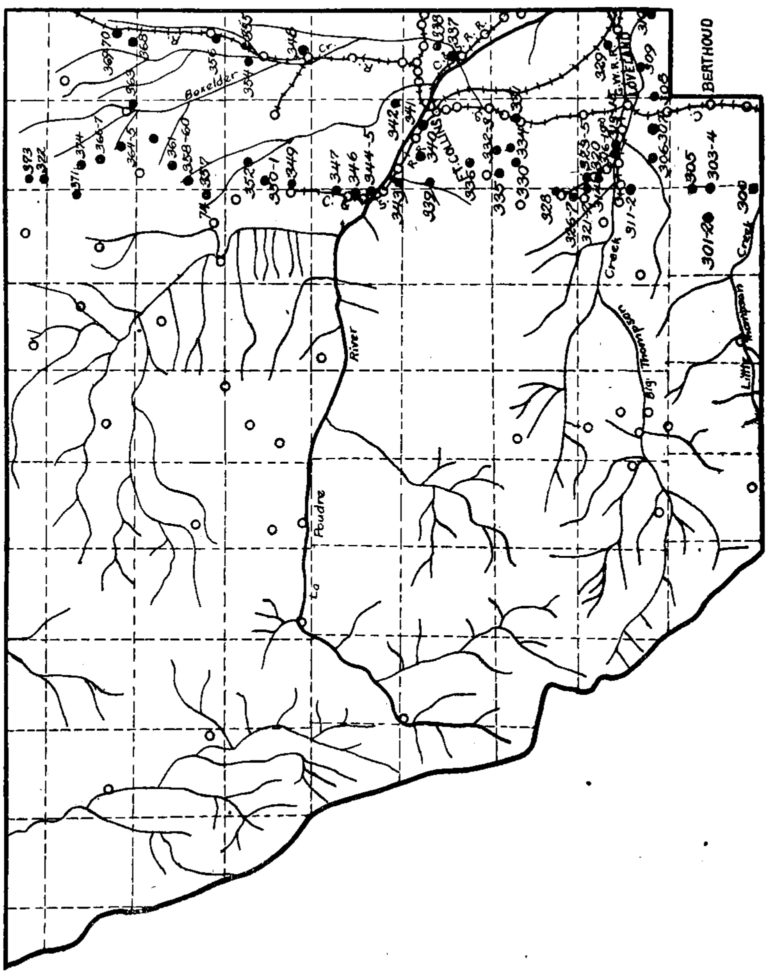
Economic Value: Should make good, red pressed bricks and, probably, soft-mud, stiff-mud, and flashed bricks and earthenware, although some of these will require grogging.

Larimer County

Geology of the County.—The greater part of Larimer County is covered with pre-Cambrian crystalline rocks, but a relatively narrow zone of more or less steeply upturned beds of from Fountain to Niobrara age lies from 10 to 20 miles west of the eastern boundary, while Pierre and Fox Hills beds occur east of these.

A little Laramie and Tertiary material is exposed in the extreme northeastern corner, and sedimentary material also outcrops near the western end of the northern boundary, but this was not sampled.

LARIMER COUNTY



Sketch map showing the approximate locations of the beds sampled

300. *Location:* 900 feet north and 800 feet west of the S.E. Cor. Sec. 36, T. 4 N., R. 70 W.; southwest of Berthoud.

Occurrence: A 30-foot exposure of nearly vertical material, with 1 foot of overburden, which strikes N. 40° E., and occurs on a bank of a ditch cut into the eastern side of a ravine. About half-way between the base of the Pierre formation and the Hygiene sandstone.

Field Characteristics: Medium-hard, yellowish-green, somewhat gritty shale.

Economic Value: Should make fine, red soft-mud and pressed bricks, earthenware, terra-cotta, hollow structural materials, conduits, and unvitrified floor tiles; also, probably, stiff-mud bricks, drain tiles, and unvitrified roofing-tiles.

301. *Location:* 1,400 feet north and 700 feet west of the S.E. Cor. Sec. 15, T. 4 N., R. 70 W. (See No. 305.)

302. *Location:* 1,500 feet north and 700 feet west of the S.E. Cor. Sec. 15, T. 4 N., R. 70 W. (See No. 305.)

303. *Location:* Near the N.E. Cor. Sec. 13, T. 4 N., R. 70 W.; west of Berthoud. Material of the same horizon and appearance is also well exposed 3 miles south in Sec. 36 along a creek, a ditch, and around a flat-topped hill.

Occurrence: A 40-foot bed which dips 35° easterly, strikes north and south, and occurs in arroyas at the base of a hogback. At the base of the Pierre formation.

Field Characteristics: A medium-hard, black to dark-gray, fine-grained shale.

Economic Value: Should make good, red soft-mud and pressed bricks and, probably, stiff-mud bricks and terra-cotta.

304. *Location:* 1,200 feet north and 1,100 feet west of the N.E. Cor. Sec. 13, T. 4 N., R. 70 W.; west of Berthoud. The same horizon is also well exposed 2½ miles south in the S.W.¼ Sec. 25.

Occurrence: A 30-foot exposure, with 4 feet of overburden, which dips 35° easterly, strikes north and south, and occurs on the bank of a ravine. At the top of the Carlile formation.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, red soft-mud, pressed, and flashed bricks, earthenware, and terra-cotta; also, probably, stiff-mud and paving-bricks; and, possibly, hollow structural materials and drain tiles.

305. *Location:* 1,200 feet north and 1,100 feet west of the N.E. Cor. Sec. 12, T. 4 N., R. 70 W.; west of Berthoud.

(Nos. 301, 302, and 305 were taken from exactly the same horizon, and appeared so nearly identical in the field that the three samples were placed in one sack and the mixture tested.)

Occurrence: A bed about 20 feet thick, with 3-5 feet of overburden, which dips about 20° easterly, strikes nearly north and south, and occurs in a slight longitudinal depression in the eastern slope of the Dakota hogback.

Field Characteristics: Medium-hard, gray, gritty clay.

Economic Value: Should make red soft-mud bricks and earthenware if slightly grogged.

306. *Location:* 200 feet north and 900 feet west of the S.E. Cor., Sec. 29, T. 5 N., R. 69 W.; southwest of Loveland; in a small test pit dug by Johnson and Carpenter, south of a ditch.

Occurrence: An 8-foot exposure of material, with 1 foot of overburden, which dips 5° easterly, strikes N. 30° E., and occurs on a gentle northerly slope. Below the Hygiene sandstone in the Pierre formation.

Field Characteristics: Soft, yellowish-green, fine-grained shale.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware, but grogging will be necessary for some of these, and there will be considerable loss due to over- and underburning.

307. *Location:* 600 feet north and 50 feet west of the S.E. Cor. Sec. 27, T. 5 N., R. 69 W.; southwest of Loveland; just above the ditch from the Plaster Mill. It seems likely that the description of the location of this sample by land subdivisions is incorrect, for the Morrison beds hardly occur as far east as the point given, and Mr. A. Wild, who had this material tested, lives some 5 miles northwest of the point on the map where this sample has been located. Exposures of material apparently identical with these are found both north and south of Arkins.

Occurrence: A 20-foot exposure of material, with 1 foot of overburden, which dips 80° westerly, strikes N. 20° W., and occurs on the western slope of the Dakota ridge. In the lower part of the Morrison formation.

Field Characteristics: Soft, light to dark, red to blue marls of various textures, occurring in beds 1-4 feet thick.

Economic Value: Should make good, flesh-colored dry-pressed bricks. Perfectly vitrified, greenish-yellow bricks have been made from this clay, but these cannot be manufactured on a large scale, as a large proportion would be either over- or underburned. They are probably too brittle to be used for paving-bricks in any case.

308. *Location:* 900 feet north and 800 feet west of the S.E. Cor. Sec. 25, T. 5 N., R. 69 W.; south of Loveland; in two small ravines above the irrigation ditch.

Occurrence: A 10-foot exposure of material, with 1 foot or more of overburden, of uncertain dip and strike, which occurs in the side of a hill 100 feet or more high. About half-way between the Hygiene sandstone and the top of the Pierre formation.

Field Characteristics: Soft, yellowish-green, fine-grained shale, containing a little sand.

Economic Value: Should make good, pink soft-mud and pressed bricks and unvitrified floor tiles; also, possibly, stiff-mud bricks and earthenware.

309. *Location:* Near the eastern side of Sec. 20, T. 5 N., R. 68 W.; southeast of Loveland where the Big Thompson River has cut into its south bank.

Occurrence: An exposure of 200 feet or more of material, with 5 feet of overburden, which dips 20° easterly, strikes N. 20° W., and occurs along the bank of the river to a height of 30 feet above water level.

Field Characteristics: Soft, yellowish-green, fine-grained shale, containing a little sand.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware.

310. *Location:* Near the middle of Sec. 25, T. 5 N., R. 68 W.; southeast of Loveland.

Occurrence: A 10-foot exposure of nearly horizontal material, with 1 foot of overburden, which strikes north and south, and occurs on the southern bank of the river. Not far above the Hygiene sandstone in the Pierre formation.

Field Characteristics: A soft, yellowish-green, slightly gritty shale, containing a good deal of gypsum.

Economic Value: Should make good, pink soft-mud and paving-bricks, earthenware, terra-cotta, hollow structural materials, and drain tiles; also pressed bricks with rather high absorption. Mr. Grub, who was using this clay for the manufacture of dry-pressed bricks when the sample was taken, claims that the shale must be weathered in order to work satisfactorily.

311. *Location:* 800 feet north and 900 feet west of the S.E. Cor. Sec. 24, T. 5 N., R. 70 W.; west of Loveland; in a ditch along Dry Creek.

Occurrence: A 20-foot bed with 2-3 feet of overburden, which dips 20° easterly, strikes north and south, and occurs near the top of the Dakota hogback.

Field Characteristics: Medium-hard, black, fine-grained shale, containing sandy streaks.

Economic Value: Should make good, pink soft-mud and pressed bricks, vitrified and unvitrified floor tiles, and, probably, stiff-mud bricks.

312. *Location:* 800 feet north and 900 feet west of the S.E. Cor. Sec. 24, T. 5 N., R. 70 W.; west of Loveland; in a ditch along Dry Creek.

Occurrence: A 20-foot bed, with 2-3 feet of overburden, which dips 20° easterly, strikes north and south, and occurs west of No. 311 and is separated therefrom by from 1-2 feet of sandstone.

Field Characteristics: Not stated.

Economic Value: Should make good, red soft-mud and flashed bricks; also, probably, stiff-mud, pressed, and paving-bricks.

313. *Location:* 1,800 feet north and 800 feet west of the S.E. Cor. Sec. 16, T. 5 N., R. 69 W.; west of Loveland and back of the schoolhouse.

Occurrence: A 20-foot exposure of material, with less than 2 feet of overburden, which dips 35° easterly, strikes north and south, and is exposed in a number of ravines. Near the base of the Pierre formation.

Field Characteristics: Medium-hard, black and brown, fine-grained shales.

Economic Value: Should make good, pink soft-mud, pressed, paving, and flashed bricks, and vitrified and unvitrified floor tiles; also, probably, stiff-mud bricks, earthenware, and terra-cotta. Mr. Johnson, who is interested in this property, has had a few bricks made. They are well vitrified, but are said to be too brittle for paving purposes.

314. *Location:* 1,500 feet north of the S.E. Cor. Sec. 7, T. 5 N., R. 69 W.; northwest of Loveland; at the end of the track leading to the Plaster Mill.

Occurrence: An 8-10-foot exposure of material which dips about 50° westerly, strikes N. 30° W., and occurs over the gypsum bed which was quarried for plaster.

Field Characteristics: A soft, red, fine-grained, crumpled shale, showing green spots.

Economic Value: Analysis shows that this clay contains nearly 50% of dolomite, and the tests indicate that it is probably worthless.

315. *Location:* 100 feet north and 1,850 feet west of the S.E. Cor. Sec. 16, T. 5 N., R. 69 W.; west of Loveland on the south bank of Big Thompson River.

Occurrence: 170-foot exposure of material, with 5-10 feet of overburden, which dips 27° easterly, strikes N. 10° E., and is exposed on the river bank to a height of 20 feet above the water. All the Graneros and Carlile formations are represented by this sample. The Greenhorn limestone seems to be lacking here.

Field Characteristics: Soft, black and brown, fine-grained shales.

Economic Value: Should make good, red soft-mud, pressed, paving, and flashed bricks, and vitrified and unvitrified floor tiles; also, probably, stiff-mud bricks.

316. *Location:* 2,000 feet north and 1,600 feet west of the S.E. Cor. Sec. 17, T. 5 N., R. 69 W.; in some test pits dug below the plaster mill.

Occurrence: A 20-foot bed, with 1 foot or more of overburden, which dips 80° westerly, strikes N. 35° W., and occurs between the low Dakota and high Lyons hogbacks. Near the base of the Morrison formation.

Field Characteristics: Medium-hard, light-gray, medium-grained, marly shales.

Economic Value: Should make fine, flesh-colored soft-mud and pressed bricks, and, probably, stiff-mud bricks. Mr. Shields, of Loveland, had some of this clay tested, and it is reported to have made nice white tiles. Later it was sold as tile material to Fort Collins people, but the tests made in this investigation indicate that the absorption is too great for floor tiles and that the clay does not burn perfectly white, at least in an oxidizing atmosphere.

317. *Location:* About 1,100 feet north and 1,500 feet west of the S.E. Cor. Sec. 17, T. 5 N., R. 69 W.; west of Loveland where the vertical Dakota sandstone projects into the Big Thompson River on the southern bank.

Occurrence: Two beds, each of a thickness of 4 feet, with 1 foot of overburden, which dip 80° westerly, strike N. 35° W., and occur on the bank of the river, between hard layers of sandstone.

Field Characteristics: Medium-hard, gray to light bluish-green, sandy, much-jointed clay.

Economic Value: Should make good, pink soft-mud, pressed, and paving-bricks; also, probably, stiff-mud bricks, earthenware, and vitrified and unvitrified floor tiles.

318. *Location:* About 1,100 feet north and 1,500 feet west of the S.E. Cor. Sec. 17, T. 5 N., R. 69 W.; west of Loveland where the vertical Dakota sandstone projects into the Big Thompson River on the southern bank.

Occurrence and *Field Characteristics:* A 2-foot bed of red, calcareous clay which lies between the two beds mentioned in No. 317.

Economic Value: Should make good, red pressed and paving bricks, and, possibly, vitrified and unvitrified floor tiles.

319. *Location:* About 1,100 feet north and 1,500 feet west of the S.E. Cor. Sec. 17, T. 5 N., R. 69 W.; west of Loveland where the vertical Dakota sandstone projects into the Big Thompson River on the southern bank.

Occurrence and *Field Characteristics:* An 8-foot bed of sandy clay which lies below No. 317 and is separated therefrom by 2 feet of sandstone.

Economic Value: Should make good, flesh-colored soft-mud bricks and, also, probably, pressed and stiff-mud bricks, and unvitrified floor tiles if burned to a high temperature.

320. *Location:* 600 feet north and 400 feet west of the S.E. Cor. Sec. 7, T. 5 N., R. 69 W.; along the railroad in front of Mr. Wild's house; northwest of Loveland.

Occurrence: 50-75-foot exposure of material, with 2 feet of overburden, which dips 75° westerly, strikes N. 25° W., and occurs at the foot of a hill capped with Dakota sandstone.

Field Characteristics: A medium-hard, yellowish to brownish, calcareous shale which is quite sandy.

Economic Value: Undoubtedly worthless, as the burned brick slakes easily. It is said that a carload of this material and No. 307, in proportions of two of No. 320 to one of No. 307, was tested, and it is claimed that it burned to a very light-weight, hard brick of value for fire-proofing material. While it is probably true that the mixture would yield a very light, porous brick, it is certain that the deficient plasticity and tensile strength would prevent the manufacture of first-class ware, and that the unburned material would be very fragile.

321. *Location:* Sec. 1, T. 5 N., R. 70 W.; at the eastern end of a reservoir dam across Buckhorn Creek.

Occurrence: 2 beds, aggregating about 6 feet, which dip 25° easterly, strike N. 5° W., and occur on the eastern side of the Dakota hogback.

Field Characteristics: Medium-hard, light greenish-blue, sandy clays.

Economic Value: Should make fine, light-pink soft-mud and pressed bricks, and, probably, paving-bricks.

322. *Location:* Sec. 1, T. 5 N., R. 70 W.; at the eastern end of a reservoir dam across Buckhorn Creek.

Occurrence: Two beds, aggregating about 4 feet, which alternate with those included in No. 321.

Field Characteristics: Medium-hard, red, sandy clays.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud and paving bricks.

323. *Location:* Near the middle of the southern side of Sec. 6, T. 5 N., R. 69 W.; in a tunnel begun years ago for irrigation purposes, but not yet completed.

Occurrence: An 8-foot bed which dips 80° westerly and strikes N. 30° W.

Field Characteristics: Very hard, gray, medium fine-grained clay, containing a few dark-red patches.

Economic Value: Should make good flashed bricks and, probably, pink pressed and paving-bricks.

324. *Location:* Near the middle of the southern side of Sec. 6, T. 5 N., R. 69 W.; in a tunnel begun years ago for irrigation purposes, but not yet completed.

Occurrence: A 10-foot bed, with 10 feet of overburden, which dips 80° westerly, strikes N. 30° W., and occurs near the top of the western slope of the Dakota hogback. Separated from No. 323 by about 75 feet of sandstone.

Field Characteristics: A hard, gray, medium-grained clay.

Economic Value: Should make good, pink soft-mud, pressed, paving, and flashed bricks, and vitrified and unvitrified floor tiles; also, probably, stiff-mud bricks.

325. *Location:* Near the middle of the southern side of Sec. 6, T. 5 N., R. 69 W.; in a tunnel begun years ago for irrigation purposes, but not yet completed.

Occurrence: A 15-foot bed, with 10 feet of overburden, which dips 80° westerly, strikes N. 30° W., and occurs near the top of the western slope of the Dakota hogback, and overlies No. 324.

Field Characteristics: A medium-hard, grayish-brown, sandy shale.

Economic Value: Should make good, pink soft-mud and pressed bricks and vitrified floor tiles; also, probably, stiff-mud and paving-bricks, earthenware, and unvitrified floor tiles; but the latter will need to be burned almost to vitrification.

326. *Location:* 700 feet north and 900 feet west of the S.E. Cor. Sec. 36, T. 6 N., R. 70 W.; southeast of Arkins. Similar material is well exposed on Dry Creek, 4 miles south.

Occurrence: A 30-foot exposure of material, with 5 feet of overburden, which dips 25° easterly, strikes N. 10° W., and occurs in the banks of an arroya.

Field Characteristics: Soft, black, fine-grained shale which weathers to white or brown streaks.

Economic Value: Should make fine, pink soft-mud, pressed, and flashed bricks and unvitrified floor tiles; also, probably, stiff-mud and paving-bricks, earthenware, and terra-cotta.

327. *Location:* Near the middle of the western side of Sec. 36, T. 6 N., R. 70 W.; southeast of Arkins.

Occurrence: A 12-foot bed, which dips 22° easterly, strikes N. 20° W., and occurs on the western side of the Dakota hogback. About 25 feet below the top of the Morrison formation.

Field Characteristics: Very hard, green, thick and thin beds of marly clay of variable textures.

Economic Value: Worthless.

328. *Location:* Near the S.E. Cor. Sec. 25, T. 6 N., R. 70 W.; in a dry lake-bed.

Occurrence: A 2-foot exposure of horizontal material between two Dakota ridges.

Field Characteristics: Soft, gray, fine-grained mud, containing some pebbles.

Economic Value: Probably worthless, but might be used for red pressed bricks if the waste due to over- and underburning is not too excessive.

329. *Location:* About 700 feet north of the S.E. Cor. Sec. 15, T. 5 N., R. 68 W.; along a bluff which is capped with sandstone.

Occurrence: A 10-foot exposure of material, underlying 30 feet of sandstone, which dips about 10° easterly and strikes N. 30° W.

Field Characteristics: Medium-hard, gray, sandy clays.

Economic Value: Should make fair, red soft-mud, stiff-mud, or pressed bricks if the waste due to over- and underburning is not excessive.

330. *Location:* 400 feet north and 700 feet west of the S.E. Cor. Sec. 8, T. 6 N., R. 69 W.

Occurrence: A 6-foot bed which dips about 20° easterly, strikes N. 10° W., and occurs in a notch cut in the outer ridge of the Dakota hogback.

Field Characteristics: A hard, black, fine-grained shale.

Economic Value: May make good, red stiff- or soft-mud bricks if the waste due to over- and underburning is not excessive.

331. *Location:* 1,500 feet north and 600 feet west of the S.E. Cor. Sec. 11, T. 6 N., R. 69 W.; in the railroad cut south of Fossil Creek, at the plant of the Brick Company, but the material is not there used.

Occurrence: A 15-foot bed, with 3 feet of overburden, which dips 15° easterly, strikes N. 10° E., and occurs on the top of a low hill.

Field Characteristics: Medium-hard, yellowish, sandy shale.

Economic Value: Probably worthless.

332. *Location:* 200 feet north and 800 feet west of the S.E. Cor. Sec. 4, T. 6 N., R. 69 W.; in the Poudre Valley Pressed Brick Company's pit.

Occurrence: A 60-foot bed, with 1 foot of overburden, which dips 15° easterly, strikes north and south, and occurs in rolling land close to the hogbacks. 200 or 300 feet above the base of the Pierre formation.

Field Characteristics: Soft, yellowish-green, fine-grained, slightly gritty shales.

Economic Value: Should make good, red soft-mud and pressed bricks, although the latter will have a rather high absorption. Will probably also yield stiff-mud bricks, earthenware, and terra-cotta, although the last will be fragile before burning.

This material was being used, at the time the sample was taken, for the manufacture of salmon-colored pressed bricks, and the desire was expressed for a mixture which would be red-burning. As the samples tested burned a good brick-red in the laboratory, it seems likely that similar results can be obtained in practice by using a more highly oxidizing atmosphere. If this is not the case, it ought to be easy to find some red-burning material elsewhere in the Pierre formation nearby, or in the Graneros or Carlile formations to the west.

333. *Location:* 300 feet north and 900 feet west of the S.E. Cor. Sec. 4, T. 6 N., R. 69 W.; in an abandoned clay-pit.

Occurrence: A 50-foot exposure of material, with 1 foot of overburden, which dips 15° easterly, strikes north and south, and occurs in rolling land near the hogbacks. 50 feet above the base of the Pierre formation.

Field Characteristics: Medium-hard, black and brown, fine-grained shale.

Economic Value: Will make red pressed bricks of rather high absorption, but there will be much waste, due to over- and underburning, and the pit was abandoned because of this unfavorable characteristic.

334. *Location:* About 800 feet north of the N.W. Cor. Sec. 9, T. 6 N., R. 69 W.

Occurrence: 100 feet of material which dips 20° easterly, strikes N. 10° E., and occurs in the valley between the Niobrara and Dakota hogbacks.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, pink soft-mud, pressed, paving, and flashed bricks; also, probably, stiff-mud bricks, but there will be considerable loss, due to over- and underburning of the unvitrified bricks.

335. *Location:* About 2,000 feet north and 1,500 feet west of the S.E. Cor. Sec. 5, T. 6 N., R. 69 W.

Occurrence: 15 feet of material which dips 20° easterly, strikes N. 10° E., and occurs half-way up the western side of the Dakota hogback.

Field Characteristics: Very hard, green, thick and thin beds of various textures.

Economic Value: Should make good, pink soft-mud and paving-bricks, and, possibly, pressed and flashed bricks, but the former will be fragile before burning.

336. *Location:* 500 feet north and 1,400 feet west of the S.E. Cor. Sec. 20, T. 7 N., R. 69 W.; at forks of a stream on the south bank.

Occurrence: 15 feet of material which dips 20° easterly, strikes north and south, and occurs at the base of the Dakota hogback.

Field Characteristics: Medium to very hard, green to gray, thick and thin beds of various textures.

Economic Value: Should make yellowish-brown soft-mud and pressed bricks, and, probably, stiff-mud bricks, but there is apt to be considerable loss due to over- and underburning.

337. *Location:* Near Timnath, just north of the point where Box Elder Creek crosses the C. & S. Railroad.

Occurrence: A 15-foot exposure of nearly horizontal material, with 5 feet of overburden, which occurs along the bank of the creek to a height of 20 feet above the water level.

Field Characteristics: Medium-hard, black, sandy shale, with 2 feet of yellow material at the top.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware.

338. *Location:* Near the N.W. Cor. Sec. 15, T. 7 N., R. 68 W.; on the southern bank of Box Elder Creek.

Occurrence: A 60-foot exposure of material, with 3 feet of overburden, which dips 10° easterly and strikes north and south.

Field Characteristics: A medium-hard, gray, sandy shale.

Economic Value: Should make fairly good, red soft-mud bricks.

339. *Location:* 900 feet north and 400 feet west of the S.E. Cor. Sec. 7, T. 7 N., R. 69 W.; in an abandoned brick-yard.

Occurrence: 100 feet of material, with 1 foot of overburden, which dips 30° easterly, strikes N. 20° W., and occurs on the slope below the Dakota hogback where cut by a ravine. This sample may contain material entirely of Carlile age.

Field Characteristics: Medium-hard, black and brown, fine-grained shale.

Economic Value: Should make good, salmon-colored soft-mud, pressed, and flashed bricks, and, probably, stiff-mud and paving-bricks and earthenware; but there will be considerable waste due to over- and underburning of the unvitrified bricks.

340. *Location:* 1,100 feet north and 1,900 feet west of the S.E. Cor. Sec. 9, T. 7 N., R. 69 W.; in the basement of S. R. Wilson's house.

Occurrence: An 8-foot exposure of material, with 1 foot of overburden, of uncertain dip and strike, which probably is the same material exposed in the hill around which the ditch runs. Not far above the base of the Pierre formation.

Field Characteristics: Soft, yellowish-green, fine-grained, slightly gritty shale.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware; also, probably, stiff-mud bricks.

341. *Location:* 1,400 feet north and 700 feet west of the S.E. Cor. Sec. 10, T. 7 N., R. 69 W.; in an old brick-yard.

Occurrence: A 15-foot exposure of material, with 6 inches of overburden, which underlies a gentle slope.

Field Characteristics: Soft, yellowish, sandy loess.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware.

342. *Location:* 500 feet north and 1,900 feet west of the S.E. Cor. Sec. 36, T. 8 N., R. 69 W.; in the ditch below Terry Lake.

Occurrence: A 10-foot exposure of material underlying nearly level country.

Field Characteristics: Soft, yellowish, sandy alluvium.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware.

343. *Location:* 600 feet north and 1,000 feet west of the S.E. Cor. Sec. 31, T. 8 N., R. 69 W.; near the bed of a ravine, at the so-called "Coal Shaft."

Occurrence: A 35-foot bed, with 1 foot of overburden, which dips 30° easterly, strikes N. 30° E., and occurs in the bed of a longitudinal depression between two Dakota ridges.

Field Characteristics: Medium-hard, black and brown, fine-grained, more or less sandy shales.

Economic Value: Should make good, red soft-mud, pressed, paving, and flashed bricks.

344. *Location:* 1,700 feet north and 300 feet west of the S.E. Cor. Sec. 24, T. 8 N., R. 70 W.; in a ditch.

Occurrence: A 7-foot bed which dips 20° northerly, strikes N. 60° E., and occurs above a ditch encircling a Dakota hill.

Field Characteristics: Very hard, light bluish-green, fine-grained clay.

Economic Value: A first-class fire-clay.

345. *Location:* 1,800 feet north and 200 feet west of the S.E. Cor. Sec. 24, T. 8 N., R. 70 W.

Occurrence: A 60-foot bed which dips 30° northerly, strikes N. 60° E., and occurs above the upper ditch encircling a Dakota hill.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware; but there will be loss, due to over- and underburning.

346. *Location:* 100 feet north and 700 feet west of the S.E. Cor. Sec. 13, T. 8 N., R. 70 W.

Occurrence: A 60-foot bed which dips 30° easterly, strikes N. 20° E., and occurs above the upper ditch on a Dakota hill.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Probably worthless, as it is low-grade and requires several hours to slake.

347. *Location:* 500 feet north and 1,800 feet west of the S.E. Cor. Sec. 12, T. 8 N., R. 70 W.; in a railroad cut.

Occurrence: 35 feet of material which dips 20° easterly, strikes N. 20° E., and occurs near the western base of the Dakota hogback.

Field Characteristics: Hard to soft, green and red marls and shales of various textures, containing two 1-foot beds of limestone, which are not included in the sample.

Economic Value: Probably worthless.

348. *Location:* Near the N.W. Cor. Sec. 33, T. 9 N., R. 68 W.; near Wellington, on the bank of a ditch.

Occurrence: A 4-foot exposure of material, with 3 feet of overburden, which may be of Recent age.

Field Characteristics: Soft, gray, coarse to fine-grained clay.

Economic Value: Should make good, pink pressed bricks; but there will be considerable loss, due to over- and underburning.

349. *Location:* About 800 feet north and 1,000 feet west of the S.E. Cor. Sec. 30, T. 9 N., R. 69 W.; near Ingleside.

Occurrence: A 6-foot exposure of material which dips 15° easterly, strikes north and south, and outcrops as a low terrace on the western side of the longitudinal valley between two Dakota ridges.

Field Characteristics: A soft, light-gray, fine-grained clay.

Economic Value: Should make good, yellow to buff soft-mud and pressed bricks and earthenware; also, possibly, if grogged, terra-cotta, hollow structural material, and conduits.

350. *Location:* About 500 feet north of the S.E. Cor. Sec. 18, T. 9 N., R. 69 W.; about 2 miles north of Ingleside. A thicker exposure of what is apparently the same bed outcrops about 1,500 feet north and 1,500 feet west of the S.E. Cor., Sec. 8.

Occurrence: A 6-8-foot bed which dips 15° easterly, strikes N. 10° E., and occurs in the bottom of a long depression between two Dakota ridges. At the same horizon as No. 349.

Field Characteristics: A medium-hard to soft, black at the base, gray above- very fine-grained shale and clay—the former at the base, the latter above.

Economic Value: Should make fine, flesh-colored to pink soft-mud and pressed bricks, earthenware, and vitrified and unvitrified floor tiles; also, probably, terra-cotta, hollow structural material, conduits, and paving-bricks.

351. This sample was taken at the same point as No. 350, but several iron-stained layers as well as streaks of gypsum, which were included in No 350, were discarded from this sample.

Economic Value: Should make fine, pink soft-mud, pressed, paving, and flashed bricks, earthenware, and vitrified and unvitrified floor tile; also, probably, terra-cotta, hollow structural material, conduits, sewer pipes, and stoneware.

352. *Location:* 1,500 feet north and 1,300 feet west of the S.E. Cor. Sec. 8, T. 9 N., R. 69 W.; 4 miles northwest of Waverly.

Occurrence: 30 feet was sampled of material which dips 15° easterly, strikes N. 10° E., and occurs on the western slope of the upper Dakota ridge.

Field Characteristics: Medium-hard, black and brown, fine-grained shale.

Economic Value: Should make fine, red soft-mud and pressed bricks, earthenware, and unvitrified floor tile; also, probably, terra-cotta, hollow structural material, conduits, and sewer pipes.

353. *Location:* From the Elk Horn lode, 1½ miles from Breckenridge, Summit County. (A mistake was made in locating this clay on the map from which the samples were numbered. This accounts for the fact that it is here described with the Larimer County samples.)

Occurrence: A vertical bed over 6 feet thick.

Field Characteristics: Unstated.

Economic Value: Probably worthless.

354. *Location:* Near the S.W. Cor. Sec. 9, T. 9 N., R. 68 W.; north of Wellington.

Occurrence: A 50-foot exposure of material, with 3-4 feet of overburden, which dips 5° easterly, strikes N. 30° W., and occurs in the eastern bank of a creek to a height of 20 feet above the water level. Near the top of the Pierre formation.

Field Characteristics: A medium-hard, bright yellowish-green, somewhat gritty shale.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware, and may answer for higher-grade products if heavily grogged.

355. *Location:* About 500 feet north and 1,800 feet west of the S.E. Cor. Sec. 10, T. 9 N., R. 68 W.; north of Wellington.

Occurrence: A 15-foot exposure of material, with 3 feet of overburden, which dips 5° easterly, strikes N. 30° W., and is exposed in a ditch around a hill. May be of Fox Hills age.

Field Characteristics: Medium-hard, gray at base, yellowish-green above, sandy shale.

Economic Value: Should make attractive, pink to red soft-mud bricks or pressed bricks with high absorption, which will be fragile before burning.

356. *Location:* In the N.W. ¼ Sec. 34, T. 10 N., R. 68 W. This is the most southern of a series of exposures extending a mile north along Coal Creek, and appears to be less sandy than the rest.

Occurrence: A 50-foot exposure of material, with 3-4 feet overburden, which dips 5° easterly, strikes N. 30° W., and occurs on the eastern bank of Coal Creek, to a height of 25 feet above the water.

Field Characteristics: Medium-hard, gray at base, yellowish-green above, sandy shale.

Economic Value: Should make fine, red soft-mud bricks if burned to Cone 1.

357. *Location:* 1,750 feet north and 1,500 feet west of the S.E. Cor. Sec. 25, T. 10 N., R. 70 W.; 1 mile north of Fork's Hotel.

Occurrence: 20 feet was sampled of material which dips 30° northerly, strikes N. 75° W., and occurs near the top of the upper Dakota ridge.

Field Characteristics: Medium-hard, black and brown shales of various textures.

Economic Value: Should make fine, pink soft-mud and pressed bricks and earthenware, and, probably, terra-cotta, hollow structural material, and conduits.

358. *Location:* In the N.E. ¼ Sec. 19, T. 10 N., R. 69 W. This material is well exposed from this point northward.

Occurrence: A 30-foot exposure of material which dips about 25° easterly, strikes N. 25° E., and occurs on the western slope of a hill capped by an outlier of Dakota sandstone.

Field Characteristics: Medium-soft, black, fine-grained shale, with some brown and gray streaks.

Economic Value: Should make good, red soft-mud bricks if burned to Cone 03.

359. *Location:* On the northern side of Sec. 19, T. 10 N., R. 69 W.

Occurrence: A 60-foot exposure of material, with 5-6 feet of overburden, which dips 50° easterly, strikes N. 10° E., and occurs in the banks of an arroya. This sample includes all of the Graneros and Carlile formations, except 20 feet at the base. All these formations seem to pinch out where they cross Box Elder Creek.

Field Characteristics: Medium-hard, black, fine-grained shales.

Economic Value: Will make rather poor, red soft-mud bricks.

360. *Location:* On the northern side of Sec. 19, T. 10 N., R. 69 W.

Occurrence: A 20-foot bed which dips 50° easterly, strikes N. 10° E., and occurs on the banks of an arroya cutting a notch in a Dakota hogback. This material lies directly below No. 359 and is hard enough to make a little ridge for a few miles.

Field Characteristics: Very hard, bluish-gray, sandy shale.

Economic Value: Worthless.

361. *Location:* About 300 feet north and 1,600 feet west of the S.E. Cor. Sec. 17, T. 10 N., R. 69 W.; on Park Creek.

Occurrence: A 60-foot exposure of material, with up to 5 feet of overburden, which dips 60° easterly, strikes N. 40° E., and is exposed on the western bank of the creek. At the base of the Pierre formation.

Field Characteristics: Medium-hard, black and brown, fine-grained shales.

Economic Value: Worthless.

362. *Location:* 700 feet north and 700 feet west of the S.E. Cor. Sec. 10, T. 10 N., R. 69 W.

Occurrence: A 10-foot exposure of material, with 2 feet of overburden, of uncertain dip and strike, which occurs well up on the first hill north of Box Elder Creek.

Field Characteristics: Medium-hard, yellowish-green, fine-grained shale.

Economic Value: Should make good, red soft-mud bricks and earthenware, and, possibly, pressed bricks, terra-cotta, hollow structural material, and drain tiles.

363. *Location:* About 1,700 feet west of the S.E. Cor. Sec. 36, T. 11 N., R. 69 W.

Occurrence: A 50-foot exposure of material, with up to 5 feet of overburden, of uncertain dip and strike, which occurs where the creek cuts into a bluff on its eastern bank.

Field Characteristics: Medium-hard, yellowish-green, somewhat gritty shale.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, and, probably, terra-cotta, hollow structural material, and conduits.

364. *Location:* 600 feet west of the S.E. Cor. Sec. 28, T. 11 N., R. 69 W.

Occurrence: 15 feet of material which dips 25° northeasterly, strikes N. 45° W., and is exposed in the bottom of a large ravine in the Dakota hogback.

Field Characteristics: Medium-hard, red and green, coarse-grained, sandy clay, occurring in beds 3-5 feet thick.

Economic Value: Should make good, red soft-mud bricks and, possibly, stiff-mud and pressed bricks; but the absorption will be high, and there will be a tendency to crack on drying.

365. This sample was selected from the best-looking beds from which No. 364 was taken. The color is grayish-green.

Economic Value: Should make good, almost white pressed bricks and vitrified and unvitrified floor tiles.

366. *Location:* 300 feet north and 900 feet west of the S.E. Cor. Sec. 20, T. 11 N., R. 69 W. Material like this can be easily traced for 10 miles or more.

Occurrence: A 6-foot bed which dips 15° easterly, strikes north and south, and occurs near the top of the Lower Dakota hogback.

Field Characteristics: Very hard, white, sandy clay.

Economic Value: First-class fire-clay, but the plasticity, cohesion, and tensile strength are so low that the material could hardly be molded without the addition of a fatter clay.

367. *Location:* 300 feet north and 1,000 feet west of the S.E. Cor. Sec. 21, T. 11 N., R. 69 W. Many good exposures of this material lie within a few miles south.

Occurrence: A bed 30 feet or more thick which dips 20° easterly, strikes north and south, and occurs in the longitudinal valley between two Dakota ridges.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, red soft-mud and pressed bricks; probably, earthenware and terra-cotta; and, possibly, hollow structural material and conduits, although the last two will be fragile before burning.

368. *Location:* 500 feet north and 1,500 feet west of the S.E. Cor. Sec. 34, T. 11 N., R. 68 W.

Occurrence: A 10-foot exposure of material, with 3-5 feet of overburden, which dips 10° easterly, strikes north and south, and occurs in a creek bank a few hundred paces south of a sandstone bluff.

Field Characteristics: Soft, yellowish-green, fine-grained shale.

Economic Value: Should make fine, pink soft- and stiff-mud bricks, earthenware, terra-cotta, hollow structural material, and conduits, if heavily grogged.

369. *Location:* Near the S.W. Cor. Sec. 26, T. 11 N., R. 68 W.; in the air-shaft of a coal prospect .

Occurrence: A 3-5-foot bed, 35 feet below the surface, which dips 10° easterly, and strikes north and south. This material forms the roof of a coal bed. It usually comes down when the coal is taken out, leaving a better roof above.

Field Characteristics: A soft, light-gray, fine-grained clay.

Economic Value: Worthless.

370. This sample was taken in the same locality as No. 369. From its description it appears to have come from exactly the same point, but, as the material is described as black shale and as coming from a 1-foot exposure, it is probable that it represents the floor of the coal-seam.

Economic Value: The material was so sandy that it could not be molded, and is worthless except for grogging other clays.

371. *Location:* About 1,500 feet north and 500 feet west of the S.E. Cor. Sec. 12, T. 11 N., R. 70 W.; about 5 miles from the Wyoming line, among some pine trees; on the northwestern corner of Table Mountain.

Occurrence: A 20-foot exposure of material which dips 5° southeasterly, strikes N. 40° E., and occurs just below the heavy sandstone cap of Table Mountain.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Should make good, pink pressed and soft-mud bricks; also, probably, vitrified floor tiles and stiff-mud bricks.

372. *Location:* About 600 feet north and 600 feet west of the S. E. Cor. Sec. 31, T. 12 N., R. 69 W.; about 3 miles south of the Wyoming line.

Occurrence: A 2-foot bed which dips 5° southeasterly, strikes N. 30° E., and is exposed in the bottom of a gully.

Field Characteristics: Very hard, white and pinkish, gritty clay.

Economic Value: A first-class fire-clay, and should make wall tiles and vitrified and unvitrified floor tiles. It might prove very valuable if washed.

373. *Location:* About 1,000 feet north and 1,500 feet west of the S.E. Cor. Sec. 30, T. 12 N., R. 69 W.; about 1½ miles from the Wyoming line.

Occurrence: A 15-foot or more exposure of material which dips 5° to 10° easterly, strikes N. 10° W., and occurs high on a slope capped by a remnant of Lower Dakota sandstone.

Field Characteristics: Medium-hard to hard, purple to green, fine-grained marl.

Economic Value: Might make fair, pink soft-mud bricks, but the absorption will be a little high.

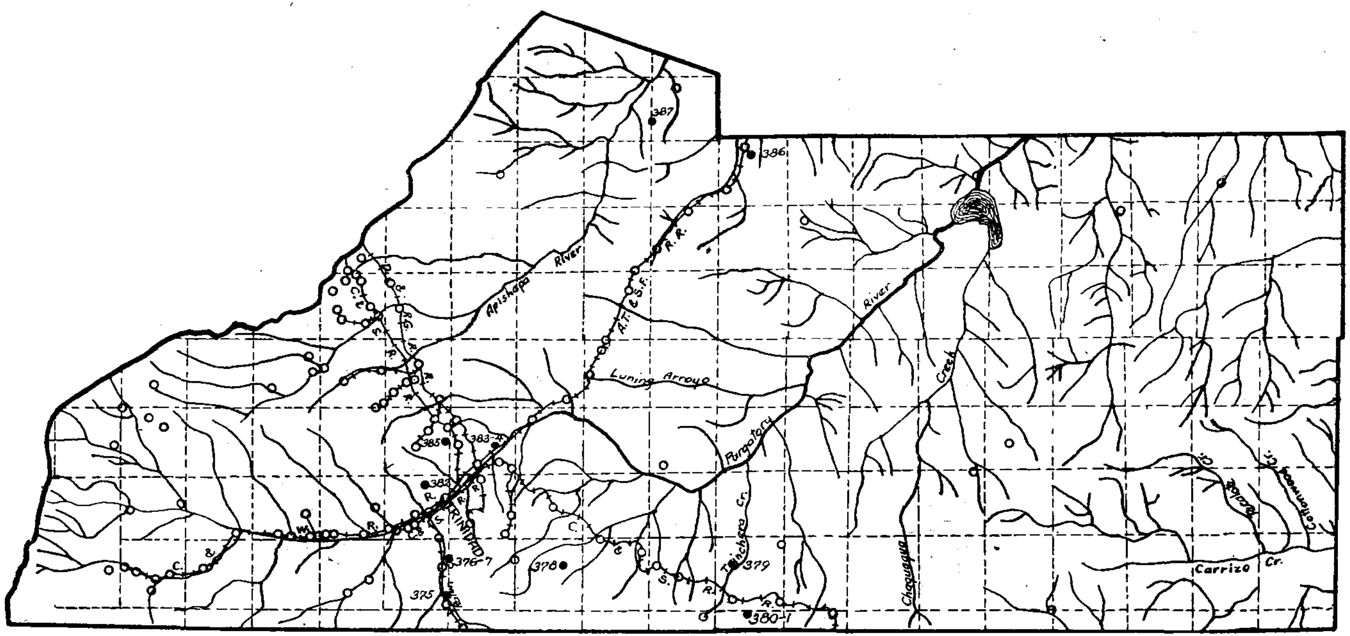
374. *Location:* About 1,700 feet north of the S.E. Cor. Sec. 17, T. 11 N., R. 69 W.

Occurrence: A 70-foot exposure of material which dips 25° easterly, strikes N. 15° W., and occurs in the banks of several arroyas below a sharp bend in the Dakota hogback. This sample includes all of the Carlile and Graneros formations exposed, except 20 feet at the base, which seems identical with No. 360.

Field Characteristics: A medium-hard, black and brown, fine-grained shale, containing two small white bands.

Economic Value: Should make fair, brownish soft-mud and pressed bricks, and, probably, stiff-mud bricks.

LAS ANIMAS COUNTY



Sketch map showing the approximate locations of the beds sampled

Las Animas County

Geology of the County.—Running southeasterly and northwesterly through Trinidad is a band of Pierre rocks from 2 to 10 miles wide. This is bordered to the westward by thin outcrops of Fox Hills age, with extensive areas of Raton, Poison Canon, and Cuchara material farther west. East of the Pierre area occur extensive exposures of Niobrara and Benton beds, which extend almost to the canon of the Purgatory River. The surface of the remainder of the county is mostly covered with Dakota rocks, except where the larger streams have exposed beds of Purgatory, Morrison, and, probably, Lykins age. There is, however, some Benton material around Mesa de Maya, and a little Tertiary rock occurs on the extreme eastern boundary.

375. *Location:* 300 feet north of Morley station.

Occurrence: A 15-foot exposure of horizontal material, with up to 12 feet of overburden, exposed in the bank of a stream.

Field Characteristics: A hard, gray to brown, coarse-grained, sandy, concretionary clay, with carbonaceous streaks in the lower part.

Economic Value: Worthless.

376. *Location:* 6 miles south of Trinidad and 200 feet from the Santa Fe tracks; on the public road. Owned by the Colorado Fuel and Iron Company.

Occurrence: An 8-foot exposure of horizontal material, with up to 1 foot of overburden, in the bank at the side of a road.

Field Characteristics: A hard, greenish-gray, medium fine grained, sandy, concretionary clay.

Economic Value: Should make fine, pink soft-mud and pressed bricks, earthenware, vitrified and unvitrified floor tiles, and stoneware; also, probably, paving-bricks, and, possibly, terra-cotta, hollow structural material, conduits, and sewer pipes, although grogging is necessary for all of these.

377. *Location:* 6 miles south of Trinidad.

Occurrence: 5 feet was sampled of a much thicker exposure of horizontal material in the bank at the side of a road.

Field Characteristics: Medium-hard, black, fine-grained shales and clays.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks.

378. *Location:* 3 miles northeast of San Francisco Pass.

Occurrence: 35 feet was sampled of a much thicker exposure of horizontal material in arroyas below the road.

Field Characteristics: Medium-soft, black, medium fine-grained, sandy shale.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks.

379. *Location:* 4 miles north of Trinchera; west of the house on W. M. Hudson's ranch.

Occurrence: 20 feet was sampled of a much thicker exposure of horizontal material, with up to 2 feet of overburden, which occurs in a knoll on the bank of Trinchera Creek. Near the top of the Carlile formation.

Field Characteristics: Hard, gray to black, medium fine-grained shales and clays, containing a 4-inch seam of sandstone.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks.

380. *Location:* 1¼ miles southeast of Trinchera.

Occurrence: 25 feet was sampled of a much thicker exposure of horizontal material, with up to several feet of overburden, which occurs on the northern side of a round knoll.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, terra-cotta, hollow structural material, and vitrified floor tiles; also, possibly, sewer pipes and drain tiles, but sawdust must be mixed with the clay, to give sufficient porosity, for the last.

381. *Location:* 1¼ miles southeast of Trinchera.

Occurrence: 10 feet was sampled of a thicker exposure of horizontal material, with up to 6 feet of overburden, which occurs in the side of an arroya between two knolls. This sample represents a somewhat lower horizon than No. 380.

Field Characteristics: Medium-soft, brown to gray, medium coarse-grained, sandy shale.

Economic Value: Worthless.

382. *Location:* 2 miles northwest of Trinidad.

Occurrence: A 40-foot bed of horizontal material, with 10 feet of overburden, which occurs in the side of a wide canon 1 mile west of the Trinidad Brick and Tile Company's plant. 500 feet below the top of the Pierre formation.

Field Characteristics: A hard, dark-gray, medium fine-grained clay.

Economic Value: Should make good, red soft-mud and pressed bricks.

383. *Location:* 6 miles northeast of Trinidad.

Occurrence: 25 feet was sampled of a thicker exposure of horizontal material which occurs in the side of an arroya below a coal mine. About 250 feet below the top of the Pierre formation.

Field Characteristics: Medium-hard, black, medium fine-grained, sandy shale, containing a 4-inch seam of sandstone.

Economic Value: Should make rather soft, dark-red, soft-mud bricks and, possibly, pressed bricks, but the latter will be fragile before burning.

384. *Location:* 6 miles northeast of Trinidad.

Occurrence: 40 feet was sampled of a thicker exposure of horizontal material occurring about 150 feet above No. 383.

Field Characteristics: A hard, black, medium coarse-grained, sandy shale.

Economic Value: Should make good, red pressed bricks.

385. *Location:* 5 miles north of Trinidad.

Occurrence: A 7½ foot horizontal bed in the bank of an arroya; ½ mile west of a coal mine.

Field Characteristics: A hard, gray, fine to coarse-grained clay which is more or less sandy.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks, earthenware, and terra-cotta.

386. *Location:* Near Delhi.

Occurrence: A 4-5-foot bed of horizontal material which occurs in a low bank under a sandstone capping.

Field Characteristics: A hard, gray, medium coarse-grained clay.

Economic Value: This is used for the manufacture of fire-bricks at the plant of the La Junta Brick and Tile Company, and tests prove that it is a first-class fire-clay.

387. *Location:* 8 miles west of the Bloom Land and Cattle Company's ranch-house.

Occurrence: 6 feet of horizontal material underlying 15-20 feet of sandstone, which occurs in the bank of Apishapa River.

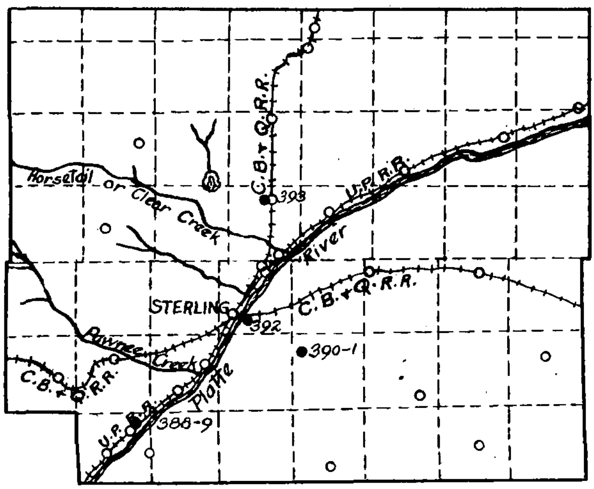
Field Characteristics: A hard, gray to black, medium fine-grained, sandy clay.

Economic Value: Should make good, red soft-mud and pressed bricks, and, probably, stiff-mud bricks.

Logan County

Geology of the County.—The South Platte River is bordered on both sides by beds of Laramie age, and their outcrops are particularly extensive in the southwestern corner of the county. North and southeast of this Laramie area are large areas of Tertiary material.

LOGAN COUNTY



Sketch map showing the approximate locations of the beds sampled

388. *Location:* 3 miles southwest of Merino; in a railroad cut on the river bluff.

Occurrence: 15 feet was sampled of material, with up to 8 feet of overburden, which dips 5° northeasterly and strikes N. 60° W.

Field Characteristics: A soft, gray to brown, sandy shale.

Economic Value: Should make attractive, pink pressed bricks and, probably, if grogged, soft- or stiff-mud bricks and earthenware.

389. *Location:* 3 miles southwest of Merino; in a railroad cut on the river bluff.

Occurrence: 15 feet was sampled of material, with up to 8 feet of overburden, which dips 5° northeasterly and strikes N.

60° W. This sample is separated from No. 388, above, by a bed of sandstone.

Field Characteristics: Medium-hard to soft, gray to brown, sandy shale.

Economic Value: Should make good, pink pressed, and, probably, if grogged, soft- and stiff-mud bricks and earthenware.

390. *Location:* 5 miles southeast of Sterling, on the main wagon-road; probably in the S.E. 1/4 Sec. 6.

Occurrence: A 15-foot bed, with 2 feet of overburden, which has a slight easterly dip, and occurs in an area covered with sand hills. It is probably of Laramie, but may be of Brule, age.

Field Characteristics: Medium-hard, yellow and gray, fine to coarse-grained shale, which is more or less sandy.

Economic Value: Should make attractive, pink pressed bricks, and, probably, soft- and stiff-mud bricks and earthenware if grogged.

391. This sample was taken from the same exposure as No. 390, but the yellow, sandy portions were excluded. The bricks appear to be no better than those obtainable from No. 390 and are somewhat more difficult to burn.

392. *Location:* At Sterling, in an abandoned brick-yard, 200 paces east of the coal trestle of the Burlington Railroad.

Occurrence: A 5-6-foot bed of material occurring in the river bottom.

Field Characteristics: A soft, brown, sandy clay.

Economic Value: This material is worthless as it stands, but should make fine grog for No. 390.

393. *Location:* On the homestead of Mr. Parr, near Padrone.

Occurrence: A bed of a thickness of 20 feet or more, with 4 feet of overburden, of unstated dip and strike, which occurs in a dry well on a nearly level plain.

Field Characteristics: A medium-hard, white, fine-grained clay.

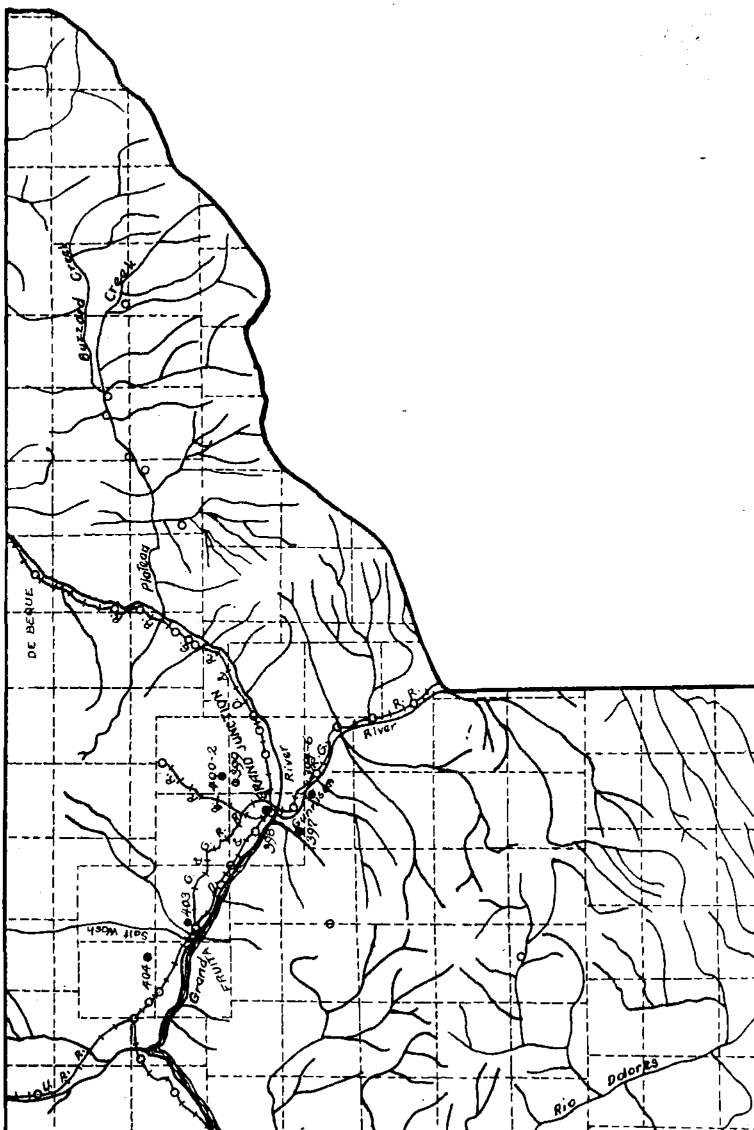
Economic Value: The air shrinkage is so extremely high (22%) that the clay is probably worthless, but very heavy grogging might give it some value. It is, however, impossible to predict the nature of the products then obtainable.

Mesa County

Geology of the County.—The northeastern corner of the county is covered with Tertiary rocks, which are bordered to the southwest by Mesa Verde material. This occurs in the Book

Cliffs, which rise about 10 miles northeast of Grand Junction and form a series of southwesterly-facing escarpments across the county from northwest to southeast. Southwest of the Mesa Verde formation occurs a broad zone of Pierre beds, which extend as far as Grand Junction. Southwest of this area lies a complex of rocks of Dakota, McElmo, La Plata, and greater age.

MESA COUNTY



Sketch map showing the approximate locations of the beds sampled

394. *Location:* About 2 miles south of Grand Junction; on land owned by Charles van Hoorbeke.

Occurrence: A 20-foot, horizontal bed which occurs on the side of the hill forming the bank of the Gunnison River.

Field Characteristics: Medium-hard, red, very fine-grained shale.

Economic Value: It is reported that this clay has been tested and pronounced a good brick and pottery clay, but that it checks when made into stiff-mud bricks. The tests made in this investigation indicate that it should make good red pressed bricks and, probably, soft-mud bricks and earthenware if grogged. It takes a reddish-brown glaze at Cone 3, and might be used for a rather-high-temperature slip.

395. *Location:* About 2 miles south of Grand Junction; on land owned by Charles van Hoorbeke.

Occurrence: A 20-foot bed of horizontal material which occurs on the side of a hill forming the bank of the Gunnison River.

Field Characteristics: Medium-hard, light-buff to light greenish-gray, medium fine to very fine-grained shale.

Economic Value: Might make buff pressed bricks, but these are apt to warp when burned.

396. *Location:* About 2 miles south of Grand Junction; on land owned by Charles van Hoorbeke.

Occurrence: A horizontal bed, 50 feet or more thick, which occurs on the side of the hill forming the bank of the Gunnison River.

Field Characteristics: A medium-hard, greenish-gray, very fine-grained shale, with sandy layers 1 foot thick every 10 feet.

Economic Value: Might make yellowish pressed bricks, if burned at low temperatures.

397. *Location:* 1 mile southwest of Grand Junction on the southern bank of Redlands ditch in the N.E. ¼ of the S.W. ¼ Sec. 22, T. 1 S., R. 1 W. of the Ute Meridian.

Occurrence: A 15-foot bed, with 1-10 feet of overburden, which occurs on the side of a hill that forms the bank of the Gunnison River.

Field Characteristics: A medium-hard, red, very fine-grained shale.

Economic Value: Should make good, red soft-mud bricks and, possibly, pressed bricks, but these will be fragile before burning.

398. *Location:* Near the northwestern edge of Grand Junction; in the brick-yard which was run by Clark and Atkinson at the time the sample was taken.

Occurrence: A 20-foot exposure of horizontal material which occurs on the side of a low hill.

Field Characteristics: Soft, light-brown, coarse-grained, sandy clay.

Economic Value: The bricks made here are very soft and check considerably when burned. The tests made in this investigation indicate that the material should make good, red soft-mud and pressed bricks and, probably, stiff-mud bricks, but that a relatively high temperature is required to make them hard, and an oxidizing atmosphere should be used in burning them.

399. *Location:* In the S.E. ¼ Sec. 6, T. 1 S., R. 1 E. of the Ute Meridian; in the gully in which the waste water from Price ditch flows; near Grand Junction.

Occurrence: A 15-foot bed of horizontal material which occurs in the bottom of a broad valley.

Field Characteristics: A soft, brown, coarse-grained, sandy clay.

Economic Value: Should make fair, red soft-mud bricks with rather high absorption.

400. *Location:* 500 feet east of the "Wellington Wheel;" near Grand Junction.

Occurrence: 5 feet was sampled of horizontal material at the base of a small hill.

Field Characteristics: Very fine-grained shale, containing a large amount of gypsum in the cracks of the shale, and some fossils.

Economic Value: Might make buff pressed bricks, but there will be considerable waste, due to over- and underburning.

401. This sample is identical with No. 400, but was taken with the purpose of screening out the gypsum and testing the residue. The results were rather disappointing, due possibly to the fact that a considerable proportion of the gypsum passed through the screen with the clay. The screened product proved to be little or no better than the unscreened material.

402. *Location:* 800 feet east of the "Wellington Wheel;" near Grand Junction.

Occurrence: A 10-foot horizontal bed on top of a hill.

Field Characteristics: Soft, yellow, coarse-grained, sandy clay.

Economic Value: Worthless.

403. *Location:* Near Fruita; on land owned by George H. Garlitz, who furnished the sample.

Occurrence: Unstated.

Field Characteristics: A soft, brown, coarse-grained, gritty shale.

Economic Value: Should make good, light-pink soft-mud bricks. Pressed bricks manufactured from this clay will be attractive, but the absorption will be excessive.

404. *Location:* In S.E. ¼ Sec. 35, T. 2 N., R. 3 W. of the Ute Meridian; near Loma; on land owned by Mrs. S. C. Carpenter, who furnished the sample.

Occurrence: Unstated.

Field Characteristics: A very hard, gray, fine-grained clay.

Economic Value: Although this clay burns almost white, and bricklets made from it are very attractive, the material is probably worthless, as the absorption is about 25%, the cohesion is weak, and the tensile strength is very low.

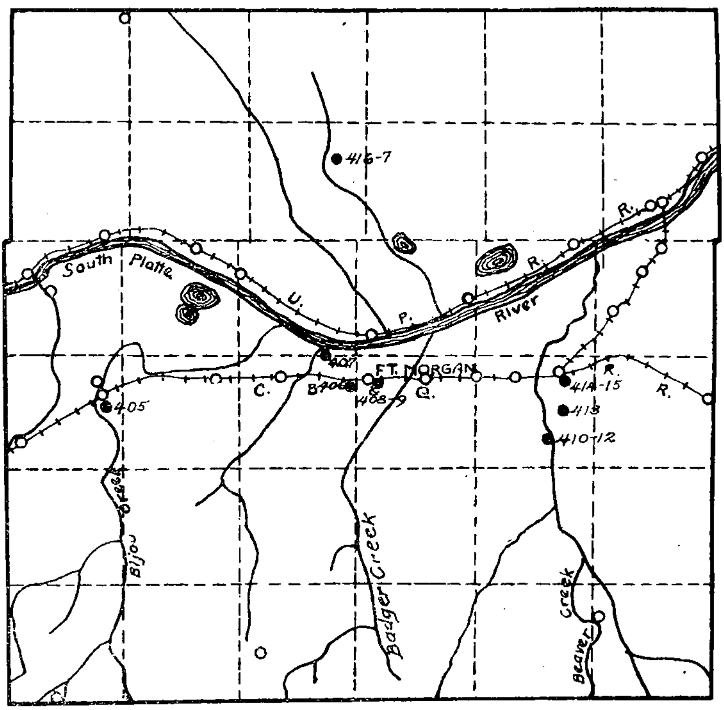
Montrose County

Geology of the County.—The only locality visited in Montrose County was the city of Montrose itself and the surrounding district. A number of samples were there taken, but were lost by the railroad in transit to Golden, and press of other duties prevented another trip to that part of the state. It may be said that the only clay-bearing beds within many miles of the town are those of the Mancos formation. The city itself is on material of Benton age, but a little shale of Pierre age is exposed on the top of a high mound west of the river, as well as extensively to the east. Benton shales and clays are being used by the Buckley Brick and Tile Company, on the western side of the Gunnison River, opposite the town. The bricks check somewhat and are a bit soft; the color varies from yellow to pink. It seems likely that the use of a higher temperature and a more decidedly oxidizing atmosphere would improve the product, which, there is reason to think, should be good if the right methods are employed. The Pierre shales are identical, in appearance, with No. 400, and are not likely to have any greater value.

Morgan County

Geology of the County.—There are considerable areas underlain with rocks of Laramie age along both the southern and northern boundaries of the county, and beds of the same system also lie along the eastern boundary as far north as the middle of Range 4. The rest of the county is entirely underlain with Fox Hills sediments.

MORGAN COUNTY



Sketch map showing the approximate locations of the points sampled

405. The location of this sample is uncertain, as it was sent in by C. B. Thomas, of Hoyt.

Occurrence: Unstated.

Field Characteristics: Soft, light-gray, fine-grained clay.

Economic Value: Worthless.

406. *Location:* ½ mile west of the Burlington depot and just south of the track, in an abandoned brick-yard near Fort Morgan.

Occurrence: A 10-foot bed on a level plain.

Field Characteristics: Soft, greenish-brown, sandy, roughly bedded clay and sand.

Economic Value: Should make good, red soft-mud and, possibly, pressed bricks, but the latter will be fragile before burning.

407. *Location:* West of Fort Morgan at the "Platte Narrows;" in a ravine just north of the dam at the head of the Platte and Beaver ditch.

Occurrence: 20 feet was sampled of material, with 3-4 feet of overburden, which dips 5° westerly, strikes N. 20° E., and occurs in an arroya below the ditch.

Field Characteristics: A medium-hard, yellowish-green, somewhat gritty shale.

Economic Value: Should make good, flesh-colored pressed bricks if burned to Cone 1 or higher.

408. *Location:* In an abandoned brick-yard south of the main street of Fort Morgan.

Occurrence: A 15-foot exposure of material beneath a gently rolling Platte River flat.

Field Characteristics: A soft, yellowish-brown alluvium, which is roughly bedded and more or less sandy.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware, and, probably, stiff-mud bricks and terra-cotta. There seems to be no reason for the abandonment of the yard, unless the clays were burned at too low a temperature.

409. *Location:* In an abandoned brick-yard, ¾ mile west of the Sugar Factory near Fort Morgan.

Occurrence: A 5-6 foot bed in the Platte River flat.

Field Characteristics: A soft, yellowish-brown, sandy clay.

Economic Value: Should make good, red soft-mud bricks and earthenware, and pressed bricks which will be tender before burning. The abandonment of this yard was due doubtless to the fact that the bricks were burned at too low a temperature.

410. *Location:* 3 miles south of Brush, in the banks of Beaver Creek. This material can be traced nearly a mile northward.

Occurrence: A 20-foot exposure of horizontal material, beneath 1 foot of overburden, which occurs in the eastern bank of a creek at the base of a hill.

Field Characteristics: Soft, yellowish-brown clay, interbedded with sandy clays.

Economic Value: Probably worthless.

411. This sample was taken from a bed 2-4 feet thick, about the middle of the exposure which yielded No. 410.

Field Characteristics: Soft, yellowish-green, fine-grained shale.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware.

412. *Location:* About 3 miles south of Brush, on an escarpment east of Beaver Creek.

Occurrence: A 50-foot exposure of horizontal material, with 1 foot of overburden, which occurs near the top of the escarpment.

Field Characteristics: Soft, gray and yellow alternately, fine-grained and sandy shales and shaly sandstones, containing one thin bed of limestone which was not included in the sample.

Economic Value: Worthless, as the temperatures of incipient vitrification and vitrification are practically the same.

413. *Location:* About 2 miles south of Brush; in an arroya close to the road on the northern side; about 20 feet north and 700 feet west of the S.E. Cor. Sec. 14.

Occurrence: A 15-foot horizontal bed, with 1 foot of overburden.

Field Characteristics: A medium-hard, brownish-green, fine-grained shale.

Economic Value: Might make good, red pressed bricks and, possibly, soft- and stiff-mud bricks and earthenware; but grog will be required in the cases of the last three, and all show a tendency to crack when burned.

414. *Location:* In a brick-yard at the eastern edge of Brush.

Occurrence: A 10-foot, horizontal bed beneath a nearly flat plain.

Field Characteristics: Soft, yellowish-brown, roughly bedded, sandy and shaly clays.

Economic Value: Should make good, red soft-mud bricks, earthenware, and terra-cotta, and, probably, stiff-mud and pressed bricks. It is said that the bricks now manufactured are rather poor. The defects could doubtless be remedied by burning them to a higher temperature.

415. *Location:* In the Silo excavation at the Sugar Factory near Brush.

Occurrence A 20-foot, horizontal bed, with 1 foot of overburden, which occurs near the western bank of Beaver Creek.

Field Characteristics: A soft, yellowish-brown, sandy clay which is more or less roughly bedded and contains very sandy layers.

Economic Value: Should make good, red soft-mud bricks and, possibly, pressed bricks, but the latter will be fragile before burning.

416. *Location:* S.E. ¼ of N.E. ¼ Sec. 11, T. 5 N., R. 58 W.; in the south bank of a creek; north of Fort Morgan.

Occurrence: A 20-foot bed, with a slight easterly dip, which occurs in the bank of a creek.

Field Characteristics: A medium-hard, yellowish-green, fine-grained, but gritty shale.

Economic Value: Should make good, pink pressed bricks.

417. *Location:* N.W. ¼ of N.E. ¼ Sec. 11, T. 5 N., R. 58 W.; in the bank of a tributary which enters the creek from the north; north of Fort Morgan.

Occurrence: An 8-10-foot bed, with a slight easterly dip, beneath 10-20 feet of recent wash, which occurs in the bank of an arroya.

Field Characteristics: Medium-hard, bluish-gray, sandy shale.

Economic Value: Should make fair, pink pressed bricks and, probably, soft- and stiff-mud bricks if grogged.

Otero County

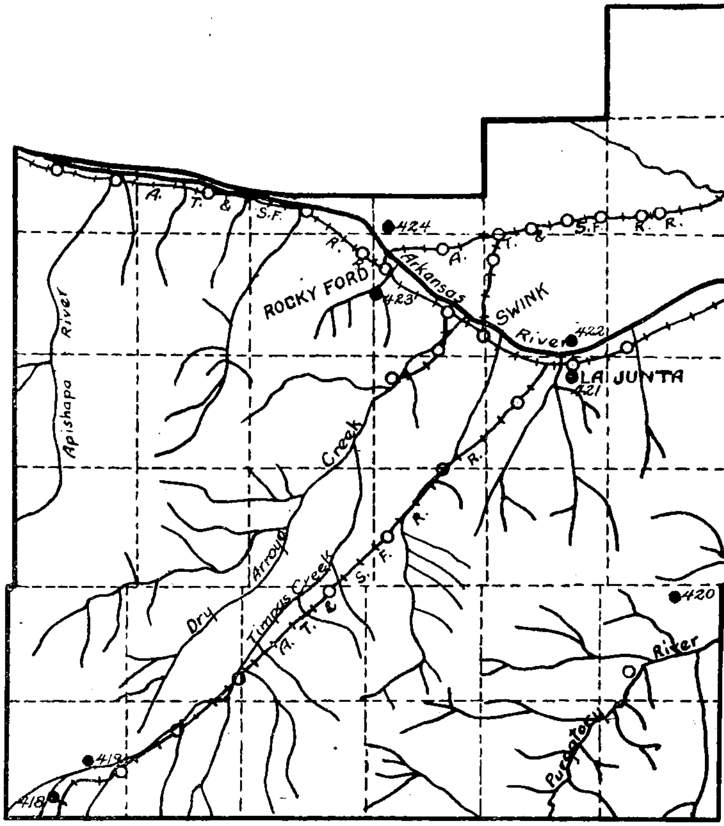
Geology of the County.—Most of the county is covered with rocks of Niobrara age, but Benton beds are exposed from La Junta eastward, in the southwestern corner of the county, and in a narrow zone connecting these two localities. Southeast of the last-mentioned Benton zone is an extensive exposure of Dakota rocks, in which the Purgatory River and Peeled Pine Creek have eroded canons and exposed Purgatory and Morrison beds. A few small areas of Tertiary material overlie the Niobrara beds first mentioned.

418. *Location:* On the Bloom Land and Cattle Company's ranch, in the canon of the Timpas Creek.

Occurrence: A 5-foot horizontal bed exposed in a tunnel driven into the wall of the canon.

Field Characteristics: A hard, gray to black, medium fine-grained, sandy clay.

OTERO COUNTY



Sketch map showing the approximate locations of the beds sampled

Economic Value: This material was formerly mined by the Bloom Land and Cattle Company and shipped to Pueblo. The tests made prove that it is a first-class fire-clay.

419. *Location:* On the Bloom Land and Cattle Company's ranch; ¾ mile from the Santa Fe Railroad.

Occurrence: An 8-foot bed of horizontal material, with up to 3 feet of overburden, which is exposed in an abandoned tunnel on the side of a knoll. Near the top of the Carlile formation.

Field Characteristics: Medium-soft, black to brown, fine-grained shales and clays.

Economic Value: This material was formerly mined and shipped to Pueblo. It should make nearly white soft-mud and pressed bricks, vitrified and unvitrified floor tiles, wall tiles, and, probably, stiff-mud bricks.

420. *Location:* 5 miles northwest of the J. J. ranch, on the public road.

Occurrence: 15 feet was sampled of horizontal material, with 2 feet of overburden, which occurs in the banks of an arroya at the side of the road. Near the top of the Carlile formation.

Field Characteristics: Medium-soft, black, medium-fine to fine-grained shales and clays.

Economic Value: Should make fair, red pressed bricks.

421. *Location:* South of La Junta; near the plant of La Junta Brick and Tile Manufacturing Company.

Occurrence: 45 feet was sampled of horizontal material, with up to 3 feet of overburden, which occurs in the side of a knoll. Near the top of the Carlile formation.

Field Characteristics: Medium-hard, gray, medium fine-grained shales and clays.

Economic Value: This material has been used for the manufacture of pressed bricks and tiles, and is reported to have been tried for sewer pipes with some success, but the tests made indicate that the absorption is too high for the best grade of bricks; and that the air shrinkage is such that tiles and sewer pipes are almost sure to warp, and will certainly be fragile before burning. In the absence of a better grade of material, it might be used for making these products, but cannot be considered as very well adapted for the manufacture of any of them.

422. *Location:* About 2 miles north of La Junta; above the public road.

Occurrence: 20 feet was sampled of horizontal material, with up to 10 feet of overburden, which is exposed in a small arroya in the side of a knoll above a ditch. Near the top of the Carlile formation.

Field Characteristics: Medium-hard, gray, medium-fine to fine-grained shales and clays.

Economic Value: Should make good, red soft-mud bricks and, probably, stiff-mud and pressed bricks, but the latter will have a rather high absorption. This clay appears to be in every way better adapted to the manufacture of bricks than No. 421, but the tensile strength is low; so there would be much loss from breakage if used for tiles or sewer pipes.

423. *Location:* In Reservoir Park; ¼ mile from Rocky Ford.

Occurrence: 12 feet was sampled of horizontal material, with up to 3 feet of overburden, which occurs in the side of a knoll.

The field blanks state that this clay is of Pierre age, although no Pierre beds are shown in this locality on the Colorado Geological Survey's map of the state.

Field Characteristics: Medium-hard, gray to brown, medium-coarse, sandy shale.

Economic Value: Worthless.

424. *Location:* At Holbrook Irrigation Company's reservoir No. 2; 2 miles north of Rocky Ford.

Occurrence: 25 feet was sampled of horizontal material, with up to 10 feet of overburden, in a cut from the reservoir to the ditch. The field blanks state that this sample is from near the top of the Pierre formation, although no beds of Pierre age are shown in this locality on the map of the Colorado Geological Survey.

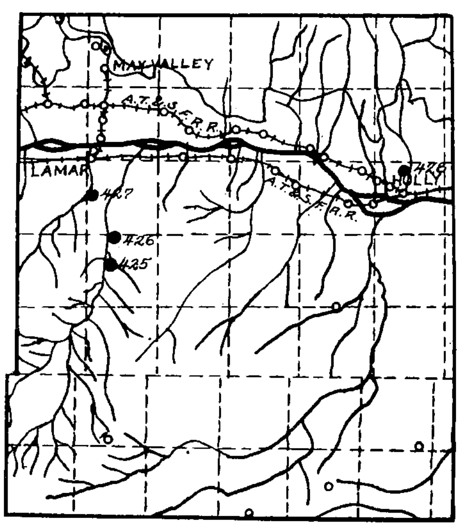
Field Characteristics: Medium-hard, gray to black, medium-fine to fine-grained shale.

Economic Value: Worthless, except, perhaps, for drain tiles, which would be very fragile before burning.

Prowers County

Geology of the County.—Extensive exposures of Tertiary material occur in the southern part of the county, although some of the stream-beds have cut through the Tertiary rocks and exposed

PROWERS COUNTY



Sketch map showing the approximate locations of the beds sampled

Dakota or Benton beds beneath. The greater portion of the rest of the county is underlain with Benton sediments, but there are extensive exposures of Dakota rocks around, and south of, Lamar; and Niobrara beds cover a large area in the northeastern, and a small area in the northwestern, corner of the county.

425. *Location:* 8 miles south of Lamar; on Clay Creek; near a schoolhouse.

Occurrence: 6 feet was sampled of horizontal material which occurs under a sandstone ledge on the bank of the creek. Near the top of the Dakota formation.

Field Characteristics: Medium-hard, gray to black shale and clay.

Economic Value: Should make good, pink soft-mud bricks and earthenware; also, probably, stiff-mud and pressed bricks, but the last will have rather high absorption.

426. *Location:* 5½ miles south of Lamar; on Clay Creek.

Occurrence: A 3-foot horizontal bed which occurs under a sandstone ledge on the eastern bank of the creek.

Field Characteristics: Hard, gray to brown, fine-grained clay and shale.

Economic Value: This clay burns pink or buff, according to the temperature used, and is adapted to the manufacture of a very wide variety of products, as shown on Table No. 1.

427. *Location:* 3 miles south of Lamar, on the public road.

Occurrence: 5 feet was sampled of a much thicker exposure of horizontal material, with up to 2 feet of overburden, which occurs in a shallow cut beside the road below a knoll. Near the top of the Carlile formation.

Field Characteristics: Medium-hard, gray to black, medium-fine to fine-grained shales.

Economic Value: Worthless, as the product was soft even after burning to Cone 10.

428. *Location:* ¾ mile north of Holly; above the Buffalo Irrigation Ditch; on a public road.

Occurrence: 5 feet was sampled of horizontal material, with up to 6 feet of overburden, which occurs on the bank of the ditch below a knoll.

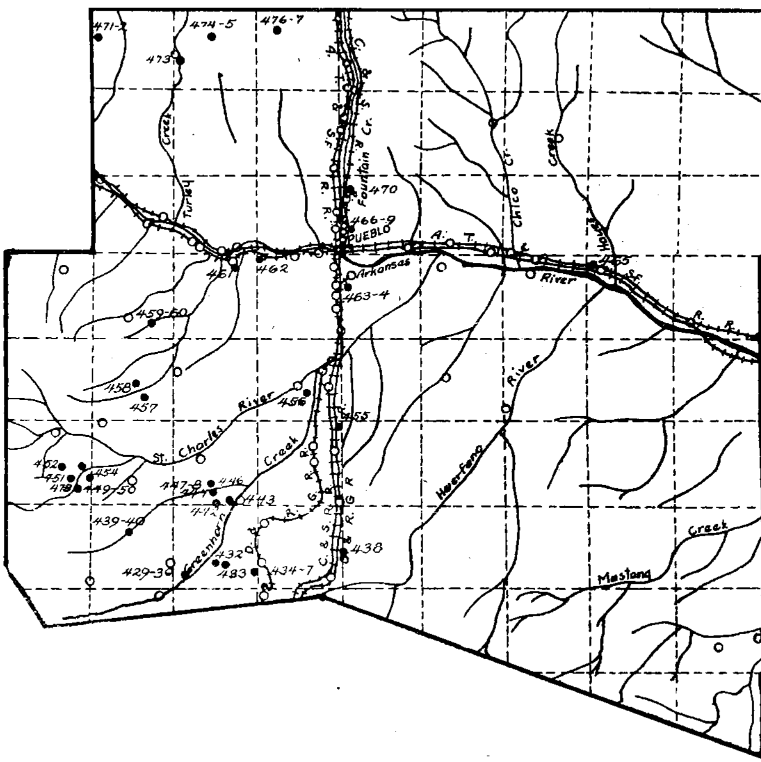
Field Characteristics: A medium-soft, gray, medium fine-grained, sandy shale.

Economic Value: Worthless, as the burned product is very soft and tends to slake in water even after burning to the hardness of steel.

Pueblo County

Geology of the County.—Along both banks of Fountain Creek and Arkansas River, north and east of Pueblo, there are extensive exposures of Pierre age, with large areas of Tertiary rocks in the northeast corner of the county. South and west of the Pierre beds is a wide zone of Niobrara material, which is bordered with relatively narrow exposures of Benton age. In the southwestern corner of the county all the older beds mentioned in this report occur, and most of them are also present to a more limited extent in the extreme northwestern corner.

PUEBLO COUNTY



Sketch map showing the approximate locations of the beds sampled

429. *Location:* About 5 miles west of Graneros; about ¼ mile below the end of the rock-walled canon.

Occurrence: A 2-foot bed, with a slight southwesterly dip, which occurs near the creek-bed in the south wall of the canon.

This bed appears to have the form of a lens, and the quantity is probably limited. The bed sampled is the thickest one in a 10-14 foot zone of alternating clays and sandstone in thin beds.

Field Characteristics: Medium-hard, black, fine-grained clay.

Economic Value: First-class fire-clay.

430. *Location:* About 5 miles west of Graneros; near the middle of the canon where the rock walls are highest.

Occurrence: A 3-foot bed which is nearly horizontal and occurs near the creek level on the southeastern side of the canon. Some distance below the top of the Purgatory formation.

Field Characteristics: Very hard, light grayish-green, sandy clay.

Economic Value: Should make good, buff pressed bricks and vitrified and unvitrified floor tiles.

431. *Location:* Something over 5 miles west of Graneros; about ¼ mile north of Graneros Creek; on the land of Mr. Chester McDaniels.

Occurrence: A 20-foot bed which dips 5° northwesterly, strikes N. 30° E., and is exposed in arroyas in a gently rounded hill. Near the center of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: This is reported to have been pronounced a fire-clay, but it is viscous at Cone 10. It is probably worthless, unless it should prove to make paving-bricks.

432. *Location:* About 3 miles west of Graneros; in a canon tributary to Greenhorn Creek; about ¾ mile east of the hill which deflects the stream at its mouth.

Occurrence: A 6-foot bed which dips 45° northerly, strikes N. 60° W., and occurs in the south bank of an arroya. May be of Purgatory age.

Field Characteristics: Very hard, dark-gray, sandy shale, containing a 4-inch coaly streak at the base.

Economic Value: First-class fire-clay.

433. *Location:* About 3 miles west of Graneros; in a canon tributary to Greenhorn Creek, and about 1 mile east of the hill which deflects the stream at its mouth.

Occurrence: A 4-foot bed which dips 40° northerly, strikes N. 60° W., and occurs in the bed of an arroya. May be of Purgatory age.

Field Characteristics: Very hard, gray, somewhat sandy clay, interbedded with thin sandstone layers not included in the sample.

Economic Value: First-class fire-clay.

434. *Location:* At the second bridge north of Caper's spur on the old track.

Occurrence: A 12-foot exposure of material, with 1-3 feet of overburden, which dips 20° northerly, strikes N. 65° W., and is exposed along an arroya for ½ mile west of the track.

Field Characteristics: Medium-hard, brown or greenish-black, fine-grained shales.

Economic Value: Should make good, pink soft-mud or pressed bricks and earthenware, but the latter will be fragile before burning.

435. *Location:* 1 mile northwest of Caper's spur, in an arroya tributary to the one mentioned in No. 434.

Occurrence: A 30-foot exposure of material which dips 30° northerly, strikes N. 65° W., and occurs just below the top of a hill. Near the top of the Carlile formation, at the horizon of the large septeria.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Should make good, pink soft-mud and pressed bricks and, possibly, paving-bricks.

436. *Location:* In the mine of the Standard Fire Clay Company at Caper's Spur.

Occurrence: A 3-14-foot bed, 40 feet below the surface, which dips 5° westerly, and strikes N. 10° E. 8 feet below the top of the Dakota formation.

Field Characteristics: Medium-hard, gray, fine-grained clay with a "soapy feel," which is interbedded with several thin beds of sandstone.

Economic Value: Should make fine vitrified floor tiles, wall tiles, and white pressed bricks with rather high absorption, if burned to high temperatures.

437. *Location:* From a tunnel in an arroya just north of the Standard Fire Clay Company's mine at Caper's Spur.

Occurrence: A 14-foot bed which dips 5° southerly, strikes N. 65° W., and occurs in the southern bank of the arroya. Near the top of the Dakota formation; under 5 feet of sandstone.

Field Characteristics: A very hard, light to dark-gray, fine-grained, shaly clay, containing thin sandstone beds which were excluded from the sample.

Economic Value: Should make fine, white pressed bricks, vitrified floor tiles, wall tiles, and, probably, earthenware, although the air shrinkage is a little high and the tensile strength somewhat low for the best grade of the last. This is probably the same bed which yielded No. 436, and the improvement in the plasticity and other qualities is doubtless due to weathering.

438. *Location:* 6 miles east of Graneros on the C. & S. Railroad. Sample furnished by E. F. Jewett, of Canon City.

Occurrence: A 6-8-foot horizontal bed which occurs below level ground. 30 feet below the top of the Dakota formation.

Field Characteristics: A gray, fine-grained clay.

Economic Value: Should make fine, white pressed bricks, earthenware, vitrified and unvitrified floor tiles, wall tiles, ball-clay, and, probably, soft- and stiff-mud bricks, whiteware, and porcelain, although grog is necessary in the cases of the last two.

439. *Location:* Northeast of Table Mountain and just above the old Wartanbee place on Muddy Creek; near Rye.

Occurrence: A 3-foot bed which dips 30° easterly, strikes N. 35° W., and occurs in the banks of the creek. Possibly of Dakota age. The beds are here so crumpled that it is difficult to determine the horizon.

Field Characteristics: A very hard, light-gray, somewhat sandy clay.

Economic Value: Probably worthless.

440. *Location:* Northeast of Table Mountain, where the Dakota formation first rises into a hogback; near Rye.

Occurrence: A 4-foot exposure of material that dips 35° easterly, strikes N. 35° W., and occurs at the foot of the Dakota hogback.

Field Characteristics: Very hard, gray and green, fine-grained marls.

Economic Value: Worthless.

441. *Location:* About 20 miles southwest of Pueblo, on the eastern slope of Eagle Rock, near the top.

Occurrence: A 10-foot bed of horizontal material, with 10-50 feet of overburden, which underlies the cap rock of the hills of all this region. 10-20 feet below the top of the Carlile formation.

Field Characteristics: Very hard, gray, sandy shale.

Economic Value: May possibly make paving or flashed bricks.

442. *Location:* About 20 miles southwest of Pueblo, on the eastern slope of Eagle Rock, about 100 feet below the highest point.

Occurrence: A 35-foot exposure of horizontal material in the middle of the slope between Greenhorn and Niobrara escarpments.

Field Characteristics: Medium-hard, black, fine-grained shale.

Economic Value: Should make attractive, flesh-tinted soft-mud or pressed bricks, and, probably, stiff-mud bricks, earthenware, and terra-cotta, although the last two will be fragile before burning.

443. *Location:* In the bank of Greenhorn Creek, just east of William Finlay's house; at Abbey.

Occurrence: A 30-foot exposure of horizontal material which occurs along the creek.

Field Characteristics: A hard, black, fine-grained shale.

Economic Value: Should make fine, pink soft-mud bricks if burned to Cone 05 or above, but the absorption will be a bit high.

Mr. Grout secured the following data from an unknown source on clays obtained near Abbey. He states that they are all white or light-yellow, very plastic clays, occurring in the bank of Muddy Creek, just below the Greenhorn limestone:

No. "a" burned hard at 1,920° F., and had then shrunk 4% and was gray. It did not shrink much after that up to 2,175°, when it was well vitrified and began to melt.

No. "b" was similar to No. "a," but could be heated to 2,250° F. before melting, and cracked in drying.

No. "c" vitrified below 1,850°, but had not melted at 2,200° and had then shrunk only 3%. It had a strong efflorescent white coating.

The analyses of these three samples follow:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	TiO_2	MgO	CaO	Na_2O	K_2O	Moist.	H_2O	Total
No. "a"	62.43	22.24	2.08	0.21	0.58	1.19	0.46	0.25	1.98	2.77	6.14	100.33
No. "b"	51.59	24.77	0.76	0.39	0.18	3.11	1.05	0.14	1.29	8.30	9.16	100.74
No. "c"	49.29	28.85	0.67	0.13	0.32	2.78	0.54	0.41	2.66	5.75	8.79	100.19

From the meager data furnished, it is impossible to say for what purpose these clays are adapted. Nos. "a" and "b" resemble No. 443, so far as can be learned from the information furnished, and may be no more valuable; while No. "c" may make paving-bricks.

444. *Location:* Directly north of Eagle Rock on Muddy Creek; about 20 miles southwest of Pueblo.

Occurrence: A 2-foot bed of alluvium in the bed of Muddy Creek.

Field Characteristics: Hard, blue, slightly sandy, alluvial clay.

Economic Value: This material is said to improve the quality of sun-dried bricks greatly if mixed with the adobe, but it seems worthless for any other purpose.

445. *Location:* On a steep bank on the southern side of Muddy Creek; just north of Eagle Rock.

Occurrence: A 40-foot bed of horizontal material exposed to a height of 40 feet above the water level. At the top of the Graneros formation.

Field Characteristics: Medium-hard, black, fine-grained shales, including one white bed 30 inches thick.

Economic Value: Probably worthless.

446. This sample was taken from the 30-inch white bed mentioned under No. 445. The same bed, or one exactly similar, can be seen on Greenhorn Creek and on a tributary to Graneros Creek. It is a soft, very fine-grained clay, and occurs 15 feet above the water level. It shrunk so badly on drying that the test-pieces fell to pieces and none could be burned.

447. *Location:* On a bluff north of Muddy Creek, north of Eagle Rock; 20 miles southwest of Pueblo.

Occurrence: A 35-foot exposure of horizontal material which occurs in the middle of the slope between Greenhorn and Niobrara escarpments.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Although this sample is from the same horizon and not far from No. 442, it is probably worthless; and affords a splendid illustration of the fact that a bed may vary widely in its properties in a short distance, although the appearance remains the same.

448. *Location:* On a bluff north of Muddy Creek, north of Eagle Rock; 20 miles southwest of Pueblo.

Occurrence: A 50-foot exposure of horizontal material which occurs in an arroya. At the base of the Carlile formation.

Field Characteristics: A medium-hard, gray, fine-grained shale.

Economic Value: Probably worthless.

449. *Location:* About 1 mile down the St. Charles River from the road past the "Three-R" ranch; about 25 miles southwest of Pueblo.

Occurrence: A 10-foot horizontal bed which occurs about half-way up the steep northern side of the canon.

Field Characteristics: Medium-hard to hard, gray to black, fine-grained to gritty shales and clays.

Economic Value: Should make good, pink earthenware, terra-cotta, and, probably, hollow structural materials and drain tiles.

450. *Location:* About 1 mile down the St. Charles River from the road past the "Three-R" ranch; about 25 miles southwest of Pueblo.

Occurrence: A lens-shaped, horizontal bed, with a maximum thickness of 3 feet, which occurs near the bottom of the southern side of the canon.

Field Characteristics: A very hard, light-blue, fine-grained, compact clay.

Economic Value: First-class fire-clay.

451. This sample is from the same horizon as No. 449, but comes from a better exposure a short distance from the point first sampled. It differs quite remarkably from No. 449, since it slakes comparatively easily, has a tensile strength of 93 pounds, and has a low absorption; while No. 449 does not slake at all, has a tensile strength of 147 pounds, and has a high absorption.

Economic Value: Should make good buff to brown soft-mud and pressed bricks, earthenware, and unvitrified floor tiles; also, probably, stiff-mud bricks and terra-cotta.

452. *Location:* 3 miles south of Beulah; where the road up South Creek reaches the top of the hill.

Occurrence: A 2-foot exposure of material of uncertain dip and strike. May be a Recent deposit.

Field Characteristics: A soft, yellowish-green, very fine-grained clay, containing some gravel.

Economic Value: Should make good, pink soft-mud and pressed bricks, earthenware, and unvitrified floor tiles; also, probably, stiff-mud bricks.

453. *Location:* ¼ mile westward up the arroya from the fork in the road west of the "Three-R" ranch; about 25 miles southwest of Pueblo.

Occurrence: A 12-foot exposure of material of uncertain dip and strike which occurs in the northern bank of the deep ravine north of the road.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, red pressed bricks and unvitrified floor tiles; also, probably, soft- and stiff-mud bricks if heavily grogged.

454. *Location:* About 4 miles southeast of Beulah and ½ mile southeast of the "Three-R" ranch-house.

Occurrence: A 30-foot bed, with 3 feet of overburden, which dips about 20° southerly, strikes about N. 70° E., and occurs in an arroya in a Niobrara-capped hill.

Field Characteristics: Medium-hard, black and gray, fine to coarse-grained shales.

Economic Value: Should make good, pink soft-mud and pressed bricks and earthenware.

455. *Location:* About 4 miles south of San Carlos and within ½ mile east of the railroad.

Occurrence: A 20-foot bed, with up to 2 feet of overburden, which dips 5° easterly, strikes about north and south, and occurs in some small arroyas that run west from the Greenhorn limestone which caps the first rise.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Might make paving-bricks.

456. *Location:* 1½ miles due southwest from the mouth of Greenhorn Creek.

Occurrence: A 30-foot exposure, with 1-4 feet of overburden, which dips 10° westerly, strikes N. 20° E., and occurs in the bed of a small arroya. At the center of the Carlile formation.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make good, pink soft-mud, pressed, and flashed bricks, and vitrified floor tiles; also, possibly, paving-bricks.

457. *Location:* Northeast of Beulah; near the point where the two roads meet at Galbreth Creek; about ¼ mile above Kearney's house.

Occurrence: An 8-10-foot bed which dips 5° northeasterly, strikes N. 30° W., and is exposed in the canon wall.

Field Characteristics: Very hard, bluish-gray, fine-grained clay, with a sandy layer in the middle.

Economic Value: Should make fine, white pressed bricks (if burned to Cone 8), unvitrified and vitrified floor tiles, wall tiles, ball-clay, refractory ware, and, probably, whiteware and porcelain.

458. *Location:* About 6 miles northeast of Beulah, on Rock Creek.

Occurrence: A 6-foot exposure of material which dips about 5° easterly, strikes about N. 10° W., and is exposed at the face of a tunnel 150 feet long.

Field Characteristics: A very hard, light bluish-gray, fine-grained clay.

Economic Value: First-class fire-clay, and might yield other high-grade products if washed.

459. *Location:* About ¼ mile northeast of the point where No. 457 was obtained.

Occurrence: A 35-foot exposure of material which dips 5° northeasterly, strikes N. 20° W., and occurs near the top of a hill. Near the center of the Carlile formation.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Might make paving-bricks.

460. *Location:* About ¼ mile northeast of the point where No. 457 was obtained.

Occurrence: A 25-foot exposure of material, with 4 feet of overburden, which dips 5° northeasterly, strikes N. 20° W., and is exposed in an arroya on the hillside below No. 459. Near the center of the Graneros formation.

Field Characteristics: A medium-hard, black, fine-grained shale.

Economic Value: Should make fine, pink soft-mud and pressed bricks, unvitrified floor tiles, and, probably, earthenware. It might yield other products if heavily grogged.

461. *Location:* 5 miles west of Pueblo, and 300 yards south of the D. & R. G. R. R.

Occurrence: 25 feet was sampled of a much thicker exposure of nearly horizontal material, with up to 15 feet of overburden, which occurs on a high bank above the railroad grade. At the top of the Carlile formation.

Field Characteristics: Medium-hard, gray, medium fine-grained shale.

Economic Value: Bricklets made from this clay had a fine appearance, but the absorption was so great that the material is probably worthless.

462. *Location:* 3 miles west of Pueblo, and 200 yards from the Arkansas River.

Occurrence: 10 feet was sampled of a thicker exposure of nearly horizontal material, with up to 6 feet of overburden, which is exposed in a railroad cut. At the base of the Graneros formation.

Field Characteristics: A hard, gray, coarse-grained, sandy shale.

Economic Value: This material was so sandy that it would not retain its shape after molding and could not be tested further.

463. *Location:* 1 mile east of Bessemer Junction; near Pueblo.

Occurrence: A 2-foot exposure of horizontal material, with about 1 foot of overburden, which is exposed in the side of a small draw at the foot of a knoll.

Field Characteristics: Soft, gray to yellow, fine-grained shale and clay.

Economic Value: Should make good, red soft-mud bricks and earthenware, and, probably, stiff-mud and paving-bricks.

464. *Location:* 1½ miles east of Bessemer Junction; near Pueblo.

Occurrence: A 3-foot exposure of horizontal material, with about 1 foot of overburden, occurring near the top of a knoll.

Field Characteristics: A soft, gray to yellow, medium fine-grained, sandy clay.

Economic Value: Should make very fine soft-mud bricks and earthenware; also, probably, pressed, vitrified, and flashed bricks, but the pressed bricks will have rather high absorption.

465. *Location:* ½ mile west of Boone.

Occurrence: A 12-15-foot bed of horizontal material, with up to 6 feet of overburden, which occurs in a low knoll.

Field Characteristics: A medium-hard, gray to brown, medium coarse-grained clay.

Economic Value: Should make good, red soft-mud and pressed bricks and earthenware, and is used for the manufacture of such bricks at the plant of the La Junta Brick and Tile Manufacturing Company.

466. *Location:* ½ mile west of the yard of the Summit Pressed Brick and Tile Company, in Pueblo.

Occurrence: Unstated.

Field Characteristics: Unstated.

Economic Value: The data on tests made on this sample, except the chemical analysis, were lost, but it is known that the material is used for the manufacture of red pressed bricks.

467. *Location:* At the yard of the Summit Pressed Brick and Tile Company, at Pueblo.

Occurrence: Unstated.

Field Characteristics: Unstated.

Economic Value: Although this clay is used for the manufacture of pink pressed bricks, the absorption is too high for the best grade of this product.

468. *Location:* At the yard of the Summit Brick and Tile Company, at Pueblo.

Occurrence: Unstated.

Field Characteristics: Unstated.

Economic Value: It is claimed that this material burns white and that gray tints are made by the addition of manganese oxide. It is also claimed that the bricks are burned to a temperature between 2,200° and 2,300° F. The tests made on the sample show that the material burns light pink in an oxidizing atmosphere, has very high absorption, but makes good looking bricks, and fuses at cone 3, or at 2,174° F.

469. *Location:* At the plant of the Acme Brick Works, 1 mile north of the Summit Pressed Brick and Tile Company's yard.

Occurrence: Unstated.

Field Characteristics: Unstated.

Economic Value: Should make good, red soft-mud and pressed bricks, earthenware, and unvitrified floor tiles.

470. *Location:* At the plant of the Colorado Brick and Tile Company, on the eastern bank of Fountain Creek, 5 miles north of Pueblo.

Occurrence: Unstated.

Field Characteristics: Unstated.

Economic Value: Should make fine, red pressed bricks.

471. *Location:* 10 miles northeast of Florence.

Occurrence: A 15-foot bed which dips 3° southwesterly, strikes N. 65° W., and occurs below the Niobrara escarpment. 40 feet below the top of the Carlile formation.

Filed Characteristics: A medium-hard, black and brown, fine-grained shale.

Economic Value: Should make good, pink pressed bricks and unvitrified floor tiles.

472. *Location:* 10 miles northeast of Florence.

Occurrence: 30-feet was sampled of a much thicker exposure of material which dips 3° southwesterly, strikes N. 65° W., and occurs below No. 471. 75 feet from the top of the Carlile formation.

Field Characteristics: Soft, yellowish-brown, fine-grained shale, containing a large amount of gypsum.

Economic Value: Probably worthless.

473. *Location:* Near Myrtle. Sample was obtained from E. F. Jewett, of Canon City.

Occurrence: A 5-8-foot bed of horizontal material. 20-30 feet below the top of the Dakota formation.

Field Characteristics: A hard, light-gray, fine-grained clay.

Economic Value: This is an exceptionally fine fire-clay, as the test-cone is in fine condition at Cone 30. It would also answer as mined for wall tiles and white pressed bricks, but is not now used because of its distance from the railroad.

474. *Location:* 6 miles south of Quinby's ranch; 1 mile north of the reservoir.

Occurrence: 25 feet was sampled of a much thicker exposure of material which has a slight easterly dip and occurs at the western base of the Niobrara escarpment. 40 feet below the top of the Carlile formation.

Field Characteristics: A medium-soft, gray, fine-grained shale.

Economic Value: Worthless.

475. *Location:* 6 miles south of Quinby's ranch; 1 mile north of the reservoir.

Occurrence: 30 feet was sampled of a much thicker exposure of material just below No. 474. 65 feet below the top of the Carlile formation.

Field Characteristics: Medium-hard, black and gray, fine-grained shales and clays.

Economic Value: Should make good, pink pressed bricks and unvitrified floor tiles.

476. *Location:* 5 miles south of Quinby's ranch; ¼ mile from the Pueblo road.

Occurrence: 40 feet was sampled of a much thicker exposure of nearly horizontal material occurring at the base of a round butte. Near the top of the Pierre formation.

Field Characteristics: Medium-hard, gray, medium coarse-grained shale.

Economic Value: Worthless.

477. *Location:* 5 miles south of Quinby's ranch; ¼ mile from the Pueblo road.

Occurrence: 35 feet was sampled of a much thicker exposure of nearly horizontal material occurring on the east side of a round butte above No. 476. At the base of the Fox Hills formation.

Field Characteristics: A medium-hard, yellow, medium coarse-grained sandy shale.

Economic Value: Worthless.

478. *Location:* ¼ mile down the St. Charles River from the road past the "Three-R" ranch; about 25 miles southwest of Pueblo.

Occurrence: A 12-foot, nearly horizontal bed which occurs just above the water level on the south side of the canon. About 50 feet below the top of the Dakota formation.

Field Characteristics: Rather hard, black, fine-grained clays in beds 2-6 inches thick, containing sandy streaks.

Economic Value: Worthless.

Routt County

Geology of the County.—The geology of Routt County is too complicated to be presented without the aid of a geological map.

479. *Location:* 12 miles west of Steamboat Springs on Trout Creek; ¾ of a mile above its junction with Bear River, and on the western side of Saddle Mountain.

Occurrence: A 5-foot bed which dips 5° southeasterly, strikes S. 60° W., and occurs at the base of the bluff above the stream and below a 6-inch sandstone layer.

Field Characteristics: A soft, blue, coarse-grained, shaly clay.

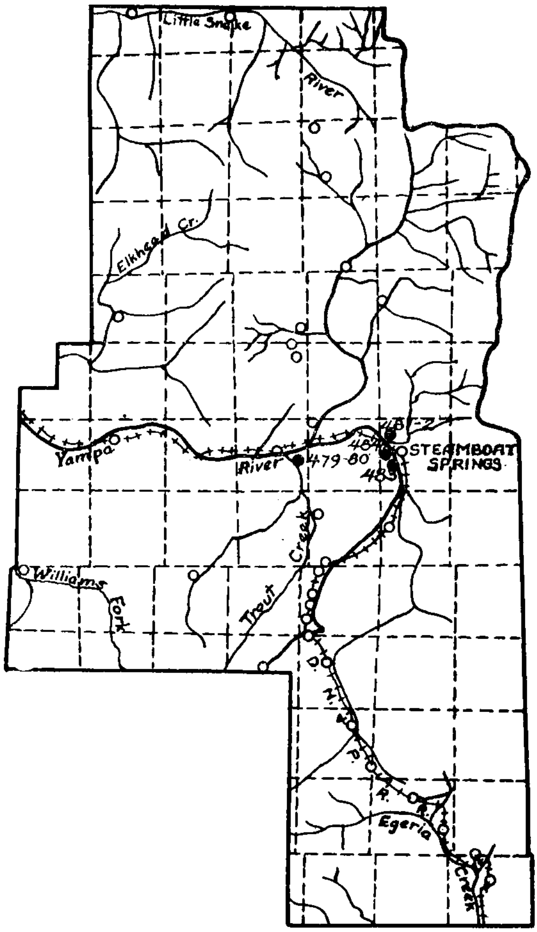
Economic Value: Worthless.

480. *Location:* 12 miles west of Steamboat Springs on Bear River; ½ mile above its junction with Trout Creek, and on the eastern side of Saddle Mountain.

Occurrence: A 50-foot exposure of material which dips 5° southeasterly, strikes S. 60° W., and occurs 100 feet above the river, in a bluff.

Field Characteristics: A medium-hard, light-gray, fine-grained clay, containing more or less gritty material.

ROUTT COUNTY



Sketch map showing the approximate locations of the beds sampled

Economic Value: Should make good, red pressed bricks with rather high absorption.

481. *Location:* 1¼ miles northwest of Steamboat Springs; on the Harvey Woolery ranch.

Occurrence: A 100-foot exposure of material which dips 7° westerly, strikes north and south, and occurs at the top of a bluff on the western side of Bear River. In the lower or Benton division of the Mancos formation.

Field Characteristics: A hard, gray, fine-grained shale, containing several sandstone streaks at the base.

Economic Value: It is reported that tests have been made on this clay and that good light flesh-tinted pressed bricks were made from it, but the absorption is altogether too high for a good grade of face-bricks.

482. This sample is from the same locality as No. 481, but includes only the lower half of the exposure. The product is very similar to that obtained from No. 481, but the absorption and the temperatures of vitrification and viscosity are higher.

483. *Location:* 1½ miles south of Steamboat Springs; on the bank of Bear River, beside the railroad.

Occurrence: A 4-foot exposure of horizontal alluvium.

Field Characteristics: A soft, light-blue, coarse-grained, sandy clay.

Economic Value: Although ordinary red bricks have been made of this material, they are too soft and slake too easily to have any value for facing purposes.

484. *Location:* On the saddle of the bluff across the railroad track, south of the Steamboat Cabin Hotel at Steamboat Springs.

Occurrence: An exposure of 100 feet or more of material which dips 25° westerly, strikes N. 20° E., and occurs near the top of a steep bluff. In the lower of Benton division of the Mancos formation.

Field Characteristics: Very hard, dark-gray, fine-grained shales.

Economic Value: Worthless.

Saguache County

Geology of the County.—Although the geology of the county is too complicated to be presented without the aid of a geological map, it can be said that San Luis Valley is largely underlain by Tertiary deposits.

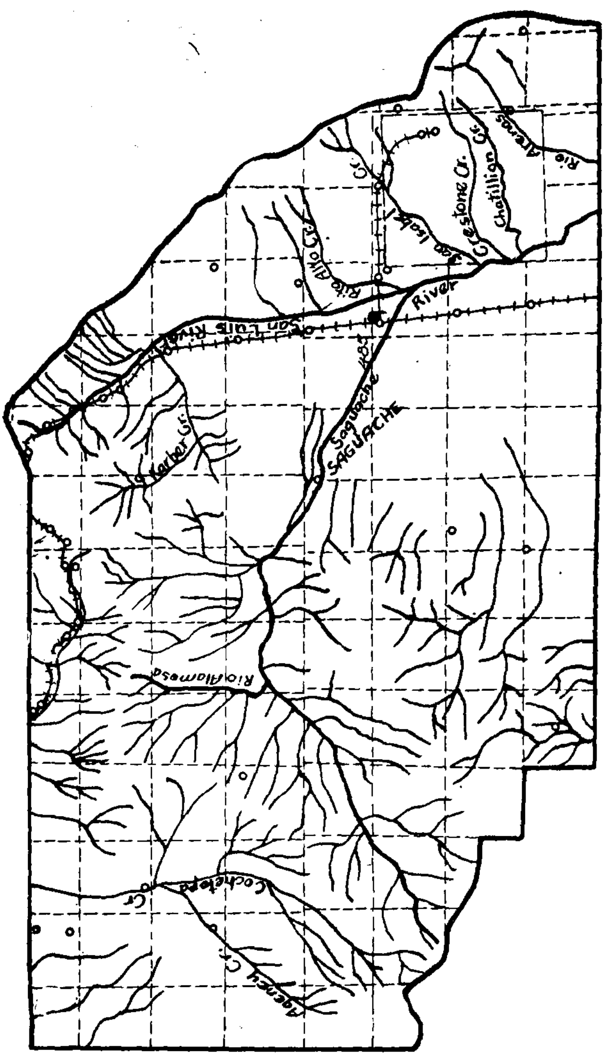
485. *Location:* On the Baker ranch; near Moffat.

Occurrence: This sample was taken from a 1½-foot exposure of horizontal material, with 6 feet of overburden, which probably extends below the water level, which lies about 7½ feet below the surface. It may be Tertiary age.

Field Characteristics: Soft, gray, fine-grained shale and clay.

Economic Value: Worthless.

SAGUACHE COUNTY

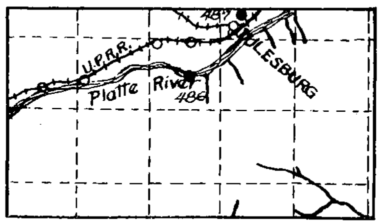


Sketch map showing the approximate locations of the beds sampled

Sedgwick County

Geology of the County.—Sedgwick County is entirely underlain with Tertiary sediments, which are principally of Arikaree or Ogallala age, but there is a band of Brule material along the South Platte River in the western half of the county.

SEDGWICK COUNTY



Sketch map showing the approximate locations of the beds sampled

486. *Location:* 3 miles west of Julesburg and south of the river.

Occurrence: A 12-foot exposure, containing two beds of horizontal material which occur in several scattered hummocks on a hill.

Field Characteristics: Medium-hard, chocolate-colored, fine-grained clay.

Economic Value: Might make good, red pressed bricks, but the absorption will be a bit high. A much better product than that obtained from No. 487, but could not be used for soft-mud bricks under any condition.

487. *Location:* In the brick-yard at Julesburg.

Occurrence: A 10-foot bed of horizontal material, with 2 feet of overburden.

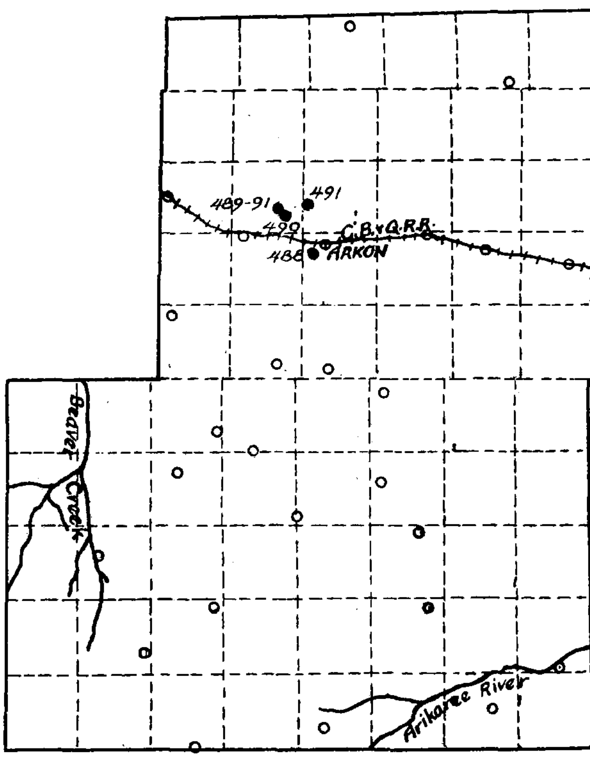
Field Characteristics: Soft, brownish-gray, sandy and gravelly, roughly bedded alluvium.

Economic Value: Should make good, red soft-mud bricks if burned to Cone 03 or above. Mr. Grout describes the product as poor, which is doubtless due to the fact that the bricks are underburned.

Washington County

Geology of the County.—The greater part of Washington County is underlain with Arikaree and Ogalalla material, but this is bordered by a narrow band of Brule rocks to the westward, and extensive exposures of Laramie age occur still farther west.

WASHINGTON COUNTY



Sketch map showing the approximate locations of the beds sampled

488. *Location:* In the brick-yard between the railroad and the Fair Grounds at Akron.

Occurrence: A 10-12-foot exposure of material in a slight ravine.

Field Characteristics: Soft, brownish, sandy clay which may be loess.

Economic Value: Should make fair, sandy, red soft-mud and, probably, stiff-mud bricks if burned to Cone 1. Mr. Grout described the product as poor, which is doubtless due to underburning.

489. *Location:* S.W. ¼ Sec. 23, T. 3 N., R. 53 W.; northwest of Akron.

Occurrence: A 10-foot bed of horizontal material which occurs in a northerly-facing bluff at the top of the hill south of the gap through which the road passes. May be of Arikaree age.

Field Characteristics: A medium-hard, white, chalky clay.

Economic Value: Worthless.

490. *Location:* S.W. ¼ Sec. 25, T. 3 N., R. 53 W.; in the so-called Fuller's Earth Mine; northwest of Akron.

Occurrence: A 10-foot exposure of horizontal material occurring near the bottom of a steep slope. May be of Arikaree age.

Field Characteristics: A medium-hard, tough, very light brownish-gray, fine-grained, gritty clay.

Economic Value: Worthless for clay products.

491. *Location:* S.W. ¼ Sec. 23, T. 3 N., R. 53 W.; northwest of Akron.

Occurrence: A 40-foot exposure of horizontal material occurring in a bare chalky spot on the northern slope of the hill. May be of Arikaree age.

Field Characteristics: Medium-hard, tough, cream-colored, chalky material.

Economic Value: It is reported that this is a fire-clay, but it fuses at Cone 3 and is valueless.

492. *Location:* Near the S.E. Cor. Sec. 19, T. 3 N., R. 52 W.; northwest of Akron.

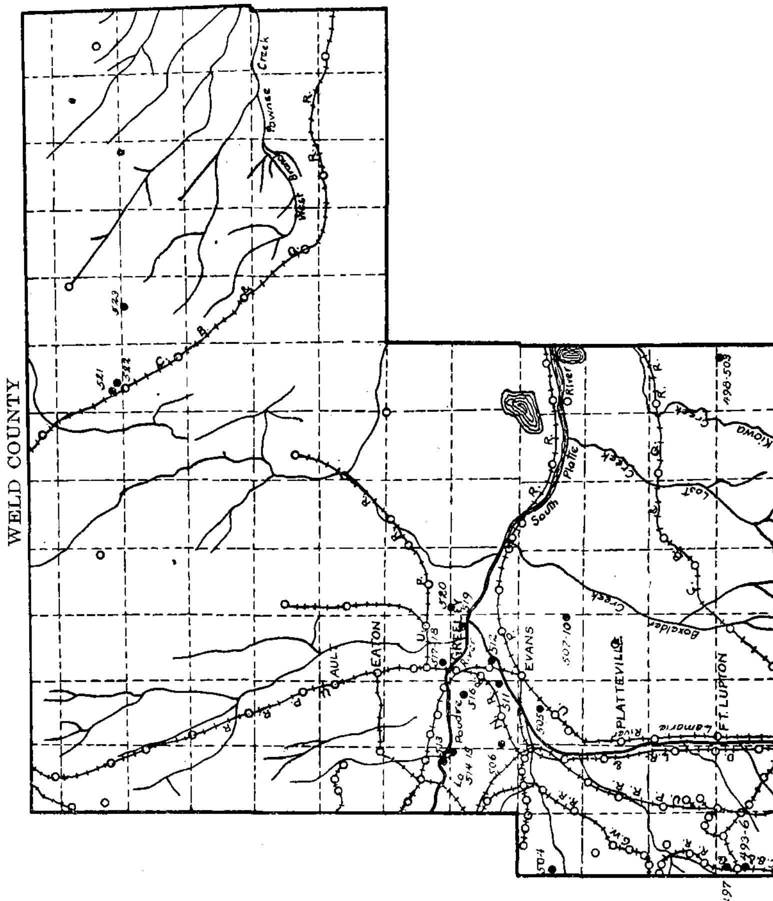
Occurrence: A 6-foot exposure of horizontal material occurring in a gulch just below the cap rock of a mesa. May be of Arikaree age.

Field Characteristics: Medium-grained, tough, very light-brownish, chalky material.

Economic Value: Worthless for clay products.

Weld County

Geology of the County.—The greater part of the county is underlain with rocks of Laramie age, but there are extensive occurrences of Fox Hills sediments on both banks of the South Platte River and its western tributaries. There is also a large area of Arapahoe material near the center of the southern boundary, while the northern boundary is covered with beds of Brule, Arikaree, or Ogalalla age.



Sketch map showing the approximate locations of the beds sampled

493. *Location:* In the coal prospect about a mile southeast of Erie.

Occurrence: The bed was not seen, but was reported by the foreman to be 10 feet thick and to occur 200 feet below the surface.

Field Characteristics: A hard, light-gray, fine-grained, clay.

Economic Value: Should make good flashed bricks, and might answer for paving-bricks.

494. *Location:* In the Lehigh Mine south of Erie.

Occurrence: A 3-5-foot bed which dips 5° southeasterly, strikes N. 45° E., and occurs 120 feet below the surface. Above the second coal-seam.

Field Characteristics: A medium-hard, gray, fine-grained clay.

Economic Value: Might make red earthenware if grogged, and should be tested for paving and flashed bricks.

495. This is the same material as No. 494, but is taken from a dump which is mostly made up of this clay in a weathered condition.

Economic Value: Should make good, red soft-mud bricks and, probably, paving and flashed bricks. An odd feature of this clay is that the plasticity is lower when weathered than when fresh.

496. *Location:* In the Lehigh Mine south of Erie.

Occurrence: A 4-foot exposure of material which dips 5° southeasterly, strikes N. 45° E., and is exposed in the steep banks of two arroyas east of the creek.

Field Characteristics: Medium-hard, light-gray, gritty shale.

Economic Value: Should make good, buff soft-mud and pressed bricks, earthenware, and unvitrified floor tiles; also, possibly, terra-cotta, hollow structural materials, conduits, and drain tiles, if grogging will reduce the tendency to crack in drying. The bricks should be burned to Cone 03 to obtain a lower absorption.

497. *Location:* On the first railroad cut on the Union Pacific north of Erie and east of the creek.

Occurrence: A 4-foot bed which dips 15° northeasterly, has a variable strike, and forms the roof of a small coal seam.

Field Characteristics: A medium-hard, gray, fine-grained shale.

Economic Value: Worthless.

498. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 63 feet.

Economic Value: Probably worthless, but could be made into yellowish pressed bricks with rather high absorption.

499. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 77 feet.

Economic Value: Should make fine, red pressed bricks and unvitrified floor tiles.

500. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 80 feet.

Economic Value: Should make fine, red pressed bricks and unvitrified floor tiles.

501. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 92 feet.

Economic Value: Should make fine pink pressed bricks and unvitrified floor tiles.

502. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 98 feet.

Economic Value: Worthless.

503. *Location:* S.W. ¼ Sec. 2, T. 1 N., R. 61 W.

Occurrence: This sample is from a churn-drill hole sunk in prospecting for coal, and comes from a depth of 100 feet.

Economic Value: Worthless.

504. *Location:* In the Berthoud Brick and Tile Company's yard; about 1,000 feet north and 1,900 feet west of the S.E. Cor. Sec. 19, T. 4 N., R. 68 W.

Occurrence: A 20-foot bed of uncertain dip and strike occurring in a gentle slope north of the river.

Field Characteristics: Medium-hard, yellowish-green with gray below, fine-grained, thick-bedded shale.

Economic Value: Should make attractive, pink soft-mud and pressed bricks, earthenware, and, probably, stiff-mud bricks, hollow structural materials, conduits, and drain tiles, provided grogging does not reduce the plasticity too much.

505. *Location:* 10 miles southwest of Greeley; along the railroad.

Occurrence: A 12-foot exposure of nearly horizontal material, with 1 foot or more of overburden, which occurs in the banks of the first arroya which crosses the railroad south of Greeley.

Field Characteristics: A medium-hard, gray to yellow, somewhat gritty shale.

Economic Value: Should make attractive, pink soft-mud bricks.

506. *Location:* 1,200 feet north and 1,300 feet west of the S.E. Cor. Sec. 30, T. 5 N., R. 66 W.; at a coal prospect about 10 miles southwest of Greeley.

Occurrence: A 10-foot exposure of nearly horizontal material, with 1 foot or more of overburden, which occurs on the side of a hill. About 30 feet above a coal-seam.

Field Characteristics: A medium-hard, bluish-gray when weathered and yellowish when fresh, fine-grained, somewhat gritty shale.

Economic Value: Should make good, pink soft-mud bricks and earthenware, and, possibly, stiff-mud bricks.

507. *Location:* In the Black Prince Coal Mine, about 11 miles southeast of Greeley. From the western of the two shafts working when the sample was taken.

Occurrence: A 5-foot bed which dips 5° southerly, strikes east and west, and occurs 15 feet below the surface.

Field Characteristics: A soft, yellowish, sandy shale.

Economic Value: Should make good, red pressed bricks.

508. *Location:* In the Black Prince Coal Mine, about 11 miles southeast of Greeley. From the western of the two shafts working when the sample was taken.

Occurrence: An 8-foot bed which dips 5° southerly, strikes east and west, and occurs 38 feet below the surface and just below the higher coal-seam exposed in the shaft.

Field Characteristics: A medium-hard, gray, fine-grained clay.

Economic Value: Should make good, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks, but there will be considerable loss, due to over- and underburning.

509. *Location:* In the Black Prince Coal Mine, about 11 miles southeast of Greeley. From the western of the two shafts working when the sample was taken.

Occurrence: A 5-8-foot bed which dips 5° southerly, strikes east and west, and occurs 75 feet below the surface. Just above the lower coal-seam.

Field Characteristics: A soft, black, fine-grained shale.

Economic Value: Should make attractive, buff soft-mud and flashed bricks, and, possibly, paving-bricks, but the absorption will be rather high.

510. *Location:* In the Black Prince Coal Mine, about 11 miles southeast of Greeley. From the eastern of the two shafts working when the sample was taken.

Occurrence: A bed of uncertain thickness which dips slightly southeasterly, strikes northeasterly, and occurs 65 feet below the surface, beneath the middle of the three coal-seams found in the shaft.

Field Characteristics: Medium-hard, gray and white, sandy material of variable texture.

Economic Value: Should make good, buff soft-mud, pressed, and paving-bricks, earthenware, and vitrified floor tiles; also, probably, flashed bricks.

511. *Location:* 300 feet north and 1,000 feet west of the S.E. Cor. Sec. 25, T. 5 N., R. 66 W.; south of Greeley.

Occurrence: A 4-foot bed, with 5-6 feet of overburden, which occurs in railroad cuts in a low hill north of the South Platte River.

Field Characteristics: Soft, yellowish, sandy clay.

Economic Value: Should make fine, pink soft-mud bricks and, probably, stiff-mud bricks and earthenware.

512. *Location:* 1,150 feet north and 1,300 feet west of the S.E. Cor. Sec. 20, T. 5 N., R. 65 W.; near Evans.

Occurrence: A 10-foot exposure of material, with about 1 foot of overburden, which occurs in the first large ditch north of Evans; on a hill above the Platte River.

Field Characteristics: A soft, yellowish, sandy clay.

Economic Value: Should make red soft-mud and pressed bricks and earthenware, and, possibly, stiff-mud bricks; but there is apt to be considerable loss, due to over- and underburning.

513. *Location:* 300 feet north and 1,400 feet west of the S.E. Cor. Sec. 35, T. 6 N., R. 67 W.; west of Greeley.

Occurrence: A 40-foot exposure of material, with 1 foot of overburden, which has a slight southeasterly dip and occurs on a bluff just south of the Cache la Poudre River.

Field Characteristics: Soft, gray and yellow, gritty shale, alternating with sandstone layers.

Economic Value: Probably worthless, although it might be used to make red pressed bricks, which would be fragile before burning.

514. *Location:* 1,700 feet north and 1,300 feet west of the S.E. Cor. Sec. 1, T. 5 N., R. 67 W.; west of Greeley.

Occurrence: A 6-foot bed, with a slight easterly dip, which occurs under a sandstone ledge at the head of a ravine.

Field Characteristics: Soft to medium-hard, dark-gray, fine-grained shale.

Economic Value: Should make good, red pressed bricks and, probably, soft-mud bricks, although the latter will be fragile before burning.

515. *Location:* 1,750 feet north and 1,300 feet west of the S.E. Cor., Sec. 1, T. 5 N., R. 67 W.

Occurrence: A 20-foot bed which has a slight southeasterly dip, and occurs under a level sandstone bed at the head of a ravine, south of the river.

Field Characteristics: Soft, gray, gritty shale with sandy layers.

Economic Value: Should make fine, pink pressed bricks.

516. *Location:* 900 feet north and 600 feet west of the S.E. Cor. Sec. 11, T. 5 N., R. 66 W.

Occurrence: A 10-foot horizontal bed, with 1 foot of overburden, which occurs in an arroya below the reservoir.

Field Characteristics: A soft, yellowish, sandy, roughly bedded clay.

Economic Value: Might make yellowish-white, soft-mud bricks if burned to Cone 02.

517. *Location:* Greeley Brick Yard.

Occurrence: An 8-foot bed, with 10 feet of overburden.

Field Characteristics: Soft, yellowish, sandy, roughly bedded sands and clays.

Economic Value: Should make good, pink soft-mud bricks, and might answer for pressed bricks, but these will be fragile before burning.

518. *Location:* Greeley Brick Yard.

Occurrence: A 20-foot exposure of horizontal material, including the beds sampled separately as No. 517.

Field Characteristics: Soft, yellowish, sandy, roughly bedded sands and clay.

Economic Value: Should make good, pink soft-mud bricks and earthenware.

519. *Location:* N.E. ¼ of the N.E. ¼ Sec. 11, T. 5 N., R. 65 W.; on land owned by Mr. Bethge, who furnished the sample.

Occurrence: A 40-foot bed, with a thin overburden, which occurs at the water's edge in the bank of the Poudre River.

Field Characteristics: Medium-hard, yellowish, sandy clay.

Economic Value: Might make red, soft-mud bricks if burned to Cone 3, but there will be considerable waste, due to over- and underburning.

520. *Location:* 600 feet north and 400 feet west of the S.E. Cor. Sec. 6, T. 5 N., R. 64 W.; east of Greeley.

Occurrence: A 5-foot exposure of material, with up to 2 feet of overburden, which has an uncertain dip and strike, and occurs in a ditch along Lone Tree Creek.

Field Characteristics: A soft, light bluish-gray, fine-grained clay.

Economic Value: Worthless.

521. *Location:* A little over a mile northwest of Grover; along the railroad.

Occurrence: A 10-foot horizontal bed in more calcareous material that occurs in the first isolated hill east of the railroad.

Field Characteristics: Medium-hard, tough, cream-colored, chalky material.

Economic Value: Worthless for clay products.

522. *Location:* 1 mile north of Grover.

Occurrence: Three 5-foot beds of horizontal material that occur below a bluff in the third hill east of the railroad. These beds alternate with material like No. 521.

Field Characteristics: Medium-hard, brown and green, very fine-grained clays.

Economic Value: Worthless.

523. *Location:* 7 or 8 miles due east of Grover.

Occurrence: Three beds, each 5-10 feet thick, of horizontal material, which occur near the base of a high vertical bluff. These beds alternate with material like No. 521.

Field Characteristics: Very hard, chocolate-brown, fine-grained clay.

Economic Value: Should make fine, pink soft-mud and pressed bricks, and, probably, stiff-mud bricks and earthenware. Might also be used as a brown slip.

Yuma County

Geology of the County.—Yuma County is entirely underlain with beds of Arikaree or Ogalalla age, except where the Arikaree and Republican Rivers have exposed narrow zones of Pierre rocks.

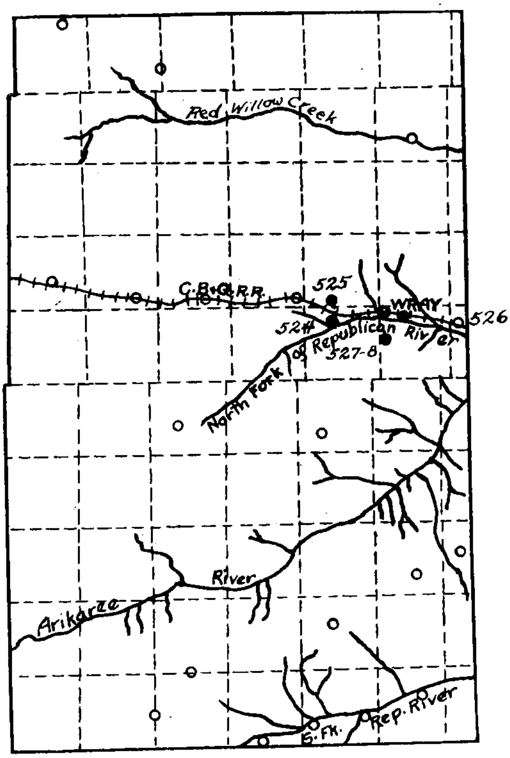
524. *Location:* Near the S.W. Cor. Sec. 9, T. 1 N., R. 44 W.; on the property of Mr. Funk; west of Wray.

Occurrence: A 10-foot bed of horizontal material, with 10 feet of overburden, that occurs in the bluff along the southern side of the river. Just below the zone of "pipey concretions" in the Arikaree formation.

Field Characteristics: Soft, very light-brownish, finely-gritty volcanic ash.

Economic Value: This material has been mined and shipped east for the manufacture of polishing-powder. It is said to yield red bricks, with much shrinkage, but the tests made show that the absorption is excessive and that the material is worthless for clay products.

YUMA COUNTY



Sketch map showing the approximate locations of the beds sampled

525. *Location:* Sec. 32, T. 2 N., R. 44 W.; west of Wray. This material is exposed for about a mile along a creek.

Occurrence: A 10-foot bed of horizontal material, with up to 10 feet of sandy overburden, which occurs where the creek cuts into its banks.

Field Characteristics: Soft, dark-gray, sandy clay.

Economic Value: Worthless unless blended with highly plastic material. Its vitrifying properties are first-class, and a blend may yield paving-bricks.

526. *Location:* On the side of Flirtation Peak nearest Wray.

Occurrence: A 15-foot exposure of horizontal material occurring on the side of a high bluff.

Field Characteristics: Medium-hard, yellow, somewhat gritty shale.

Economic Value: Should make attractive, pink pressed bricks.

527. *Location:* Brick Company's yard; south of Wray.

Occurrence: An 8-10-foot bed of horizontal material, with 4 feet of overburden, which occurs in a slight ravine on a mesa.

Field Characteristics: A medium-hard, brownish to gray, somewhat gritty clay.

Economic Value: Should make good, red soft-mud and pressed bricks, but the latter will have rather high absorption.

528. *Location:* Brick Company's yard; south of Wray.

Occurrence: An 8-foot bed of horizontal material, with 3 feet of overburden, which occurs in a slight ravine on a high mesa.

Field Characteristics: Soft, yellowish-brown, sandy clay.

Economic Value: Should make good, red soft-mud bricks and earthenware, and, probably, pressed bricks, hollow structural materials, and drain tiles; but the first will have a rather high absorption, and the last two will be fragile before burning. This clay is mixed with No. 527 and used for the manufacture of soft-mud and dry-pressed bricks.

PART IV

A Tabulation of Geological Horizons and Economic Possibilities

CHAPTER I

EXPLANATION OF THE TABLE

Geological Horizon.—The geological horizon or age of each of the samples is usually indicated on the table that follows. In some cases it was impossible to determine this with any degree of certainty in the brief period that could be allotted to such work in the field; and, then, an interrogation mark replaces an abbreviated geological period name such as is ordinarily given.

Where an abbreviated period name is followed by an interrogation mark, it should be understood that the period given is probably, but not certainly, correct. In all such cases the bed is certain to lie very close to the horizon indicated, if not of exactly the age given. In many cases little attempt to differentiate between Lower Dakota or Purgatory and Dakota beds was made in the field, or, at least, shown on the blanks; and the same is true of the Graneros and Carlile shales. It was often possible to locate such samples with certainty from other data contained on the blanks, but in other cases the horizon indicated it little more than a guess.

The following abbreviations of the names of the various geological periods have been used:

Ar = Arapahoe	F.H. = Fox Hills	Mo = Morrison
Ark = Arikaree	Fo = Fountain	Ni = Niobrara
Br = Brule	Gr = Graneros	Pi = Pierre
Ca = Carlile	La = Laramie	Pu = Purgatory
Da = Dakota	L.D. = Lower Dakota	Ra = Raton
Daw = Dawson	Ly = Lykins	Re = Recent
F.G. = Flaming Gorge	Ma = Mancos	Tr = Trinidad

Economic Possibilities.—When the tests indicate that a given sample of clay is practically sure to make a high-grade product of any kind, this is indicated by an X mark in the proper column. In such cases no grogging, washing, blending, or unusual care in handling the green ware is required; but the possibility of burning troubles is not considered, as these may usually be eliminated by proper manipulations.

A / mark means either that grogging may be needed or that the clay is not otherwise so well adapted to the purpose indicated as are those samples marked with the X mark. In many cases the deficiency is of such a nature as to lead to more or less loss through breakage of the green ware; but in other instances grogging may reduce the plasticity, or the air shrinkage may be such as to make some warping or cracking possible in full-sized pieces. There are other features that may explain the use of the / mark instead of the X, but those given should suffice to give an idea of its meaning. All clays so marked should be considered promising, however—much better than some in use for the purpose indicated; while those samples marked with an X should be classified as possessing unusual merit.

When no marks appear after the number of a sample, *it does not necessarily mean that the sample is utterly worthless,* although this is true in many such cases. There are a number of brick and tile plants making fairly satisfactory products out of clays whose numbers are followed by blanks on the table, but in such cases the products cannot be considered first-class in every respect. The bricks may be too porous—some of the pressed bricks made in the state absorb over 20 per cent of water; the tiles may warp or crack to some extent; or there may be a large loss in handling, due to the tenderness of the green ware. It is quite possible, however, that there may be no better raw material in the neighborhood, and freight rates may be such as to prohibit the use of products manufactured elsewhere. Under such conditions a poorer grade of clay may have as much value as a much better grade situated where there is more competition. Anyone can readily determine the economic possibilities of any sample for himself by referring to the data given in Part I, Chapters V and VI; and Part V.

TABLE I

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
1	Re	×																								
2	Re	×																								
3	?			×	×							×														
4	La?			×																						
5	La			/								/														
6	La	/	/	×	×	/																				
7	Da																									
8	Da																									
9	Mo			/	/																					
10	Pu																									
11	Mo			×	×																					
12	Da	×		×	×	×	/	/	/		×	×	×	×	/		/									
13	Da	/																								
14	Gr					/		/		×																
15	Ca	/		/	/	/	/	/		/	×	×					/									
16	La	/																								
17	La	/				/	/																			
18	La			×	×																					
19	La	/		/	/						/	/														
20	La	×	×	×	×						/	/														
21	La	×		×	×	×	/	/		/																
22	La	×		/	/						×		/	/												
23	La			/	/								/													
24	La										×															
25	La										×	/														
26	La	×									×	/														
27	La	/																								
28	La	×	/																							
29	La	/		/	/	/																				
30	La					/																				
31	La	×		×	×	×	/	/	/		×	×					/	/								
32	La	/				×	/	/		/		×					/		/							
33	La					×	/	/		/	×	×					/									
34	La					/					×	×														
35	La	/		×	×	×	/	/	/		×	×					/			/						
36	La	/				/	/	/		/																
37	La	/		/	/	/	/	/		/																
38	La	/		×	×	×	/	/		/								/								
39	La					/					/															
40	La	/									/															
41	La	×	/	×	×	×	×	/	/				×													
42	La	/		×	×	/	/	/					/													
43	Gr																									
44	Gr?	×	/	×	×	/					/		×	×												
45	L.D.			/	/																					
46	Mo	×	×	×	×																					
47	Pi	/	/	/	/																					
48	Ig	/	/	×	×																					
49	Pi	×	×	×	×																					
50	Pi	×	/	×	×																					
51	Da	×		/	/						×		/	/												

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
52	Gr	×	/			/	×	/		/																
53	Mo	×	×	/	/						/															
54	Pi	×	×	/	/																					
55	Pi	×	/	/	/	×																				
56	Pi	/	/																							
57	Gr	/	/			/																				
58	Ig	×	×	/	/																					
59	Ig	×		×	×																					
60	Ig	×		×	×																					
61	Mo	/	/	×	×	/																				
62	Pi	×		/	/																					
63	Gr	×	/	×	×	/	×	/	/		/	×														
64	Mo	×		/	/																					
65	Pi	×		/	/																					
66	Pi	×	×	/	/																					
67	Pi	×		/	/																					
68	Gr?	×		/	/																					
69	Mo?			×	×								×	×												
70	L.D.?	×		/	/	/							/													
71	Da?	×	/	/	/																					
72	L.D.	×																								
73	L.D.										×															
74	L.D.	×		×	×	×	/	/	/																	
75	Pi	×		×	×	/				/																
76	Pi	×		×	×	/				/																
77	Pi	×	/	×	×	/	×	/		/					/											
78	Pi	×	/	×	×	/	×	/	/																	
79	Mo																									
80	Ca	×	/	×	×	×																				
81	L.D.	×																								
82	L.D.	×	×	×	×								×													
83	Gr																									
84	Ca	×	/	×	×	/	/																			
85	?			/	/																					
86	?	/																								
87	Mo?	×	/	×	×	×	/	/	/				×													
88	Mo?	×																								
89	Mo?	×	×	×	×																					
90	Mo?	×		×	×	×	/	/	/		/															
91	Mo?	×									/															
92	Mo?	/	/	×	×	/																				
93	Mo?			/	/																					
94	Mo?	/																								
95	Mo?					/																				
96	Ly?	×										×														
97	Mo?					/																				
98	Mo?			×	×								×													
99	Pu																								×	
100	Mo	×		×	×	×	×	/	/		×	×	×	×												
101	Gr	/	/	×	×																					
102	Mo	/				/																				

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
103	Mo	X		X	X	X	/																			
104	Mo	/	/	X	X																					
105	Ly	X				X																				
106	Ni?																									
107	La																									
108	Daw	X	/	X	X						X															
109	Daw	X	/	X	X						X															
110	Daw	X		X	X						X															
111	Daw	X		X	X						X															
112	Ly																									
113	Mo			/																						
114	F.H.			/																						
115	La			/	/								/	/							/					
116	La	X	/	/	/								/	/							/					
117	F.H.?			/	/																					
118	L.D			X	X																X				X	
119	Gr	X	/	X	X	X																				
120	L.D	X	/	/	/								/	/												
121	Ca	X		/	/																					
122	Ca					/																				
123	La			X	X																					
124	Mo	X	X	X	X																					
125	Mo																									
126	L.D	/		X	X						X															
127	Ca			X	X																					
128	Pi																									
129	F.H																									
130	Pi																									
131	Pi																									
132	Ly																									
133	Mo																									
134	Mo	/	/	/	/																					
135	Da	X	/	X	X	/																				
136	Da																								X	
137	Gr	/	/																							
138	Gr																									
139	Ca	X	/	X	X																					
140	Pi	X	/																							
141	Pi	/		X	X	/																				
142	Pi	/	/	X	X	/																				
143	Pi	/	/	X	X	/																				
144	Pi	X	/	X	X	/																				
145	Pi	/	/	X	X	/																				
146	Pi	X	/	/	/																					
147	Daw			X	X						/	X													X	
148	Daw																								X	
149	Pi	/	/	X	X																					
150	F.H	/	/	X	X	/																				
151	Pi	X	/	X	X	/																				
152	Gr	X	/	X	X																					
153	Gr	X	/	X	X	/																				

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
154	Gr	×	/	×	×						/															
155	Gr	/	/	×	×	/																				
156	Da?																								×	
157	L.D.	/	/	×	×																					
158	Fo	×	/	×	×						×	×														
159	La	×		/	/	/					×	×														
160	Daw	×		×	×						×			×	×			/			×					
161	La																									
162	La																									
163	La																									
164	Daw	×	/	×	×	×	/	/	/		×		×	×				/	/		×					
165	Daw	×	/	×	×	×	/	/	/		×		×	×				/								
166	Daw	×	/	×	×	×	/				×		×	×				/	/		×					
167	La	×	/	×	×	/					/		×	×							×					
168	Daw			×	×	×	×	/										×							×	
169	Daw			×	×	×	/											×							×	
170	Daw			/	/						/			×												
171	Daw			/	/	×	/	/		×				×							×				×	
172	Daw			×	×	×	×	×					×	×				×			×	/	/	×	×	
173	Daw			×	×								×	×							×				×	
174	Cr																									
175	Da?																								×	
176	Da?																								×	
177	Mo			/	/																					
178	Gr?			×	×																					
179	Cr	×	/	/	/																					
180	Mo	×	/	×	×	×	×	×	×		/	×	/	×												
181	Da																								×	
182	Gr	×		×	×	×	/	/	/		×						/									
183	Mo	×	/	/	/	×					/															
184	Pu																								×	
185	Ca	/	/	×	×																					
186	Gr	×		×	×																					
187	Re	×		×	×	×	×	×	/	×																
188	Ca	/		×	×																					
189	Gr			×	×																					
190	Pu?																								/	
191	Gr	×		×	×						/															
192	Da	×		×	×								×	/												
193	Da	×		×	×	/							×	×												
194	Mo																									
195	Gr?																									
196	Pu																									
197	?	/		×	×																					
198	?																									
199	?																									
200	?																									
201	?			×	×								×													
202	?																									
203	?			×	×								×													
204	?			×	×								×													

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
205	?	X		X	X	X							X													
206	?																									
207	?																									
208	?																									
209	?			/	/																					
210	?																									
211	Wa?	X	/	X	X																					
212	Re.	X																								
213	Ma.	/		X	X																					
214	Ma.	X		/	/																					
215	Ma.					X	X	/		/																
216	Re.																									
217	Ma.			X	X																					
218	Ma.																									
219	Ma.			X	X																					
220	Da.			/	/																					
221	F.G.			/	/						X	X														
222	F.G.	/		X	X	/																				
223	Re.																									
224	Re.	X																								
225	Pi.	X		/	/	/																				
226	Pi.	X	/			/	/	/		/																
227	Ca.	X	/	X	X	/	/	/	/		/	X														
228	Pu?			X	X	X	/	/	/			/								X						
229	Pi.																									
230	Pi.	X	/	X	X	X	X	X	X		/		X	X												
231	Pu.	X		X	X	X	/	X	/				X													
232	Da.			X	X	X	X	/	/				X	X	/	/		X			X	X	X	X	X	
233	Gr.	X	/	/	/	X	/	/	/		X	X					/									
234	Pu.	X	/	X	X	X	/						X	X							X					
235	Pu.			X	X	X							X	X				/			X			X	X	
236	Pu.	X																								
237	Mo.	X																								
238	Pu.																								X	
239	Mo?	/																								
240	Pu.			X	X	X	/	/	/		/	X	X	X	/		/									
241	Da.																								X	
242	Mo.																									
243	Da?	X	/	X	X	X	X	/	/				X		/											
244	Pu.													X							X				X	
245	Pu.																								X	
246	Pi.	X	/	/	/	X	X	/		/					/	/	/									
247	Da?																								X	
248	Pu.																								X	
249	F.H.	/		/	/																					
250	Ca.																									
251	Gr.																									
252	Mo.	X																								
253	Ly.	X	/	X	X	X	/																			
254	Ca.	X	/	X	X	X	X	/	/				X	X	/	/	/									
255	Pi.	/	/	/	/																					

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
256	La	/	/	X	X	X					X	X	X	X												
257	La	X	/	X	X	X					/	/	X	X				/	/							
258	La	/	/	X	X	X						/	X	X												
259	La	X	/	X	X	X					/	/	X	X												
260	L.D.																								X	
261	Mo	X		X	X	X																				
262	La	X		X	X	X							X	X				/		/						
263	F.H.	/	/	/	/																					
264	F.H.	/	/								X															
265	F.H.	X	X																							
266	Ly																									
267	La	X	/	X	X									X												
268	La	X		/	/	/																				
269	La	X		/	/	/																				
270	La	X																								
271	La	/		/	/																					
272	Gr	X	/	X	X	X					/		X	X												
273	Pi?																									
274	Pi?	X	/	X	X	X																				
275	?	X		X	X	X	X	X		X																
276	Pi?	X	/	X	X	X																				
277	Pi?	/	/			/																				
278	Pi?	/	/	/	/																					
279	Pi?																									
280	Pi?																									
281	Pi?			X	X	X																				
282	Pi?	/		/	/																					
283	Pi?																									
284	Pi?	/		/	/	/																				
285	Pi?	/	/	/	/	/																				
286	Pi?	X	/	/	/																					
287	Pi?	/	/	/	/																					
288	Pi?	/	/	/	/																					
289	Pi?	X		/	/																					
290	Pi?	/	/	/	/																					
291	Pi?	X	/	/	/																					
292	Pi?																									
293	Pu?	X	/	/	/																					
294	Pi?	/	/	/	/																					
295	Pi?										/															
296	La			X	X																					
297	La	/	/	X	X																					
298	Ar	X																								
299	La	/	/	X	X	/						/														
300	Pi	X	/	X	X	X	X	X	X	/			X		/											
301	L.D.	/				/																				
302	L.D.	/				/																				
303	Pi	X	/	X	X		/																			
304	Ca	X	/	X	X	X	X	/		/	/	X														
305	L.D.	/				/																				
306	Pi	X	/	X	X	/																				

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
307	Mo	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
308	Pi	×	/	×	×	/	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
309	Pi	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
310	Pi	×	..	/	/	×	×	×	..	×	×	..	..	×	..	×	..	..	..	..	..	..	..	..	..	..
311	L.D.	×	/	×	×	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..
312	L.D.	×	..	/	/	..	..	..	..	..	/	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
313	Pi	×	/	×	×	/	/	..	..	..	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
314	Ly	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
315	Ca-Gr	×	/	×	×	..	..	..	..	..	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
316	Mo	×	/	×	×	..	..	..	..	..	..	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..
317	L.D.	×	/	×	×	/	..	..	..	..	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..
318	L.D.	..	..	×	×	..	..	..	..	..	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..
319	L.D.	×	/	/	/	..	..	..	..	..	..	..	/	..	/	..	..	..	..	..	..	..	..	..	..	..
320	Ni	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
321	Mo	×	..	×	×	..	..	..	..	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
322	Mo	×	/	×	×	..	..	..	..	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
323	Mo	..	..	/	/	..	..	..	..	..	/	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
324	Da	×	/	×	×	..	..	..	..	..	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
325	Da	×	/	×	×	/	..	..	..	..	/	..	/	×	..	..	..	..	..	..	..	..	..	..	..	..
326	Gr	×	/	×	×	/	/	..	..	..	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
327	Mo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
328	Re	..	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
329	F.H.	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
330	L.D.	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
331	Pi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
332	Pi	×	/	×	×	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
333	Pi	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
334	Gr	×	/	×	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
335	Mo	×	..	/	/	..	..	..	..	..	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..
336	Mo	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
337	F.H.	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
338	Pi	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
339	Ca-Gr	×	/	×	×	/	..	..	..	..	/	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
340	Pi	×	/	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
341	Re	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
342	Re	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
343	L.D.	×	..	×	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
344	L.D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..
345	L.D.	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
346	L.D.	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
347	Mo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
348	Pi?	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
349	L.D.	×	..	×	×	×	/	/	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
350	L.D.	×	..	×	×	×	/	/	/	..	/	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..
351	L.D.	×	..	×	×	×	/	/	/	..	×	×	×	×	..	..	/	/	..	..	..	..	..	..	..	..
352	L.D.	×	..	×	×	×	/	/	/	..	..	..	×	..	..	..	/	..	..	..	..	..	..	..	..	..
353	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
354	Pi	×	..	×	×	×	/	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
355	Pi?	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
356	Pi?	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
357	L.D.	×	..	×	×	×	/	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
358	L.D.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
359	Ca-Gr	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
360	Gr	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
361	Pi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
362	Pi	×	..	/	/	×	/	/	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
363	Pi	×	..	×	×	×	/	/	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
364	L.D.	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
365	L.D.	..	..	×	×	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..
366	L.D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..
367	L.D.	×	..	×	×	/	/	/	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
368	F.H.?	/	/	×	×	/	/	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
369	La	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
370	La	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
371	L.D.	..	/	×	×	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	..	..	..	×	..
372	L.D.	..	..	..	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×	..	..	..	×	..
373	Mo	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
374	Ca-Gr	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
375	Ra	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
376	Ra	×	..	×	×	×	/	/	/	..	/	..	×	×	..	..	/	×	..	..	..	..	..	..	..	..
377	Pi	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
378	Pi	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
379	Ca	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
380	Gr?	×	..	×	×	×	×	×	..	/	..	..	..	×	..	..	/	..	..	..	..	..	..	..	..	..
381	Gr?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
382	Pi	×	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
383	Pi	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
384	Pi	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
385	Ra	×	/	×	×	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
386	Pu?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..
387	Da?	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
388	Ra	/	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
389	Ra	/	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
390	La?	/	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
391	La?	/	..	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
392	Re	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
393	Br	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
394	F.G.	/	..	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×
395	F.G.	..	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
396	F.G.	..	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
397	F.G.	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
398	Re	×	/	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
399	Re	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
400	Ma	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
401	Ma	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
402	Re	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
403	Ma	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
404	?	..	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
405	La?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
406	Re	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
407	F.H	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
408	Re?	×	/	×	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
409	Re?	X		/	/	X																				
410	Re?																									
411	Re?	X		X	X	X																				
412	F.H.																									
413	F.H.	/	/	X	X	/																				
414	Re?	X	/	/	/	X	X																			
415	Re?	X																								
416	F.H.			X	X																					
417	F.H.	/	/	X	X																					
418	Pu																								X	
419	Ca	X	/	X	X								X	X							X					
420	Ca			X	X																					
421	Ca																									
422	Ca	X	/	/	/																					
423	Pi?																									
424	Pi?																									
425	Da	X	/	/	/	X																				
426	Da	X		X	X	X	X	X	X		X	X	X	X	/	X	X	/		/						
427	Ca																									
428	Ca																									
429	Pu																								X	
430	Pu			X	X								X	X												
431	Gr										/															
432	Da?																								X	
433	Da?																								X	
434	Gr	X		X	X	/																				
435	Ca	X		X	X						/															
436	Da			/	/									X							X					
437	Da			X	X	/								X							X					
438	Da	/	/	X	X	X							X	X							X	/	/	X		
439	Mo?																									
440	Mo																									
441	Ca										/	/														
442	Ca	X	/	X	X	/	/																			
443	Gr	/																								
444	Re																									
445	Gr																									
446	Gr																									
447	Ca																									
448	Ca																									
449	Da		/	X	X	X	X	/		/																
450	Pu																								X	
451	Da	X	/	X	X	X	/						X													
452	Mo?	X	/	X	X	X							X													
453	Gr	/	/	X	X								X													
454	Ca	X		X	X	X																				
455	Gr										/															
456	Ca	X		X	X						/	X		X												
457	Da?			X	X								X	X							X	/	/	X	X	
458	Da																								X	
459	Ca										/															

TABLE I—Continued

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra-Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
460	Gr.	×		×	×	/							×													
461	Ca.																									
462	Gr.																									
463	Pi.	×	/			×					/															
464	Pi.	×				×					/	/														
465	Pi.	×		×	×	×																				
466	Pi.			×	×																					
467	Pi.																									
468	Pi.																									
469	Re.	×		×	×	×							×													
470	Pi.			×	×																					
471	Ca.			×	×								×													
472	Ca.																									
473	Da.			×	×																×				×	
474	Ca.																									
475	Ca.			×	×								×													
476	Pi.																									
477	F.H.																									
478	Da.																									
479	Ma?																									
480	Ma.			/	/																					
481	Ma.																									
482	Ma.																									
483	Re.																									
484	Ma.																									
485	Re?																									
486	Br.			/	/						/															
487	Re.	×																								
488	Re.	×	/																							
489	Br?																									
490	Br?																									
491	Br?																									
492	Br?																									
493	La.										/	×														
494	La.					/					×	×						/								
495	La.	×									×	/														
496	La.	×		×	×	×	/	/	/	/			×													
497	La.																									
498	La.			/																						
499	La.			×	×								×													
500	La.			×	×								×													
501	La.	/	/	×	×	/					/	/	×													
502	La.																									
503	La.																									
504	Pi.	×	/	×	×	×		/	/	/																
505	F.H.	×																								
506	La.	×	/			×																				
507	La.			×	×																					
508	La.	×	/	×	×																					
509	La.	/									/	×														
510	La.	×		×	×	×					×	/		×												

TABLE I—Concluded

Sample Number	Geological Horizon	Soft-Mud Bricks	Stiff-Mud Bricks	Dry-Pressed Bricks	Semi-Dry Pressed Bricks	Earthenware	Terra Cotta	Hollow Blocks, etc.	Conduits	Drain Tile	Vitrified Bricks	Fresco and Flashed Bricks	Unvitrified Floor Tile	Vitrified Floor Tile	Unvitrified Roofing-Tile	Vitrified Roofing-Tile	Sewer Pipe	Stoneware	Yellow-Ware	Rockingham Ware	Wall Tile	White-Ware	Porcelain	Ball-Clay	Refractory Ware (Fire-Clay)	Slip-Clay
511	Re	×	/	..	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
512	Re	×	/	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
513	F.H.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
514	F.H.	/	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
515	F.H.	..	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
516	Re	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
517	Re	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
518	Re	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
519	Re	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
520	F.H.?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
521	Br	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
522	Br	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
523	Br	×	/	×	×	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	/
524	Ark	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
525	Re	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
526	Ark?	..	..	×	×	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
527	Re	×	..	/	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
528	Re	×	..	/	/	×	..	/	..	/	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

PART V

Tabulations of the Results of the Laboratory Tests

CHAPTER I

EXPLANATION OF THE TABLES

Table II.—The terms used on this table are all defined in Chapter II of Part I, and the manner of making the tests is described in Chapter IV of the same part. A dotted line, only, under the column headed "Visible Impurities" means that no such substances are present; while the same symbol under the "Slakes" column indicates that the sample was earthy and the sack contained no pieces of sufficient size to test for slaking. The same symbol is also used under the columns headed "% of Fire Shrinkage," "% of Absorption," and "Color," when the sample did not vitrify appreciably before fusion.

The statements concerning burning troubles are based only on the difficulties encountered in burning the small test-pieces. It is likely that slower heating would, in many cases, give satisfactory results, even when possible or probable burning troubles are indicated. On the other hand, some gypsiferous clays that gave no trouble in the laboratory are apt to be bothersome when larger pieces are burned, and no consideration was given to the probability of waste, due to the fact that the temperatures of incipient vitrification and vitrification were separated by but a few cones.

Interrogation marks indicate either that, for various reasons, the tests were not made, or that the data were mislaid or accidentally destroyed.

The following abbreviations are used:

Alk	=Alkali	Hr	=Hour
Cal	=Calcite or calcareous material	Hrs	=Hours
Carbon	=Carbonaceous material	Lim	=Limonite
Cons	=Considerably	M	=Minute or minutes
Fos	=Fossils, usually calcareous	Sid	=Siderite
Gyp	=Gypsum	Sl	=Slightly

Table III.—A dotted line indicates that none of the substance indicated was detected, or that no test for it was made. "Tr." means either that a very small amount of the substance indicated is present, or that it was determined qualitatively but not quantitatively. The rational analyses were computed according to the method described on page 18.

TABLE II

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
1	Adams	Sand	Poor	Weak	24.3	No	
2	Adams	Alk. Sand	Fine	Strong	39.1	No	
3	Adams		Very fine	Strong	41.6	No	
4	Adams	Sand	Fine	Strong	50.7	No	
5	Adams		Fine	Strong	10.4	No	
6	Adams		Fine	Strong	39.0	No	
7	Bent	Sand Limonite	Good	Strong	26.3	No	Not in 20 hrs.
8	Bent	Sand Limonite	Fair	Weak	23.2	No	Not in 20 hrs.
9	Bent	Calcite Limonite	Fine	Strong	27.4	No	Not in 20 hrs.
10	Bent		Fair	Weak	23.4	No	35 M.
11	Bent	Gyp. Cal. Limonite	Good	Strong	31.8	No	
12	Bent	Limonite	Fine	Strong	25.5	No	Not in 12 hrs.
13	Bent	Sand Limonite	Good	Weak	22.7	No	
14	Bent	Sand Gyp. Lim.	Good	Strong	23.8	No	
15	Bent	Limonite	Good	Strong	36.6	No	12 M.
16	Boulder		Good	Strong	34.9	No	Not in 12 hrs.
17	Boulder		Fine	Strong	39.7	Sl.	
18	Boulder		Fine	Strong	42.4	Badly	20 M.
19	Boulder	Coal	Good	Strong	28.7	No	25 M.
20	Boulder	Coal Fossil Plants	Fair	Strong	31.7	No	15 M.
21	Boulder	Sand Streaks	Fine	Strong	26.6	Sl.	3 hr.
22	Boulder		Poor	Weak	29.5	No	45 M.
23	Boulder		Fair	Weak	30.5	No	Not in 12 hrs.
24	Boulder		Fair	Weak	33.7	No	Not in 12 hrs.
25	Boulder		Fair	Weak	32.9	No	45 M.
26	Boulder	Sand	Fair	Weak	30.1	No	45 M.
27	Boulder		Fair	Weak	35.7	No	Not in 12 hrs.
28	Boulder		Good	Strong	28.1	No	40 M.
29	Boulder		Fine	Strong	30.5	No	1 hr.
30	Boulder		Fine	Strong	39.0	No.	15 M.
31	Boulder	Coaly	Fine	Strong	24.6	No	5 M.
32	Boulder		Fine	Strong	41.2	No	45 M.
33	Boulder		Fine	Strong	43.0	No	10 M.
34	Boulder		Good	Strong	43.8	No	10 M.
35	Boulder		Fine	Strong	40.5	No	10 M.
36	Boulder		Good	Strong	28.4	No	25 M.
37	Boulder		Good	Strong	37.8	No	45 M.
38	Boulder		Fine	Strong	30.9	Sl.	20 M.
39	Boulder	Sand	Fine	Strong	36.1		40 M.
40	Boulder		Good	Strong	41.7	No	15 M.
41	Boulder	Coaly Fossils	Good	Strong	37.4	No	15 M.
42	Boulder		Fine	Strong	39.7	Badly	15 M.
43	Boulder	Calcite	Good	Weak	20.0	No	No.
44	Boulder	Limonite	Good	Strong	28.2	No	7 M.
45	Boulder	Sand	Fair	Weak	20.5	Sl.	No.

TABLE II

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
4	118	3	Brick	2	4.1	5	Brown	2	2	8	No	No
7	74	03	Brick	0	17.7	3	Brown	3	7	5	No	No
11	60	03	Brick	0	13.4	3	Brown	1	12	8	Probable	No
16	37	03	Pink	1	18.5	3	Brick	2	2	8	No	Yes
13	136	05	Buff	2	20.2	03	Gray	6	15.2	3	Probable	No
11	126	05	Brick	4	9.5	3	Brown	5	2.8	5	Possible	No
5	24	03	Brick	0	13.2	3	Brown	2	4.7	8	Possible	No
5	28	01	Brick	0	14.0	8	Brown	4	7	16	No	No
7	43	07	White	1	24.0	4	Brown	13	0	5	No	No
1	63	3	Gray	1	18.5	10	Gray	5	12.2	16	No	No
11	87	010	Reddish Brown	0	12.4	5	Gray	4	1.5	8	No	No
7	251	05	Brick	1	11.4	1	Brick	1	8.5	8	No	Yes
5	137	010	Brick	1	21.1	5	Brick	1	12.0	10	No	No
5	133	05	White	0	32.0	12	...	...	...	12	No	No
10	188	010	Brick	5	20.6	03	Brick	6	12.5	8	Possible	Yes
10	132	010	Yellow	0	20.6	3	Brown	0	10	8	No	No
5	93	03	Light Pink	0	19.0	3	Pink	3	6	8	No	No
3	55	1	Pink	4	2.0	5	Brown	6	4	10	No	No
11	176	01	Flesh	1	17.3	5	Brown	1	5	12	No	Yes
9	141	3	Flesh	6	5.0	5	White	5	6	12	No	No
7	197	03	Light Brown	0	16.4	3	Brown	0	8	12	Possible	No
3	136	1	Pink	2	3.9	8	White	8	10.4	16	No	Yes
12	78	010	Yellow	2	19.6	3	Brown	3	17	8	Possible	No
10	68	010	Pink	2	13.3	1	Brown	3	15.5	8	No	No
8	86	010	Pink	1	22.0	1	Brick	5	13.8	14	No	No
8	75	010	Pink	2	15.0	1	Brown	4	10.9	8	No	No
9	95	05	Pink	2	24.4	5	Brown	5	9	8	Possible	No
9	136	01	White	1	18.3	5	White	6	0	12	Possible	Yes
11	165	1	Flesh	1	13.9	8	Gray	3	3.5	12	Probable	No
12	142	010	Buff	0	15.0	3	Brown	0	5	12	No	Yes
9	172	010	Pink	0	15.2	5	Gray	2	2.6	12	No	No
11	207	010	Buff	0	23.6	1	Brown	6	11.8	8	No	No
11	193	010	White	2	24.8	3	Gray	6	18.4	10	No	No
11	147	010	Pink	4	36.0	1	Light Brown	4	21.2	10	No	No
10	156	010	Yellow	0	10.7	3	Gray	5	4.5	10	No	No
11	190	010	Brick	0	24.2	1	Brown	2	12.0	5	No	No
11	170	010	Brick	0	25.7	1	Brick	3	8.0	5	No	No
8	154	01	Buff	1	21.2	5	Buff	5	10.0	12	Possible	No
11	104	01	Brown	1	15.1	3	Brown	2	10.0	10	No	Yes
8	91	010	Pink	5	22.2	5	Gray	10	6.7	12	No	No
5	131	3	Brick	3	4.9	8	Gray	7	6.5	12	No	No
4	200	3	Brick	1	11.9	8	Brown	5	5.0	10	No	No
5	87	07	Light Brown	0	21.0	03	Light Brown	0	18.0	3	No	Yes
9	146	05	Pink	2	10.2	3	Gray	3	.5	16	No	No
4	19	03	Brick	1	11.8	5	Gray	1	9.0	16	No	Yes

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
46	Boulder	Limonite	Fair	Strong	26.8	No	1 hr., 20 M.
47	Boulder	Limonite	Fair	Strong	29.4	Sl.	
48	Boulder	Mica Quartz	Fair	Strong	29.4	Sl.	
49	Boulder	Limonite	Fair	Strong	23.9	No	15 M.
50	Boulder	Fos. Gyp. Lim. Cal.	Good	Strong	27.1	No	5 M.
51	Boulder		Fair	Weak	21.4	No	No
52	Boulder	Limonite	Good	Strong	25.9	No	Not in 24 hrs.
53	Boulder	Calcite	Fair	Weak	29.4	No	4 hrs.
54	Boulder	Calcite	Fair	Strong	24.2	No	35 M.
55	Boulder	Sand	Good	Strong	24.4	No	1 M.
56	Boulder	Rock	Fair	Strong	20.1	No	1 M.
57	Boulder	Limonite	Good	Strong	30.5	No	1 M.
58	Boulder	Limonite	Fair	Strong	25.7	No	No
59	Boulder		Fine	Strong	26.5	No	No
60	Boulder		Fine	Strong	26.3	No	No
61	Boulder	Sand Calcite	Good	Strong	22.4	No	1 hr.
62	Boulder	Limonite	Poor	Weak	21.2	No	1 hr.
63	Boulder	Limonite	Good	Strong	27.1	No	5 M.
64	Boulder	Calcite Sand	Poor	Weak	17.8	No	No
65	Boulder		Fair	Weak	23.5	No	No
66	Boulder	Limonite	Fair	Strong	23.1	No	20 M.
67	Boulder	Alk. Cal.	Fair	Weak	24.4	No	40 M.
68	Boulder	Lim. Gyp.	Poor	Weak	26.9	No	5 M.
69	Boulder		Fair	Strong	36.6	No	3 M.
70	Boulder	Sand	Good	Weak	23.0	No	No
71	Boulder	Sand	Good	Weak	23.4	No	
72	Boulder	Sand Streak	Fair	Weak	25.2	No	
73	Boulder	Sand	Poor	Weak	18.7	No	
74	Larimer		Fine	Strong	29.7	No	5 M.
75	Boulder	Limonite	Good	Strong	25.7	No	17 M.
76	Boulder	Limonite	Good	Strong	19.2	No	17 M.
77	Boulder	Sand	Good	Strong	23.1	No	17 M.
78	Boulder	Sand Streaks	Good	Strong	27.5	No	15 M.
79	Boulder		Fair	Weak	22.2	No	Not in 8 hrs.
80	Boulder	Alk. Lim.	Good	Strong	21.2	No	15 M.
81	Boulder	Sand	Good	Weak	16.9	No	55 M.
82	Boulder	Sand	Fair	Strong	19.7	No	1 hr.
83	Boulder	Pyrite	Good	Strong	20.2	No	10 hrs.
84	Boulder	Limonite	Good	Strong	17.4	No	After 10 hrs.
85	Costilla		Fair	Very strong	45.6	Sl.	2 M.
86	Custer		Good	Strong	36.5	No	Not in 24 hrs.
87	Custer	Roots	Fine	Strong	32.38	No	3 M.
88	Custer	Roots	Poor	Weak	25.0	No	12 M.
89	Custer		Fair	Strong	24.97	No	50 M.
90	Custer	Roots	Fine	Strong	28.26	No	

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
5	120	05	Pink	5	14.7	3	Brown	6	3.4	7	Possible	Yes
8	117	05	Buff	4	10.8	03	Gray	7	3.0	3	No	Yes
8	117	05	Buff	4	17.9	01	Brown	8	7.0	3	Possible	Yes
5	123	07	Pink	1	14.0	01	Dark Gray	4	8.0	3	No	Yes
9	132	010	Pink	1	15.0	03	Brick	8	1.5	1	No	Yes
2	84.5	5	White	0	1.3	8	Grayish White	2	1.0	20	No	No
5	96	03	Brick	5	17.4	3	Brown	7	5.0	8	Probable	No
7	110	05	Flesh	0	22.4	1	Brick	4	11.0	8	No	No
5	103	01	Pink	1	12.0	3	Brown	8	1.1	8	No	No
7	135	05	Buff	1	15.3	3	Brown	2	4.3	5	No	Yes
5	86	05	Pink	1	18.0	01	Buff	2	16.0	3	No	Yes
7	152	05	Pink	1	15.5	3	Brown	4	5.0	12	No	Yes
2	58	05	White	0	20.9	5	White	3	7.0	10	Possible	Yes
0	58	05	White	0	16.1	5	White	5	5.0	10	Probable	No
1	51	01	White	1	15.6	5	White	5	5.0	10	No	No
2	47	1	Buff	0	5.8	3	Brown	0	4	8	No	No
3	91	05	Brick	0	6.7	3	Brick	6	4	5	Possible	No
5	135	05	Pink	0	12.2	3	Brown	9	6	8	Possible	No
2	51	03	Flesh	0	11.6	1	White	0	6	8	Possible	No
3	80	05	Brick	0	16.1	5	Brown	6	5	8	Possible	No
3	75	05	Brick	2	13.3	03	Brown	2	10.3	3	Possible	Yes
8	89.5	05	Brick	1	15.3	01	Brown	5	12	3	No	No
4	85	03	Brick	4	7.4	5	Brown	6	4	8	Probable	No
3	12	03	Brick	6	5.5	5	Brick	6	4	10	No	No
6	86	1	Pink	0	9.2	8	YellowishBr'wn	0	3.6	12	No	No
5	56	03	Flesh	0	10.8	5	Brick	2	6	8	Probable	No
6	91	1	Brick	0	3.9	5	Brown	3	1.2	8	No	No
3	39	1	Yellow	0	13.2	8	Gray	0	4.7	18	No	No
6	81	03	Pink	4	11.6	3	Brown	6	5	8	No	No
9	121	010	Light Brick	1	10.0	03	Brown	6	4.3	3	No	No
9	132	07	Light Brick	1	14.7	03	Brown	9	5	3	No	Yes
5	102	010	Pink	1	14.1	01	Brown	6	4.6	3	No	No
6	108	05	Brick	0	19.2	01	Brown	3	7.2	3	No	No
3	50	010	Light Buff	0	15.6	03	Buff	9.2	1	3	No	No
4	76	010	Brick	2	13.9	03	Brown	7	7.9	5	No	No
3	63	010	Brick	1	16.6	03	Brown	1	11.1	5	No	No
3	44	03	White	0	7	?	?	?	?	?	?	No
3	41.5	05	Buff	5	9.8	03	Brown	5	8	5	No	No
4	73	010	Light Brick	0	16.8	3	Brick	2	13.7	5	No	No
14	56	03	Brick	6	14.3	01	Gray	6	5.8	5	No	No
2	42.5	08	Light Buff	7	18	05	Gray	14	4.1	3	No	No
8	144	05	Pink	1	10.6	5	Brick	8	.9	8	No	No
6	61	010	Brick	0	16	3	Brown	3	11.5	8	No	No
6	102	010	Buff	0	14.9	8	Gray	3	4.35	12	No	No
9	202	010	Buff	0	11.4	3	Brown	2	10.9	8	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
91	Custer	Roots	Fair	Weak	30.57	No	1 hr 45M.
92	Custer	Roots	Good	Strong	37.5	No	50 M.
93	Custer	Lim. Cal. Roots	Good	Strong	48.2	Badly	3 M.
94	Custer	Lim.	Fair	Weak	36.3	No	12 M.
95	Custer	Calcite	Fine	Strong	36.0	No	3 M.
96	Custer	Lim. Roots	Fair	Weak	30.5	No	3 M.
97	Custer	Limonite	Fine	Strong	28.8	No	12 M.
98	Custer		Fine	Strong	47.9	Cons.	3 M.
99	Custer		Poor	Weak	22.8	No	Not in 12 hrs.
100	Douglas		Fine	Strong	21.6	No	7 M.
101	Douglas	Siderite	Good	Strong	31.4	No	2 M.
102	Douglas		Good	Strong	38.0	No	35 M.
103	Douglas	Limonite	Fine	Strong	31.4	No	35 M.
104	Douglas	Gyp. Lim.	Good	Strong	54.6	Badly	3 M.
105	Douglas		Fine	Strong	25.8	No	2 M.
106	Douglas		Good	Strong	38.9	Badly	
107	Douglas	Limonite	Fine	Strong	28.1	No	Not in 1 day
108	Douglas	Limonite	Good	Strong	35.5	No	7 M.
109	Douglas		Good	Strong	33.5	No	7 M.
110	Douglas	Limonite	Fine	Weak	33.3	No	7 M.
111	Douglas	Limonite	Fine	Strong	31.4	No	7 M.
112	Douglas	Calcite	Poor	Weak	23.0	No	Not in 1 day
113	Douglas		Good	Strong	42.6	Cons.	Not in 1 day
114	Douglas	Gypsum	Good	Strong	35.7	Cons.	1 M.
115	Douglas		Fair	Weak	32.2	No	20 M.
116	Douglas	Gypsum	Fair	Weak	30.0	No	20 M.
117	Douglas	Limonite	Good	Strong	32.5	Sl.	1 M.
118	Douglas	Limonite	Good	Weak	20.1	No	4 M.
119	Douglas	Limonite	Good	Strong	31.0	No	2 M.
120	Douglas	Limonite	Fair	Weak	24.9	No	4 M.
121	Douglas	Limonite	Fair	Weak	24.6	No	1 hr.
122	Douglas	Gypsum	Good	Strong	29.5	No	Not in 8 hrs.
123	Douglas		Good	Strong	29.5	No	2 M.
124	El Paso	Wash. Gyp.	Fair	Strong	26.0	No	
125	El Paso	Limonite	Good	Weak	24.6	Cons.	
126	El Paso		Fine	Strong	21.0	No	
127	El Paso	Limonite	Good	Strong	26.3	No	20 M.
128	El Paso	Siderite Limonite	Good	Weak	23.2	No	20 M.
129	El Paso	Fossils Limonite	Good	Strong	24.4	No	20 M.
130	El Paso	Fossils	Poor	Weak	28.5	No	Not in 8 hrs.
131	El Paso	Fossils	Fair	Weak	24.7	No	Not in 8 hrs.
132	El Paso		Fair	Weak	23.1	No	6 hrs.
133	El Paso		Good	Weak	25.5	No	
134	El Paso		Good	Strong	30.3	No	
135	El Paso		Good	Strong	23.8	No	20 M.

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
5	158.5	010	Buff............	1	17.3	3	Brown........	4	6.7	10	No	No
11	218	010	Buff............	1	13.2	3	Brown........	5	7.9	8	No	No
17	43.5	010	Buff............	3	9.3	03	Brick.........	4	5.7	8	Possible	No
9	110.5	05	Buff............	0	17.2	3	Buff..........	1	15.4	8	No	No
9	169	05	Gray...........	4	22.9	3	Gray.........	4	21.1	8	No	No
9	152.5	010	Brick...........	1	13.4	3	Brick.........	?	?	8	Possible	No
10	97	03	Buff............	2	64.2	3	Gray.........	3	20.8	8	No	No
15	29	010	Buff............	1	7.8	5	Light Gray...	6	6.4	8	No	No
1	51.5	8	White..........	2	20.5	26	Gray.........	6	8	30+	No	No
6	97	010	Pink...........	1	11.8	3	Brown........	3	7.1	20	No	No
11	139	05	Brick...........	1	9.1	03	Dark Gray ...	2	5.1	3	No	No
5	96	05	Buff............	1	15.5	03	Gray.........	1	13.0	5	Probable	No
?	93	010	Flesh...........	0	13.8	10	Brown........	5	14.6	16	No	No
15	90	03	Pink...........	0	13.0	01	Brown........	0	0	3	Possible	No
9	100	03	Pink...........	2	17.2	2	Brown........	4	5.0	3	No	No
14	76	07	Light Buff......	0	18.5	01	Light Buff....	0	5.8	3	No	No
6	56	3	Brown..........	1	9.5	5	Gray.........	1	9.3	20	Possible	No
7	70	01	Brick...........	6	4.8	3	Dark Gray ...	7	1.6	24	Probable	No
6	53	01	Brick...........	6	4.5	5	Dark Gray ...	8	2.1	22	No	Yes
6	51	01	Brick...........	6	4.2	5	Dark Gray ...	7	0.8	16	No	No
6	43	010	Brick...........	5	3.7	5	Black........	7	4.6	18	No	No
1	58	01	Light Buff......	5	15.4	3	Gray.........	10	5.7	5	No	No
13	18	010	Brown..........	2	14.2	03	....	....	......	03	No	No
12	22	010	Brick...........	0	9.9	05	....	....	......	05	No	No
6	30	05	Yellow.........	5	13.8	5	Gray.........	7	6.1	16	No	Yes
6	93	010	White..........	1	14.9	5	Light Gray ...	6	3.9	16+	No	No
9	41	010	Brick...........	1	15.0	05	Black........	3	7.1	03	No	No
4	61.5	3	White..........	2	15.2	20	White........	5	3	30+	No	No
8	102	05	Flesh...........	3	13.2	01	Yellowish White	4	11.1	5	No	No
5	65	03	White..........	3	17.9	10	Brownish White	0	12.2	20	No	Yes
7	89	010	Light Pink......	1	15.5	5	Gray.........	4	2.6	10	No	No
9	102	010	Pink...........	1	22.8	1	White........	2	21.6	3	No	Yes
11	46	07	Buff............	1	10.0	01	Brown........	3	5.8	5	No	Yes
9	81	010	Buff............	1	11.9	2	Brown........	3	5.0	3	No	No
4	47	010	Brick...........	0	12.6	3	....	....	......	3	No	No
5	42	05	Pink...........	0	12.4	5	Gray.........	3	4.3	20	No	No
5	28	010	Dark Brick......	0	14.9	01	Brick.........	1	8.7	1	No	No
1	24	3	White..........	3	20.6	5	....	....	......	5	No	No
2	25	10	White..........	1	20.0	10	White........	1	20.0	12	No	No
7	34	01	White..........	0	32.9	8	Brown........	21	2.8	10	No	No
3	56	03	White	3	30.0	3	Brown........	4	13.5	5	No	No
1	22	3	Grayish Brick ..	6	2.6	3	Gray.........	6	2.6	5	No	No
1	36	3	Gray...........	0	7.1	3	Gray.........	0	7.1	5	No	No
7	55	03	Brown..........	5	22.5	5	Yellow.......	6	7.0	8	No	No
7	79	03	Yellowish White	1	11.2	1	Yellowish White	2	11.1	5	No	Yes

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
136	El Paso	Limonite	Fine	Strong	25.4	No	
137	El Paso	Limonite	Good	Strong	36.1	No	20 M.
138	El Paso	Gyp. Cal. Lim.	Fine	Strong	37.1	No	20 M.
139	El Paso	Siderite Limonite	Good	Strong	30.0	No	20 M.
140	El Paso	Siderite Gypsum	Good	Strong	27.9	No	20 M.
141	El Paso	Gypsum	Fine	Strong	35.6	No	
142	El Paso	Gypsum	Fine	Strong	35.1	No	10 M.
143	El Paso	Gypsum	Fine	Strong	33.7	No	1 M.
144	El Paso	Siderite Gyp. Lim.	Good	Strong	34.1	No	3 M.
145	El Paso	Siderite Gyp. Lim.	Good	Strong	34.9	No	10 M.
146	El Paso	Limonite	Good	Strong	30.2	No	10 M.
147	El Paso		Good	Strong	33.9	No	
148	El Paso		Fair	Weak	18.5	No	
149	El Paso	Fossils Lim. Gyp.	Fair	Strong	35.3	No	3 M.
150	El Paso	Siderite	Good	Strong	35.0	No	10 M.
151	El Paso	Siderite Gypsum	Good	Strong	37.0	No	10 M.
152	El Paso	Calcite Limonite	Good	Strong	39.8	No	3 M.
153	El Paso	Limonite	Good	Strong	35.4	No	3 M.
154	El Paso	Gypsum Limonite	Good	Strong	32.9	No	10 M.
155	El Paso	Selenite Limonite	Good	Strong	39.4	No	3 M.
156	El Paso	Gypsum	Good	Strong	28.3	No	3 M.
157	El Paso	Limonite	Good	Strong	31.8	No	
158	El Paso		Good	Strong	28.4	No	25 M.
159	El Paso	Sand Limonite	Fine	Weak	26.6	No	35 M.
160	El Paso	Quartz Pebbles	Fine	Strong	28.1	No	10 M.
161	El Paso	Gyp. Lim.	Good	Strong	57.9	Cons.	1 M.
162	El Paso	Lim. Cal.	Fair	Weak	43.0	Cons.	1 M.
163	El Paso	Limonite	Fair	Weak	24.3	Cons.	1 M.
164	El Paso		Fair	Strong	28.8	No	20 M.
165	El Paso		Fine	Strong	22.9	No	20 M.
166	El Paso	Quartz Pebbles	Good	Strong	27.5	No	10 M.
167	El Paso	Gyp. Lim.	Good	Strong	34.0	No	20 M.
168	El Paso	Limonite	Fine	Strong	34.1	No	10 M.
169	El Paso	Limonite	Fine	Strong	41.2	No	25 M.
170	El Paso	Limonite	Fine	Strong	36.6	No	3 M.
171	El Paso	Limonite	Fine	Strong	38.2	No	3 M.
172	El Paso	Limonite	Fine	Strong	23.6	No	3 M.
173	El Paso	Limonite	Fine	Strong	37.8	No	3 M.
174	Fremont	Lim. Gyp.	Fair	Weak	24.0	No	3.5 hrs.
175	Fremont		Fair	Weak	16.5	No	13 M.
176	Fremont		Fair	Weak	21.2	No	13 M.
177	Fremont	Gypsum	Poor	Weak	20.6	No	Not in 16 hrs.
178	Fremont	Bitumen Lim. Gyp.	Good	Strong	39.8	Sl.	
179	Fremont	Lim. Gyp.	Good	Strong	25.2	No	35 M.
180	Fremont	Limonite	Good	Strong	25.3	No	50 M.

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
9	59	05	White	2	15.1	10	White	8	2.0	30+	No	No
9	72	05	Pink	4	15.1	3	Gray	5	5.0	5	No	No
9	61	07	Yellowish White	4	32.8	3	Gray	6	3.4	8	No	No
7	61	05	Brick	1	9.2	01	Dark Brown	3	5.8	3	No	No
3	59	010	Pink	0	17.0	3	Brown	5	3.4	5	No	No
11	120	010	Brick	1	13.0	1	Gray	3	11.2	5	Probable	No
10	142	05	Brick	2	8.7	03	...	...	...	03	Probable	No
10	122	010	Brick	1	8.6	05	Brick	2	5.7	03	No	No
8	128	010	Brick	0	8.5	01	Brown	2	5.0	01	Probable	No
12	90	010	Brick	1	9.3	03	Brown	2	5.6	01	No	Yes
8	72	010	Brick	0	16.0	03	Gray	?	?	1	No	No
4	40	01	Buff	7	13.0	10	Buff	12	2.4	30+	No	Yes
1	13	3	White	0	16.8	18	White	3	10	30+	No	Yes
10	124	05	Brick	2	9.5	01	Brown	3	5.0	01	Probable	Yes
11	94	05	Brick	2	11.7	01	Brown	3	6.0	01	Probable	No
9	85	010	Brick	1	7.3	01	Brown	3	4	01	Probable	No
9	68	05	Pink	2	13.5	3	Gray	3	4.1	5	Possible	Yes
9	86	05	Flesh	3	12.3	3	Light Gray	4	6.3	12	Possible	No
8	64	03	Yellowish White	2	13.2	5	Light Gray	3	8.8	18	No	No
12	107	01	Brick	2	9.0	3	Gray	4	6	8	Possible	Yes
7	50	03	White	1	19.4	10	Light Brown	3	12	30+	No	No
6	59	01	White	2	4.8	5	Light Brown	3	4.5	8	No	No
5	66	05	Flesh	1	12.8	01	Black	7	1.2	16	No	Yes
5	70	05	White	1	13.8	8	Gray	5	2	20	No	No
7	58	05	Yellowish White	0	13.3	5	Light Gray	3	2.5	22	No	No
17	15	06	Buff	0	14.9	05	Black	2	6.6	03	No	No
11	7	03	...	...	...	03	...	...	...	03	No	No
11	18	01	...	...	...	01	...	...	...	01	No	No
6	97	05	White	1	13.3	3	Light Brown	5	2.7	20	No	No
6	95	03	Pink	4	9.2	5	Gray	6	1.2	12	No	Yes
7	86	05	White	1	12.6	5	Gray	4	5.5	22	No	No
8	93	05	White	1	12.4	5	White	5	2.8	14	No	No
5	103	3	Flesh	4	14.8	8	Light Brown	5	12	30+	No	No
7	116.5	03	Light Brick	2	21.8	?	Light Brown	?	?	30+	No	Yes
4	56	03	Brick	2	21.2	8	Brown	4	7.1	22	No	No
5	91	3	Light Buff	6	13.6	8	Brown	?	?	30+	No	Yes
6	121	03	White	2	19.4	12	Gray	?	?	30+	No	No
6	62.5	03	Light Buff	3	11.4	8	Gray	8	5	30+	No	Yes
3	27	3	White	0	35.2	5	...	...	...	5	No	No
2	62.5	01	White	1	16.1	12	White	5	9.6	30+	No	Yes
1	27	3	White	1	20.2	20	White	4	11	30+	No	No
2	58	05	Buff	1	18.9	5	Gray	7	2.2	10	No	No
10	29	010	Pink	2	20.0	3	Brown	8	7	5	No	No
5	41	05	Brick	0	16.5	3	Brown	6	2.3	5	Possible	No
6	114	010	Pink	1	16.7	03	Light Gray	4	3.7	5	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
181	Fremont.......	....	Fair........	Weak......	21.6	No	Not in 16 hrs.
182	Fremont.......	Siderite Lim. Gyp........	Fine........	Strong	27.8	No	16 hrs.........
183	Fremont.......	Lim. Cal...............	Good......	Strong	29.9	No	40 M.........
184	Fremont.......	....	Good.......	Strong	23.9	No	50 M.........
185	Fremont.......	Lim. Gyp...............	Good.......	Strong	34.4	Cons.	13 M.........
186	Fremont.......	Lim. Gyp...............	Fine........	Strong	25.4	No	40 M.........
187	Fremont.......	....	Fine........	Strong	26.0	No	1 M.........
188	Fremont.......	Siderite Gypsum.........	Fine........	Strong	28.5	No	35 M.........
189	Fremont.......	Siderite Gyp. Lim........	Good.......	Strong	24.5	No	....
190	Fremont.......	Limonite...............	Fair........	Weak......	19.8	Badly	Not in 16 hrs..
191	Fremont.......	Gyp. Lim...............	Fine........	Strong	31.6	No	35 M.........
192	Fremont.......	Limonite...............	Fine........	Strong	21.3	No	6 hrs..........
193	Fremont.......	Limonite...............	Good.......	Strong	26.3	No	35 M.........
194	Fremont.......	Calcite................	Fair........	Weak......	25.9	No	Not in 1 day..
195	Fremont.......	Cal. Sid. Lim. Gyp.......	Fair........	Weak......	27.6	No	Not in 20 hrs..
196	Fremont.......	Limonite...............	Good.......	Strong	21.2	No	Not in 24 hrs..
197	Garfield.......	....	Fine........	Strong	32.3	No	2 M.........
198	Garfield.......	Lim. Cal...............	Fine........	Strong	20.6	No	7 M.........
199	Garfield.......	Lim. Cal...............	Fine........	Strong	23.9	No	12 M.........
200	Garfield.......	Lim' Cal...............	Fine........	Strong	22.9	No	....
201	Garfield.......	Lim. Cal...............	Fine........	Strong	33.1	No	10 M.........
202	Garfield.......	Lim Cal...............	Fine........	Strong	14.7	No	50 M.........
203	Garfield.......	Limonite...............	Fine........	Strong	31.3	No	15 M.........
204	Garfield.......	....	Fine........	Strong	24.2	No	15 M.........
205	Garfield.......	....	Fine........	Strong	22.3	No	5 M.........
206	Garfield.......	Cal. Gyp...............	Good.......	Weak......	19.5	No	55 M.........
207	Garfield.......	Cal. Gyp...............	Fine........	Strong	21.3	No	....
208	Garfield.......	....	Good.......	Weak......	21.3	No	38 M.........
209	Garfield.......	....	Fair........	Weak......	22.3	No	7 M.........
210	Garfield.......	Mica...................	Fine........	Strong	24.8	No	7 M.........
211	Garfield.......	....	Good.......	Strong	21.3	No	2 M.........
212	Garfield.......	....	Fair........	Weak......	23.0	No	....
213	Garfield.......	Roots Limonite..........	Fine........	Strong	43.9	No	7 M.........
214	Garfield.......	....	Fair........	Weak......	20.7	No	7 M.........
215	Garfield.......	....	Good.......	Strong	29.3	No	....
216	Garfield.......	....	Good.......	Strong	27.3	No	....
217	Grand.........	Limonite...............	Good.......	Strong	27.3	No	20 M.........
218	Grand.........	Limonite...............	Good.......	Strong	20.7	No	....
219	Grand.........	Lim. Gyp...............	Fine........	Strong	21.5	No	20 M.........
220	Gunnison......	....	Fair........	Weak......	21.0	No	20 M.........
221	Gunnison......	....	Poor........	Weak......	19.5	No	Not in 8 hrs...
222	Gunnison......	Roots..................	Fine........	Strong	31.2	No	....
223	Gunnison......	Roots..................	Good.......	Weak......	20.8	No	1 M.........
224	Huerfano......	....	Fair........	Weak......	19.3	No	....
225	Huerfano......	Limonite...............	Good.......	Weak......	25.2	No	....

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
2	19.5	03	White..........	0	21.5	12	White........	2	9	30+	No	No
7	118	05	Pink...........	2	15.5	5	Gray.........	5	4.1	16	No	No
8	114	05	Buff...........	2	13.4	03	Brown........	10	15.3	3	No	No
3	60	03	White..........	2	20.1	16	White........	4	10	30+	No	No
11	99	07	Brick..........	5	12.2	01	Brown........	7	5.7	5	No	No
5	91	05	Brick..........	2	17.3	3	Brown........	6	7.9	8	No	No
6	136	05	Pink...........	2	20.0	01	Brown........	7	2.4	3	No	No
7	54	05	Pink...........	3	9.8	3	Brown........	6	1.8	5	No	No
5	30	05	Pink...........	1	15.2	3	Brown........	3	2.2	5	Possible	No
1	28	10	White..........	0	15.0	18	White........	1	8	30+	No	No
6	50	05	Pink...........	3	12.6	3	Brown........	7	2	12	No	No
4	65	05	White..........	1	13.3	10	Gray.........	10	2.5	16	No	Yes
8	77	03	White..........	4	14.1	5	Gray.........	5	5.9	16	No	No
3	37	05	Gray...........	2	21.6	03	Gray.........	2	21.0	3	No	No
4	16	03	Brick..........	7	16.2	3	Brown........	14	5.4	5	No	No
1	23	3	Pink...........	0	20.0	10	Brownish Gray	1	4	20	No	No
10	91	03	Brownish Brick..	7	12.0	3	Brown........	8	3.4	5	No	No
1	16	03	White..........	0	23.0	4	Buff..........	1	20.0	5	No	Yes
1	28	01	White..........	0	31.0	3	White........	0	30.0	5	No	No
3	20	3	White..........	0	29.0	5	....	....	......	5	No	No
3	33	03	Flesh..........	3	31.0	3	Brown........	5	4.9	5	No	No
3	24	3	White..........	0	25.0	5	....	....	......	5	No	No
3	32	05	Buff...........	5	15.0	3	....	....	......	3	No	Yes
2	34.5	03	Pinkish White ..	3	12.0	3	Gray.........	5	4	5	No	No
2	93.5	05	Buff...........	0	21.0	3	Brown........	7	3.8	5	No	Yes
0	29	5	White..........	9	4.0	8	....	....	......	8	No	Yes
3	35	3	White..........	0	33.0	8	White........	9	1.4	10	No	No
0	19	3	White..........	0	24.0	8	White........	4	2.5	10	No	No
2	40	03	Brownish Brick..	5	4.0	01	Brown........	5	1.9	5	No	Yes
1	51	03	Buff...........	1	30.0	3	Brown........	1	25	5	No	No
4	52	07	Pink...........	1	14	3	Brown........	4	7.5	5	No	Yes
2	70	01	Pink...........	5	7.7	3	Brown........	6	4.2	5	No	No
12	92	010	Brown..........	6	9.5	3	Gray.........	3	1.9	8	No	Yes
4	67	05	Buff...........	0	17	01	Brown........	5	3.0	5	Probable	No
5	99	08	Buff...........	2	22·	03	Gray.........	5	.3	5	No	No
3	83	03	....	....	......	03	....	....	......	03	No	No
5	35	05	Pink...........	4	13.2	3	Brown........	9	3	10	No	No
5	30	05	Brick..........	0	17.8	03	Brick.........	2	18.2	5	No	Yes
5	25.5	01	Brick..........	5	8.9	3	Gray.........	5	2.3	5	No	No
2	31	010	Pink...........	0	14.2	5	Light Brown.	6	0	8	No	Yes
0	29.5	03	Brick..........	0	15.2	3	Brown........	0	12.6	12	No	No
10	114	05	Buff...........	6	5.8	3	Brown........	6	1.8	5	No	No
5	67	5	Brick..........	....	......	5	Brick.........	....	......	5	No	No
2	95	01	Brick..........	0	16	2	Dark Brown..	?	?	3	No	Yes
9	133	05	Brick..........	2	14.5	03	Brown........	4	5.1	3	No	Yes

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
226	Huerfano......	Concretions............	Good.......	Strong	24.6	No	....
227	Huerfano......	....	Good.......	Strong	34.4	No	2.5 hrs........
228	Huerfano......	Sand..................	Fine........	Strong	27.0	No	No...........
229	Huerfano......	Calcite................	Poor.......	Weak......	22.2	No	35 M.........
230	Huerfano......	Gypsum...............	Good.......	Strong.....	19.7	No	20 M.........
231	Huerfano......	Gypsum...............	Fine........	Strong	34.5	No	2.5 hrs........
232	Huerfano......	....	Fine........	Strong	25.0	No	....
233	Huerfano......	....	Good.......	Strong	11.2	No	20 M.........
234	Huerfano......	....	Good.......	Strong	33.7	No	6 hrs..........
235	Huerfano......	....	Fine........	Strong	48.3	No	....
236	Huerfano......	Limonite Sand..........	Poor.......	Weak......	28.0	No	1 hr..........
237	Huerfano......	Sand..................	Poor.......	Weak......	25.5	No	10 M.........
238	Huerfano......	....	Poor.......	Weak......	23.4	No	Not in 18 hrs..
239	Huerfano......	....	Poor.......	Weak......	21.8	No	18 hrs.........
240	Huerfano......	Limonite...............	Fine........	Strong	28.4	No	Not in 18 hrs..
241	Huerfano......	....	Fair........	Weak......	24.6	No	50 M.........
242	Huerfano......	....	Poor.......	Weak......	23.1	No	8 hrs..........
243	Huerfano......	Limonite Sand..........	Good.......	Strong	32.7	No	20 M.........
244	Huerfano......	....	Good.......	Strong	39.1	No	4 hrs..........
245	Huerfano......	....	Good.......	Strong	29.6	No	35 M.........
246	Huerfano......	Gypsum...............	Good.......	Strong	32.2	No	20 M.........
247	Huerfano......	....	Good.......	Strong	26.95	No	35 M.........
248	Huerfano......	Gypsum...............	Fair........	Weak......	20.7	No	10 M.........
249	Jefferson.......	Calcite................	Fair........	Weak......	36.3	No	2 M..........
250	Jefferson.......	Limonite Concretions	Fair........	Weak......	23.4	No	7 M..........
251	Jefferson.......	Limonite...............	Poor.......	Weak......	23.0	No	....
252	Jefferson.......	Limonite...............	Fair........	Weak......	21.0	No	7 M..........
253	Jefferson.......	....	Good.......	Strong	20.9	No	30 M.........
254	Jefferson.......	Lim. Gyp..............	Good.......	Strong	24.0	No	7 M..........
255	Jefferson.......	Cal. Lim...............	Good.......	Strong	13.4	No	4 M..........
256	Jefferson.......	Limonite...............	Good.......	Strong	29.1	No	1 M..........
257	Jefferson.......	Limonite...............	Good	Strong	24.8	No	....
258	Jefferson.......	Limonite...............	Good.......	Strong	26.3	No	15 M.........
259	Jefferson.......	Limonite...............	Good.......	Strong	28.0	No	30 M.........
260	Jefferson.......	....	Fair........	Weak......	17.5	No	10 M.........
261	Jefferson.......	....	Fine........	Strong	19.8	No	2 M..........
262	Jefferson.......	Limonite...............	Fine........	Strong	27.0	No	2 M..........
263	Jefferson.......	Cal. Lim...............	Good.......	Strong	34.5	No	....
264	Jefferson.......	Cal. Lim...............	Good	Strong	27.7	No	6 M..........
265	Jefferson.......	Cal. Lim. Barite.........	Fair........	Strong	30.3	No	....
266	Jefferson.......	Mica..................	Good.......	Strong	20.6	No	10 M.........
267	Jefferson.......	....	Good.......	Strong	25.7	No	45 M.........
268	Jefferson.......	....	Good.......	Weak......	22.4	No	2 hrs., 20 M...
269	Jefferson.......	....	Good.......	Weak......	25.3	No	8 M..........
270	Jefferson.......	....	Fair........	Weak......	22.6	No	10 M.........

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
6	124	05	Pink...........	1	15.4	03	Brown........	5	8.3	3	No	Yes
7	133	05	Flesh...........	0	12.1	1	Brick.........	4	3	8	No	No
7	127	5	White..........	1	3	10	White........	4	1	20	No	No
3	21	03	Pink...........	3	4.5	5	Brown........	7	2	8	No	No
4	129	05	Pink...........	0	5.5	03	Brick.........	1	5.4	8	No	No
6	171	05	Pink...........	0	10.4	3	Brown........	2	6.2	8	No	Yes
4	100.5	1	White..........	0	4.4	10	White........	1	1	30+	No	No
5	140	05	Yellowish White	0	13.1	03	Buff..........	5	7	8	No	No
5	90	03	White..........	1	14.5	3	White........	2	7	12	No	No
8	106	03	White..........	9	8.6	5	White........	13	6	30+	No	Yes
5	64	03	Flesh...........	0	5.8	5	Brick.........	1	.6	8	No	No
5	76	03	Pink...........	4	15.1	3	Dark Brick...	4	5	8	No	No
1	20	8	White..........	0	12.5	10	White........	1	6	30	No	No
1	45	1	Pink...........	1	9.6	3	Dark Brick...	1	4	12	No	No
4	82.5	03	Flesh...........	4	7	8	Brownish White	4	2	20	No	No
2	59.5	10	White..........	0	15.5	20	White........	6	4	30+	No	Yes
4	76	03	Brick.....	1	15.2	5	Brick.........	2	6	8	No	No
5	123	03	Pink...........	2	7.7	5	Brick.........	2	3.6	10	Possible	No
3	69.5	8	White..........	1	6.9	12	White........	3	5	30	Possible	No
0	18	10	White..........	8	8.0	16	White........	12	5	30+	No	No
5	193	05	Pink...........	0	21.6	3	Brick.........	11	10	8	Possible	No
5	74.5	03	White..........	1	11.9	10	White........	4	2	30+	No	No
5	99.5	03	White..........	1	6.3	8	White........	1	2	30+	No	No
11	126	010	Brick...........	1	14.0	05	Brick.........	2	7.1	03	No	No
2	26	05	White..........	3	14.0	01	Dark Gray ...	3	9.1	10	No	No
2	30	05	Yellowish White	0	21.0	8	White........	4	8.6	16	No	No
4	83	03	Pink...........	4	3.6	5	Dark Gray ...	4	2.5	8	No	No
4	86	03	Pink...........	0	16.7	5	Brown........	3	7	8	No	No
4	125	05	Pink...........	1	13.1	01	Dark Gray ...	1	5.4	5	No	No
13	116	05	Pink...........	3	8.1	03	Yellow.......	3	6.2	01	No	No
10	125	010	Yellow..........	0	12.8	01	Brown........	3	4.3	10	No	Yes
7	149	010	Yellow..........	0	10.6	01	Brown........	1	6.9	12	No	Yes
9	144	010	Yellow..........	0	10.0	03	Gray..........	2	2.9	8	No	Yes
8	123.5	010	Yellow..........	0	12.5	03	Gray..........	3	4.3	10	No	No
4	45	03	White..........	5	14.0	20?	White........	?	?	30+	No	No
3	90	05	Flesh...........	0	14.0	8	White........	4	1.6	12	No	No
7	102.5	05	Flesh...........	0	14.0	01	White........	3	8.3	20	No	No
11	129	05	Brick...........	1	12.0	01	Brown........	6	3.6	3	No	No
6	93	010	Brick...........	0	19.5	03	Brown........	5	8	5	No	No
9	82	05	Brick...........	0	16.5	03	Brown........	2	12	3	No	No
4	67	05	Pink...........	0	22.0	01	Brown........	5	10	3	No	No
6	56.5	05	White..........	1	13.9	01	White........	5	8.6	12	No	Yes
4	84.5	05	Light Gray	0	14.2	3	Gray..........	2	3.2	10	No	Yes
4	63	05	Flesh...........	1.5	14.8	01	Yellowish Br'wn	3.5	11.6	12	No	Yes
4	48.5	05	Light Gray	2	14.9	3	Gray..........	8	1.8	12	No	Yes

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
271	Jefferson		Good	Weak	18.4	No	1 hr., 45 M
272	Jefferson	Limonite	Good	Strong	32.3	No	8 M
273	Jefferson	Limonite	Fine	?	18.5	No	
274	Jefferson	Limonite	Good	?	28.0	No	
275	Jefferson		Very fine	?	20.0	No	
276	Jefferson	Limonite	Good	?	13.0	No	
277	Jefferson	Limonite	Good	?	18.0	No	
278	Jefferson	Limonite	Good	?	20.0	Sl.	
279	Jefferson	Limonite	Fine	?	25.0	No	
280	Jefferson	Limonite	Fine	?	28.0	Badly	
281	Jefferson	Limonite	Very fine	?	31.0	Badly	
282	Jefferson	Limonite	Fair	?	24.0	No	
283	Jefferson	Limonite	Very fine	?	26.0	Badly	
284	Jefferson	Limonite	Fine	?	36.0	Badly	
285	Jefferson	Limonite	Fine	?	30.0	Badly	
286	Jefferson	Limonite	Fair	?	22.0	No	
287	Jefferson	Limonite	Fair	?	30.0	Badly	
288	Jefferson	Limonite	Good	?	30.0	No	
289	Jefferson	Limonite	Very poor	?	26.0	No	
290	Jefferson	Limonite	Good	?	21.0	Badly	
291	Jefferson		Poor	?	23.0	No	
292	Jefferson	Limonite	Good	?	20.0	No	
293	Jefferson		Poor	?	22.0	No	
294	Jefferson		Fair	?	29.0	Sl.	
295	Jefferson	?	?	?	?	?	?
296	Jefferson	Lim. Alk.	Fine	Strong	13.4	No	45 M
297	Jefferson	Lim. Alk.	Fine	Strong	18.2	No	30 M
298	Jefferson	Lim. Alk.	Fair	Weak	33.8	No	
299	Jefferson	Lim. Alk.	Fine	Strong	42.5	No	
300	Larimer		Good	Strong	27.6	No	5 M
301	Larimer	Limonite Sand	Fine	Strong	22.1	No	
302	Larimer	Limonite Sand	Fine	Strong	22.1	No	
303	Larimer		Good	Strong	29.7	No	1 hr.
304	Larimer		Good	Strong	27.7	No	10 M
305	Larimer	Limonite Sand	Fine	Strong	22.1	No	
306	Larimer	Limonite	Good	Strong	27.2	No	5 M
307	Larimer	Calcite	Good	Strong	19.1	No	1 hr., 25 M
308	Larimer	Gypsum	Good	Strong	26.6	No	2 M
309	Larimer	Gypsum	Good	Strong	30.8	No	1 hr.
310	Larimer	Gypsum	Fine	Strong	22.2	No	4 M
311	Larimer	Sand	Good	Strong	26.9	No	8 M
312	Larimer	Sand	Good	Strong	29.0	No	30 M
313	Larimer		Good	Strong	24.6	No	25 M
314	Larimer	Limonite	Good	Strong	20.0	No	5 M
315	Larimer	Little Limonite	Good	Strong	25.9	No	5 M

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
2	42	01	Gray..........	2	10.3	3	Brown........	?	?	5	No	Yes
7	84	05	White..........	1	14	3	Gray.........	8	4.7	10	No	Yes
12.5	151.4	05	Pink...........	2	15	03	Reddish Brown	8	1	4	Probable	Yes
8	161.4	03	Brick..........	6	7	01	Brown........	9	1	4	No	Yes
5.5	121.9	03	Yellowish White	2	13	3	Gray.........	3	7.7	6	No	Yes
8	214.1	03	Brick..........	5	12	4	Brown........	?	?	5	No	Yes
9.5	231.3	05	Pink...........	0	16	03	Light Brown.	6	5	6	No	Yes
11.5	173	05	Brick..........	5	16	03	Dark Brown..	6	1	3	No	Yes
7.5	212.8	04	Brick..........	6	15	03	Brown........	7	1	3	No	Yes
10.5	?	04	Brick..........	6	15	03	Brown........	7	0	3	No	Yes
11	?	05	Buff...........	0	13	03	Brown........	3	3	5	No	Yes
10	22.5	03	Brick..........	1.5	10	4	Gray.........	?	?	5	No	Yes
12	?	04	Brick..........	1	10	03	Brown........	6	2	5	No	Yes
12.5	?	05	Pink...........	.5	11	03	Brown........	2	2	4	No	Yes
11.5	100	03	Pink...........	2	9	3	Brown........	?	?	5	No	Yes
6.5	282.2	04	Pink...........	0	15	4	Brown........	?	?	5	No	Yes
11	115	05	Light Brick.....	1	10	01	Brown........	2	2	5	No	Yes
11	170	03	Light Brick.....	1.5	9	01	Dark Brown..	4.5	3	5	No	Yes
8	193	03	Brick..........	0	14	3	Brown........	2	5	5	No	Yes
10.5	65	04	Light Brick.....	0	13	4	Brown........	?	?	5	No	Yes
8	280.5	03	Brick..........	2.5	14	4	Dark Brown..	?	?	5	No	Yes
7	245	04	Pink...........	3	15	03	Reddish Brown	5	9	5	No	Yes
5.5	58	05	White..........	2	20	?	White........	?	?	?	No	Yes
11	?	05	Pink...........	0	13	03	Brown........	5	6	3	No	Yes
?	?	?	?..............	?	?	?	?............	?	?	?	?	Yes
12	21	05	Pink...........	1	10.3	3	Gray.........	3	0	8	No	No
11	86	010	Pink...........	1	16.3	3	Gray.........	3	2.9	8	No	No
5	65	03	Brick..........	1	14.0	5	Gray.........	?	?	10	Possible	No
10	105	05	Brick..........	0	13.9	3	Gray.........	?	?	8	No	No
4	115	03	Brick..........	2	9.0	1	Brown........	4	8	5	No	No
9	124	03	Brick..........	2	10.5	3	Brown........	3	4	8	No	No
9	124	03	Brick..........	2	10.5	3	Brown........	3	4	8	No	No
5	97.5	03	Brick..........	2	9.7	1	Brown........	3	5	5	No	No
5	111.5	03	Brick..........	1	8.0	1	Brown........	1	4	8	No	No
9	124	03	Brick..........	2	10.5	3	Brown........	3	4	8	No	No
10	79	05	Pink...........	7	3.0	03	Brown........	7	1.5	8	No	No
5	19	05	Flesh..........	1	16.4	01	Buff..........	1	13	3	No	Yes
9	79	05	Pink...........	0	15.0	01	Gray.........	5	4.5	3	No	Yes
9	90	05	Pink...........	2	13.2	01	Brown........	8	3	3	No	No
4	117	05	Brick..........	2	15.4	03	Brown........	3	10	5	No	Yes
6	61	05	Pink...........	2	14.6	3	Gray.........	5	5.2	8	No	No
6	56	03	Pink...........	7	8.0	01	Gray.........	7	4.1	8	No	No
5	85	05	Brick..........	5	4.1	01	Brown........	6	2.6	8	No	Yes
6	56	03	White..........	2	22.4	3	Buff..........	4	10.6	8	No	Yes
5	65	05	Brick..........	3	10.3	01	Brick.........	4	11.3	5	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
316	Larimer	Calcite	Good	Strong	23.5	No	2 M.
317	Larimer	Gypsum	Good	Strong	18.9	No	15 M.
318	Larimer	Calcite Limonite	Fair	Strong	19.3	No	15 M.
319	Larimer	Sand	Good	Weak	19.1	No	2 hrs., 40 M.
320	Larimer	Calcite Sand	Good	Strong	25.0	No	
321	Larimer	Sand	Fine	Strong	23.0	No	6 M.
322	Larimer		Good	Strong	24.4	No	9 hrs.
323	Larimer	Limonite	Good	Weak	16.4		8 M.
324	Larimer		Good	Strong	21.4	No	8 M.
325	Larimer	Sand	Good	Strong	26.6	No	8 M.
326	Larimer	Limonite	Good	Strong	24.2	No	5 M.
327	Larimer		Very poor	None	20.0	No	1 hr.
328	Larimer	Pebbles	Fine	Strong	33.6	Sl.	6 M.
329	Larimer	Sand	Fair	Strong	29.0	No	15 M.
330	Larimer		Good	Strong	25.0	No	20 M.
331	Larimer	Sand Gypsum	Good	Weak	26.5	No	17 M.
332	Larimer	Lim. Gyp.	Good	Strong	27.7	No	1 hr.
333	Larimer	Limonite	Good	Strong	26.0	No	1 hr.
334	Larimer		Good	Strong	43.7	No	4 M.
335	Larimer		Fair	Weak	6.4	No	6 hrs.
336	Larimer		Good	Strong	6.7	No	6 hrs.
337	Larimer	Fos. Cal. Sand	Good	Strong	33.4	No	5 M.
338	Larimer	Sand	Good	Weak	27.0	No	17 M.
339	Larimer	Gypsum	Good	Strong	40.6	No	2 M.
340	Larimer		Good	Strong	28.9	No	5 M.
341	Larimer	Mica Sand	Good	Strong	20.7	No	1 M.
342	Larimer	Alk. Sand	Good	Strong	20.7	No	1 M.
343	Larimer	Sand	Fine	Strong	21.5	No	4 M.
344	Larimer	Sand	Good	Weak	14.2	No	2 M.
345	Larimer	Sand Gyp.	Good	Strong	22.6	No	2 M.
346	Larimer	Sand Gyp.	Good	Strong	21.6	No	7 hrs.
347	Larimer	Calcite	Good	Weak	18.9	No	5 M.
348	Larimer	Various Grains	Good	Strong	29.0	No	1 M.
349	Larimer	Sand	Fine	Strong	32.7	No	
350	Larimer	Lim. Gyp.	Fine	Strong	33.5	No	No
351	Larimer	Slight	Fair	Strong	34.9	No	10 M.
352	Larimer	Sand	Fine	Strong	34.0	No	10 M.
353	Summit	Carbon	Fine	Strong	27.1	No	1 M.
354	Larimer	Sand	Very fine	Strong	42.3	No	5 M.
355	Larimer	Sand	Fair	Weak	35.2	No	5 M.
356	Larimer	Lim. Sand	Fair	Weak	32.6	No	5 M.
357	Larimer	Lim. Sand	Fine	Strong	28.1	No	5 M.
358	Larimer	Limonite	Fair	Weak	21.6	No	5 M.
359	Larimer		Fair	Weak	27.8	No	15 M.
360	Larimer	Lim. Sand	Poor	Weak	23.5	No	No

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
7	53	010	Flesh	2	13.9	01	Gray	5	1.7	3	No	Yes
6	80	05	Pink	0	11.4	01	Brown	1	8	8	No	Yes
7	39.5	03	Brick	0	11.9	01	Brick	2	9.8	8	No	No
3	57	05	White	0	13.9	5	White	1	8.6	20	No	No
1	54	05	Pink	2	27.5	2	Buff	9	13	4	No	Yes
6	71	05	Pink	1	9.0	01	Brown	5	2.8	6	No	No
6	66	05	Pink	1	11.0	03	Brick	5	5.1	5	No	No
3	39	05	Brick	0	12.0	1	Brown	2	7	10	No	Yes
4	50	03	Pink	3	8.1	01	Brown	4	7	8	No	No
7	79	010	Pink	2	11.8	03	Brown	5	3.6	5	No	No
6	114	08	Pink	6	6.7	03	Brown	2	7.9	5	No	No
4	23	05	Brick	1	13.9	3	Brick	5	4.1	5	No	No
11	47.5	05	Brick	6	3.5	03	Brick	6	2	3	Probable	No
9	61	03	Red	3	9.8	01	Brown	5	5.6	3	No	No
3	71	05	Brick	2	17.4	03	Brick	4	10	5	No	Yes
2	33	01	Brick	1	19.2	3	Dark Brown	2	16	5	No	No
5	83	010	Brick	0	17.2	03	Brick	3	11	3	No	Yes
3	44	05	Brick	3	14.9	03	Brick	4	6	5	No	No
6	73	05	Pink	4	14.0	03	Brown	7	4	10	No	Yes
3	73	05	Pink	0	16.0	01	Brown	2	10	5	No	No
7	54	05	Buff	2	11.0	03	Light Brown	2	8	3	No	No
7	88	03	Pink	0	20.0	5	Brown	6	4	8	No	No
6	75	05	Pink	0	18.6	01	Brown	3	5	3	No	No
9	136	05	Brick	5	7.6	03	Brown	8	1	5	No	No
8	113	010	Pink	0	14.9	03	Brown	5	1	5	No	No
2	77	01	Brick	5	4.2	3	Brown	7	3	5	No	No
4	82	05	Brick	0	13.9	01	Brown	2	7	5	No	No
6	58	05	Pink	2	12.0	01	Brown	4	8.5	8	No	No
2	40	01	White	0	11.0	20	White	0	6	30	No	No
6	98	05	Brick	4	6.4	03	Brown	6	2	5	No	No
4	48	05	Pink	3	15.0	03	Brown	5	8	5	No	No
3	49	05	Pink	1	16.0	01	Gray	4	7	5	No	No
11	61	05	Pink	1	12.1	01	Brown	3	7	5	Probable	No
7	156	05	Buff	2	9.9	5	Gray	5	1	8	No	No
6	113	03	Flesh	3	13.1	8	Light Brown	5	5	16	No	No
6	121	03	Pink	6	11.2	5	YellowishBr'wn	7	7	18	No	No
6	102	03	Brick	5	12.3	5	Brown	5	3	10	Possible	No
2	35	01	Brick	2	19.1	2	Brown	?	?	3	No	Yes
9	172	03	Brick	3	8.6	1	Brown	8	6	3	No	No
7	135	05	Brick	0	17.1	1	Brown	6	8	3	No	No
4	78	05	Brick	0	24.0	3	Brown	6	1	5	No	No
6	111	03	Pink	6	10.9	5	Brick	6	2	8	Probable	No
5	51	03	Brick	2	14.9	3	Gray	4	12	8	Probable	No
5	51	03	Brick	2	14.5	3	Brown	4	8	8	Probable	No
1	50	1	Pink	0	25.0	3	Gray	0	25	10	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
361	Larimer	Limonite	Very poor	Weak	23.8	No	3 hrs
362	Larimer		Fine	Strong	36.7	No	
363	Larimer	Sand	Fine	Strong	34.5	No	10 M.
364	Larimer	Sand	Good	Strong	29.4	Sl.	
365	Larimer	Sand	Good	Strong	19.1	No	5 hrs
366	Larimer	Sand	Very poor	None	19.8	No	No
367	Larimer		Fine	Strong	28.6	No	1 hr
368	Larimer		Fine	Strong	42.5	No	
369	Larimer		Fine	Strong	54.5	No	15 M.
370	Larimer	Sand Coal	None	None			15 M.
371	Larimer		Good	Strong	21.0	No	
372	Larimer		Good	Strong	19.9	No	40 M.
373	Larimer		Fair	Weak	21.9	No	
374	Larimer	Concretions Sand	Good	Strong	29.3	No	
375	Las Animas	Bitumen Gypsum	Poor	Weak	23.7	No	Not in 1 day
376	Las Animas	Limonite	Fine	Strong	26.2	No	Not in 24 hrs
377	Las Animas	Siderite Limonite	Good	Strong	24.2	No	35 M.
378	Las Animas	Limonite	Good	Strong	22.6	No	Not in 1 day
379	Las Animas	Siderite Lim. Gyp.	Good	Strong	18.4	No	
380	Las Animas	Limonite	Fine	Strong	29.7	No	35 M.
381	Las Animas	Gyp. Cal. Lim.	Good	Strong	26.1	No	35 M.
382	Las Animas	Siderite Gypsum	Fine	Strong	19.5	No	35 M.
383	Las Animas	Sand Siderite	Fair	Weak	21.8	No	35 M.
384	Las Animas	Siderite Lim. Gyp.	Good	Strong	22.5	No	
385	Las Animas	Sid. Lim.	Good	Strong	22.1	No	
386	Las Animas		Good	Strong	17.8	No	Not in 24 hrs
387	Las Animas	Limonite	Good	Strong	30.5	No	15 M.
388	Logan	Sand	Fine	Strong	39.0	No	5 M.
389	Logan	Sand	Fine	Strong	40.5	No	5 M.
390	Logan	Sand	Fine	Strong	42.4	No	
391	Logan		Fine	Strong	41.2	No	
392	Logan	Sand	Fair	Weak	27.7	No	
393	Logan	Calcareous	Very fine	Strong	32.59	No	5 M.
394	Mesa	None	Good	Strong	33.3	No	38 M.
395	Mesa	None	Good	Strong	42.6	Sl.	3 hrs
396	Mesa	None	Good	Strong	25.5	Badly	3 hrs
397	Mesa	None	Fair	Weak	23.8	No	12 M.
398	Mesa		Good	Strong	19.1	No	15 M.
399	Mesa	None	Fair	Weak	18.7	No	1 M.
400	Mesa	Gyp. Fos.	Fair	Strong	20.7	No	No
401	Mesa	Gyp. Fos.	Practically the same as No 400.				
402	Mesa	None	Fair	Weak	20.4	No	
403	Mesa	Gypsum	Fine	Strong	26.4	No	15 M.
404	Mesa	Limonite	Good	Weak	22.9	No	Not in 10 hrs
405	Morgan	Calcite	Good	Strong	29.78	No	3 M.

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
1	50	05	Brick..........	0	23.8	3	Light Brown..	2	18	8	Possible	No
6	137	03	Brick..........	1	12.0	1	Brown........	6	12	5	Probable	No
6	111	03	Pink..........	3	8.9	1	Brown........	4	5	5	No	No
4	73	03	Brick..........	0	11.0	3	Gray........	2	8	8	Probable	No
2	58	1	White..........	0	9.0	8	White........	1	3	18	No	No
1	13	12	White..........	0	15.0	20	White........	1	9	30+	No	No
5	85.5	03	Brick..........	1	13.6	3	Brown........	3	6	8	No	No
12	230	010	Pink..........	0	12 7	03	Brown........	3	8	5	No	No
18	151	03	Buff..........	7	15.0	3	Brown........	7	12	8	Possible	No
	Too sandy to be moulded.											No
3	68	1	Light Brick.....	1	12.8	5	Gray........	2	8	12	No	No
3	43	1	White..........	1	14.8	8	White........	5	6	30+	No	No
3	69	07	Pink..........	0	16.8	1	Gray........	2	2	5	No	No
4	59	03	Brown..........	2	14 4	3	Brown........	2	7	8	Possible	No
1	35	03	Light Brown....	1	15.7	3	Brown........	3	11.1	5	Possible	No
7	128	05	Pink..........	4	9.2	5	Brown........	5	1.8	16	No	No
2	50	07	Brick..........	1	17.0	01	Brown........	5	4.3	5	Possible	No
5	64	05	Brick..........	2	14.1	3	Brown........	6	2.3	5	No	No
7	66	05	Pink..........	4	11.3	3	Brown........	7	2.1	5	Probable	No
5	137	010	Pink..........	0	13.1	01	Brownish Gray	3	8.0	3	Possible	No
5	74	010	Pink..........	2	18.9	01	Brown........	7	1.8	3	No	No
4	68	010	Brick..........	1	13.8	03	Brown........	3	2.2	5	No	No
4	54	05	Dark Brick.....	2	14.8	3	Brown........	5	.6	5	Possible	No
2	35	05	Dark Brick.....	1	14.6	3	Brown........	5	1.1	5	Possible	No
3	84	03	Brick..........	4	14.2	3	Brown........	8	5.9	5	No	No
0	40	3	Pinkish White ..	0	15.3	10	Pinkish White	3	8	?	No	No
4	56	07	Brick..........	4	12.1	03	Brown........	8	3	5	No	Yes
12	128.5	03	Pink..........	0	8.2	5	Brown........	5	1.6	8	No	No
12	144	03	Pink..........	0	25.8	5	Brown........	6	7.5	8	Probable	No
11	140	07	Pink..........	0	9.4	1	Brown........	5	2.5	3	Possible	Yes
11	138.5	03	Pink..........	2	4.5	1	Brown........	3	2	3	Probable	No
3	51	3	Gray..........	3	8	5	Gray........	3	4.8	8	No	No
22	213	010	Pink..........	0	22	03	Brick........	2	7.7	2	No	No
12	119	05	Brick..........	2	11.1	3	Brown........	5	4.2	5	No	Yes
16	17.5	010	Buff..........	3	15.1	03	Brown........	6	2.9	5	No	No
21	22.5	010	Yellow..........	3	9.2	05	Brown........	3	2.8	3	No	Yes
4	51	010	Dark Brick.....	3	15.8	3	Brown........	4	6.2	5	No	No
4	53	01	Brick..........	3	13.5	2	Light Brown..	3	5	3	No	No
1	56	05	Light Brick....	0	13.2	3	Gray........	5	3.5	8	No	No
3	81	03	Buff..........	4	13.0	01	....	....	......	01	No	No
3	79	03	Light Brick.....	1	22	3	Light Gray ...	9	3	5	No	No
5	73	07	Light Pink......	0	17.2	1	White........	0	14.6	5	Possible	No
1	35	3	White..........	1	21.6	5	White........	1	12.8	8	No	No
3	108	1	White..........	0	40.3	5	White........	0	30.2	8	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
406	Morgan	Sand	Fair	Weak	24.1	No	5 M
407	Morgan		Very fine	Strong	37.9	No	5 M
408	Morgan	Sand	Good	Strong	34.0	No	10 M
409	Morgan	Sand	Good	Weak	21.4	No	5 M
410	Morgan	Sand	Very fine	Strong	48.3	No	5 M
411	Morgan		Fine	Strong	27.9	No	
412	Morgan	Cal. Sand	Very fine	Strong	36.4	No	
413	Morgan	Alkali	Fine	Strong	41.6	No	10 M
414	Morgan	Sand	Good	Strong	26.3	No	10 M
415	Morgan	Sand	Fair	Weak	22.4	No	
416	Morgan	Sand	Very fine	Strong	50.5	No	10 M
417	Morgan	Sand	Very fine	Strong	39.5	No	10 M
418	Otero	Limonite Bitumen	Good	Strong	17.5	No	Not in 24 hrs.
419	Otero	Limonite Gypsum	Good	Strong	17.2	No	15 M
420	Otero	Limonite	Fine	Strong	38.2	No	25 M
421	Otero	Gyp. Lim.	Good	Strong	31.5	No	15 M
422	Otero	Gyp. Lim.	Good	Strong	28.2	No	
423	Otero	Cal. Lim.	Fine	Strong	29.9	No	15 M
424	Otero	Gyp. Lim.	Fine	Strong	27.0	No	1 hr.
425	Prowers	Sand Cal. Gyp.	Good	Strong	24.5	No	
426	Prowers	Sand Limonite	Fine	Strong	23.6	No	
427	Prowers	Lim. Gyp.	Fair	Weak	25.5	No	Not in 12 hrs.
428	Prowers	Sand Lim.	Fair	Weak	30.4	No	Not in 12 hrs.
429	Pueblo	Sand	Poor	Weak	17.9	No	Not in 18 hrs.
430	Pueblo	Sand	Fine	Strong	24.0	No	3 hrs.
431	Pueblo	Gypsum	Fine	Strong	31.3	No	10 M
432	Pueblo	Sand	Poor	Weak	33 3	No	2 hrs.
433	Pueblo	Carbon	Poor	Weak	17.8	No	No
434	Pueblo	Gypsum	Fine	Strong	32.8	No	5 M
435	Pueblo	Cal. Gyp.	Fine	Strong	35.6	No	
436	Pueblo	Gyp. Sand	Good	Strong	24.0	No	10 M
437	Pueblo	Sand	Fine	Strong	26.3	No	10 M
438	Pueblo		Fine	Strong	23.0	No	1 M
439	Pueblo	Sand	Poor	Weak	23.0	No	2 hrs.
440	Pueblo		Poor	Weak	21.9	No	5 hrs.
441	Pueblo	Sand	Fair	Weak	30.7	No	1 hr.
442	Pueblo	Gypsum	Good	Strong	32.2	No	
443	Pueblo	Gypsum	Fair	Weak	26.0	No	5 M
444	Pueblo	Sand	Fine	Strong	32.8	No	
445	Pueblo	Gypsum	Good	Strong	54.7	No	Not in 1 day
446	Pueblo	Gypsum Pyrite	Fine	Strong	73.6	No	5 M
447	Pueblo	Gypsum	Good	Strong	31.0	No	1 hr.
448	Pueblo	Cal. Gyp.	Good	Strong	32.0	No	10 M
449	Pueblo	Lim. Sand	Good	Strong	31.0	No	No
450	Pueblo	Limonite	Poor	Weak	26.3	No	No

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
3	79	03	Brick..........	0	2	5	Brown.......	2	7	8	No	No
11	41	01	Brick..........	1	12.7	3	Brown.......	5	6.7	8	No	Yes
6	129	03	Brick..........	0	6.1	5	Brown.......	2	1	8	No	No
3	116	3	Brick..........	2	5.4	5	Brown.......	2	4	8	No	No
15	42	05	Brick..........	0	25.9	03	Brick........	2	25	1	No	No
8	96.5	05	Brick..........	0	12	2	Brown.......	1	8	3	Possible	No
11	23	03	Pink..........	0	14.3	03	Gray........	0	13	3	No	No
11	124	03	Brick..........	1	9.9	1	Brick........	2	4.8	3	Probable	No
5	147	05	Brick..........	0	15.1	3	Brown.......	8	3.8	5	No	No
2	126	05	Brick..........	0	11.1	3	Brown.......	2	3.5	8	No	No
13	68	05	Pink..........	1	11.6	1	Brown.......	2	5.7	3	No	No
13	99	05	Brick..........	1	16.7	3	Brown.......	2	6.7	5	Probable	No
5	43.5	03	White..........	2	12.5	10	White........	3	7	30+	No	No
4	60.5	010	White..........	2	13.4	5	Yellowish White	3	7.3	16	No	No
13	53.5	03	Brick..........	2	4.3	3	Brown.......	3	2.5	8	Possible	No
10	86	010	Brick..........	0	17.7	01	Brown.......	5	9.6	5	No	Yes
5	54	010	Brick..........	0	17.1	01	Brown.......	4	6	5	No	No
8	72	05	Pink..........	4	22.8	1	Brown.......	5	9.8	3	No	No
6	77	05	Pink..........	2	25.8	01	Brown.......	6	12	1	No	No
4	76	05	Pink..........	0	13.7	8	Brick........	1	9	12	No	No
4	135	03	Pink..........	0	13.7	3	Brown.......	2	7.3	10	No	Yes
5	159	10	White..........	0	16.0	12	Brown.......	0	11.1	14	No	No
7	146	4	Light Buff......	4	......	8	Brown.......	8	......	12	No	No
3	61	1	White..........	1	2.9	10	White........	2	1	30+	No	No
4	73	1	Light Buff......	2	3.0	8	Gray........	3	0	14	No	No
10	90	03	Pink..........	3	27.0	1	Brick........	3	13	10	No	No
0	27	10	White..........	0	30.0	20	White........	5	8	30	No	No
3	41	1	White..........	0	14.5	12	White........	0	8	30	No	No
8	76	010	Pink..........	2	13.2	3	Brown.......	2	7	8	Possible	No
5	61	010	Pink..........	1	13.1	1	Brick........	3	4	8	No	No
5	52	010	Pink..........	0	18.3	8	Yellowish White	1	6.7	20	No	No
9	79	010	Pink..........	0	14.1	8	Gray........	2	3.7	20	No	No
9	180	010	White..........	3	15.0	5	White........	9	0	12	No	No
3	67	03	Buff...........	1	16.5	01	Gray........	1	10	1	Possible	No
2	42	07	Brick..........	0	21.0	8	Brown.......	3	10	10	No	No
3	25	05	Pink..........	0	17.3	10	Grayish Brown	0	8.8	18	Possible	No
3	80	010	Pink..........	3	12.2	3	Brick........	3	5	8	Probable	No
5	111	05	Pink..........	0	18.1	1	Brown.......	4	14	3	No	No
7	59	05	Buff...........	0	28.4	3	Gray........	4	22	8	No	No
7	57	010	Light Brick.....	1	27.6	1	Brown.......	1	12	8	No	Yes
22	27	Fell to	pieces on heating.									No
7	59	05	Flesh..........	3	22.2	03	Buff.........	3	19	1	No	No
7	53	010	Light Brick.....	2	25.5	1	Brick........	8	8	3	No	No
5	147	05	Pink..........	1	26.8	3	Brick........	0	12	8	No	No
4	31	8	White..........	1	16.0	20	White........	3	8	30	No	No

TABLE II—Continued

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent of Water for Maximum Plasticity	Cracks in Air?	Slakes?
451	Pueblo	Sand	Good	Strong	30.3	No	40 M
452	Pueblo	Sand	Good	Strong	36.4	No	10 M
453	Pueblo		Good	Strong	44.2	No	10 M
454	Pueblo	Calcite	Fine	Strong	37.7	No	5 M
455	Pueblo	Gypsum	Fine	Strong	31.3	No	5 M
456	Pueblo		Fine	Strong	34.6	No	5 M
457	Pueblo	Sand	Fine	Strong	25.5	No	35 M
458	Pueblo	Fossil Wood	Fair	Weak	22.7	No	25 M
459	Pueblo	Gypsum	Good	Strong	35.4	No	20 M
460	Pueblo	Gypsum	Fine	Strong	36.0	No	10 M
461	Pueblo	Lim. Gyp	Fair	Weak	22.3	No	Not in 8 hrs
462	Pueblo	Gyp	Very poor	Very weak	Test pieces crumble in fingers		
463	Pueblo	Lim. Gyp	Good	Strong	27.8	No	2 M
464	Pueblo	Limonite	Fine	Strong	27.0	No	2 M
465	Pueblo	Gyp. Lim	Fine	Strong	28.0	No	
466	Pueblo	?	?	?	?	?	?
467	Pueblo	Gypsum	Fine	Strong	25.5	No	
468	Pueblo	Gypsum	Good	Strong	22.1	No	
469	Pueblo		Fine.	Strong	26.3	No	
470	Pueblo	Gypsum	Fine	Strong	25.4	No	
471	Pueblo	Limonite	Good	Strong	31.9	No	35 M
472	Pueblo	Lim. Gyp	Good	Strong.	31.2	No	35 M
473	Pueblo		Good	Strong	20.9	No	1 M
474	Pueblo	Lim. Gyp. Calcite	Fine	Strong	35.3	No	10 M
475	Pueblo	Lim. Gyp. Calcite	Good	Strong	29.3	No	10 M
476	Pueblo	Gypsum Barite	Good	Strong	24.9	No	10 M
477	Pueblo	Calcite	Good	Weak	23.0	No	10 M
478	Pueblo	Sand	Poor	Weak	34.4	No	No
479	Routt	None	Good	Strong	22.0	No	Not in 7 hrs
480	Routt	None	Fine	Strong	19.7	No	Not in 7 hrs
481	Routt	Sand	Fair	Weak	20.5	No	Not in 7 hrs
482	Routt	Sand	Fair	Weak	18.6	No	Not in 7 hrs
483	Routt	Roots Pebbles	Fine	Strong	23.3	No	
484	Routt	Lim. Sand	Poor	Weak	18.1	No	Not in 7 hrs
485	Saguache	Roots Mica	Fine	Strong	28.5	No	5 M
486	Sedgwick		Fine	Strong	63.6	Badly	
487	Sedgwick		Poor	Weak	21.4	No	5 M
488	Washington	Sand	Good	Strong	29.6	No	
489	Washington		Poor	Weak	36.5	No	40 M
490	Washington		Fair	Weak	48.6	No	5 M
491	Washington	Calcite	Good	Strong	41.4	No	20 M
492	Washington		Good	Strong	56.3	No	25 M
493	Weld		Fine	Strong	42.3	Very Badly	25 M
494	Weld		Good	Strong	46.6	Sl.	5 M

TABLE II—Continued

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
5	93	03	Brick..........	2	5.9	3	Brick.........	2	5	8	No	No
9	192	03	Pink...........	7	4.9	5	Brick.........	10	4	8	Possible	No
13	223.5	03	Brick..........	7	8.3	5	Brick.........	7	9	8	Probable	No
8	92	010	Pink...........	2	12.7	1	Light Brick...	4	8	8	Possible	No
6	64	010	Light Brick.....	3	23.8	03	Brick.........	5	15	8	Possible	No
9	62	010	Light Brick.....	2	12.4	1	Brick.........	2	6	8	No	No
6	100	8	White..........	2	5.0	16	White........	4	3	30	No	No
2	61.5	08	White..........	2	26.8	22	White........	3	8	30	No	No
8	132	05	Pink...........	1	28.2	03	Gray.........	5	13	8	No	No
9	190	05	Pink...........	1	8.1	5	Brick.........	7	7	8	Possible	No
2	48	010	Pink...........	1	27.4	2	Yellowish White	6	10	3	No	No
												No
7	110	010	Brick..........	2	16.3	03	Brown........	5	.6	5	No	No
9	91	010	Brick..........	1	15.0	03	Brown........	6	7.4	5	No	No
8	93	05	Brick..........	3	11.0	01	Brown........	6	.5	3	No	No
?	?	?	?..............	?	?	?	?............	?	?	?	?	Yes
6	77.5	03	Pink...........	1.5	19.8	01	Gray.........	2	15	3	No	Yes
4	34	05	Light Pink......	1.5	25.2	01	Yellowish White	2	23	3	No	Yes
7	112	010	Brick..........	2	11.3	01	Dark Gray ...	5	.5	3	No	Yes
6	42	05	Brick..........	2	12.6	03	Dark Gray ...	5	4.4	3	No	Yes
9	31	05	Pink...........	5	13.5	3	Brown........	6	1.7	5	Possible	Yes
8	31	010	Pink...........	3	22.5	01	Gray.........	3	23	3	No	No
5	63.5	01	White..........	7	11.8	18	White........	9	3	30+	No	No
5	33	07	Pink...........	1	22.0	01	Gray.........	4	17.4	3	No	No
6	35	05	Pink...........	1	13.4	01	Brick.........	2	8.6	3	No	No
3	26	3	Gray...........	1	23.6	3	Gray.........	1	23.6	5	No	No
3	38	2	Gray...........	2	12.0	3	Gray.........	3	5.0	5	No	No
4	137	03	Light Brick.....	1	19.6	2	Brick.........	1	12.0	8	No	No
2	13	03	Pink...........	1	20.4	3	Brown........	8	1.8	5	No	No
2	19	05	Brick..........	0	13.3	3	Brown........	8	1.8	5	Probable	Yes
2	28	03	Flesh..........	0	23.0	2	White........	2	12	5	No	No
2	26	03	White..........	0	34.8	5	White........	18	0	8	No	Yes
3	10.5	1	Brick..........	....	.....	3	Brick.........	....	.....	5	No	No
1	10	01	Pink...........	2	11.4	10	White........	3	14.5	16	No	No
2	47	01	Brownish White	8	11.9	1	Brown........	?	?	3	No	No
20	20	010	Brick..........	0	17.1	1	Brown........	3	7.6	8	No	No
2	45	03	Dark Pink......	2	12.0	3	Gray.........	4	7.9	8	No	No
1	68	1	Brick..........	2	10.4	5	Dark Brown..	9	3.0	8	No	No
2	16	07	Brick..........	4	17.5	1	Brown........	6.9	15.0	3	No	No
8	81	05	Brick..........	4	36.6	01	Brown........	9	36.0	3	No	No
2	18	05	Pink...........	3	28.4	1	Buff..........	7	14.0	3	No	No
6	24	010	Pink...........	4	53.3	03	Pink.........	18	29.0	3	No	No
10	90	010	Pink...........	2	22.0	1	Light Brown..	2	12.0	8	No	No
8	126	010	Pink...........	0	35.0	3	Brown........	3	9.0	12	No	Yes

Table II—Concluded

Sample Number	COUNTY	Visible Impurities	Degree of Plasticity	Degree of Cohesion	Per Cent Water for Maximum Plasticity	Cracks in Air?	Slakes?
495	Weld	Sand	Fair	Weak	36.1	Badly	
496	Weld		Fine	Strong	37.4	Badly	
497	Weld		Good	Strong	43.4	Badly	5 M.
498	Weld		Fine	Strong	59.3	Badly	5 M.
499	Weld		Fine	Strong	43.0	No	10 M.
500	Weld		Fine	Strong	46.2	Badly	5 M.
501	Weld		Fine	Strong	39.3	Badly	10 M.
502	Weld		Fine	Strong	54.4	Very Badly	5 M.
503	Weld		Good	Weak	29.9	Badly	
504	Weld	Gypsum	Good	Strong	39.7	No	
505	Weld	Sand	Fair	Weak	30.3	No	20 M.
506	Weld	Limonite	Good	Strong	31.4	No	35 M.
507	Weld	Sand	Good	Strong	37.7	No	8 M.
508	Weld		Good	Strong	36.9	No	10 M.
509	Weld		Good	Strong	23.6	No	20 M.
510	Weld	Sand	Fine	Strong	32.0	No	35 M.
511	Weld	Alk. Sand	Good	Strong	25.6	No	?
512	Weld	Cal. Sand	Good	Strong	27.3	No	3 M.
513	Weld	Cal. Sand	Fair	Weak	30.6	No	No
514	Weld	Sand	Fair	Weak	36.8	No	8 M.
515	Weld	Sand	Good	Strong	33.8	No	8 M.
516	Weld	Sand Alk.	Fair	Weak	22.1	No	8 M.
517	Weld	Sand	Good	Weak	30.1	No	3 M.
518	Weld	Sand Cal.	Good	Weak	25.2	No	
519	Weld	Sand Cal.	Fair	Weak	27.0	No	3 M.
520	Weld	Limonite	Good	Strong	30.1	No	3 M.
521	Weld	Calcareous	Fair	Weak	38.9	No	15 M.
522	Weld	Calcite	Good	Strong	53.8	No	
523	Weld	Calcite	Good	Strong	33.7	No	40 M.
524	Yuma		Poor	Weak	60.3	No	1 hr.
525	Yuma	Peat	Poor	Weak	26.2	No	5 M.
526	Yuma		Fine	Strong	43.6	Badly	10 M.
527	Yuma	Alkali	Good	Weak	37.2	No	15 M.
528	Yuma	Calcite	Fine	Strong	28.5	No	5 M.

TABLE II—Concluded

Per Cent of Air Shrinkage	Tensile Strength Pounds	Incipient Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Vitrification (Cone Number)	Color	Per Cent of Fire Shrinkage	Per Cent of Absorption	Viscosity (Cone Number)	Burning Trouble?	Analysis?
8	130	05	Pink..........	2	12.6	5	Brown.......	5	2.0	12	No	No
7	156	010	Pink..........	0	19.4	3	Light Brown..	3	14.0	8	Possible	No
10	73	010	Pink..........	0	26.4	5	Gray.........	5	12.0	8	Probable	No
12	26	010	Yellow.........	2	20.4	5	Gray.........	2	7.0	8	Probable	No
12	50	010	Brick..........	0	10.8	5	Gray.........	2	3.0	8	No	No
11	77	010	Brick..........	1	12.5	5	Gray.........	1	5.0	8	Possible	No
11	125	05	Pink..........	0	11.8	3	Gray.........	1	20.0	8	Possible	No
10	25	010	Buff..........	0	36.8	1	Gray.........	2	24.0	8	Probable	No
6	37	1	Light Brown....	0	21.5	5	Gray.........	2	12.0	8	No	No
8	155	03	Pink..........	1	10.8	1	Brown.......	6	5.0	5	No	Yes
8	120	07	Pink..........	1	13.3	01	Brick.........	1	11.0	3	No	No
9	100	05	Pink..........	1	15.7	02	Brick.........	1	14.0	3	No	No
12	52	010	Brick..........	0	11.9	03	Gray.........	1	9.4	5	No	No
8	60	05	Pink..........	2	10.3	03	Dark Gray ...	3	12.6	3	No	No
9	59	05	Buff..........	3	15	03	Gray.........	3	15.8	8	No	No
7	102	03	Light Buff......	3	11.6	01	Gray.........	5	6.0	8	No	No
8	80	07	Pink..........	1	13.2	03	Brick.........	1	12.2	3	No	No
6	89	07	Brick..........	2	10	05	Gray.........	5	7.0	03	No	No
6	26	05	Brick..........	1	15.7	01	Gray.........	3	3.0	8	No	No
9	49	07	Brick..........	1	9.7	01	Gray.........	4	3.0	2	No	No
6	39	05	Pink..........	2	12.5	01	Gray.........	4	6.0	3	No	No
3	56	03	Buff..........	1	16.5	1	Gray.........	14	2.5	3	No	No
6	147	05	Pink..........	1	11.5	01	Dark Gray ...	4	5.4	1	No	No
2	83	03	Brick..........	2	14.5	4	Gray.........	3	1.5	5	No	No
5	89	3	Brick..........	3	15.4	5	Dark Gray ...	5	1.9	8	No	No
6	62	05	Pink..........	0	21.8	01	Gray.........	9	10.0	3	No	No
3	46	05	Brick..........	3	25.6	03	Brown.......	7	15.7	4	No	No
17	86	05	Brick..........	3	30.7	03	Brown.......	3	12.8	1	No	No
7	72	05	Pink..........	4	13.2	1	Brown.......	10	2.0	3	No	No
1	7	03	Pink..........	6	33.6	5	Gray.........	20	13.0	10	No	No
1	28	3	Gray..........	1	11.1	8	Gray.........	2	7.0	16	No	No
9	18	010	Brick..........	2	13.7	1	Brown.......	5	2.4	3	No	No
4	112	07	Brick..........	0	17.2	1	Gray.........	6	8	5	No	No
6	96	07	Brick..........	1	18.4	1	Brick.........	3	12	5	Possible	No

TABLE III

Sample Number	Ultimate Analysis (In percentages)											Rational Analysis (In percentages)						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on Ignition	Moisture	CO_2	SO_3	Total	Kaolin	Quartz	Feldspar	Limonite	Calcite	Gypsum	Total
4	65.40	16.91	2.69	1.65	Tr.	1.40	.32	7.36	3.42	......	Tr.	99.15	37.40	40.66	11.01	3.16	......	5.08	97.31
12	62.20	14.19	2.6	5.28	None	.63	.34	13.34	1.71	......	Tr.	100.35	32.60	42.75	6.08	3.02	......	16.30	100.75
15	57.76	18.65	3.75	2.80	.29	2.75	Tr.	9.68	3.52	......	Tr.	99.30	39.10	28.65	16.50	4.45	......	11.70	100.40
19	65.97	16.02	4.28	1.46	1.47	1.80	.18	8.13	.22	......	......	99.53	34.90	41.74	12.18	5.00	2.62	......	96.44
22	69.16	19.82	1.53	.99	Tr.	1.98	Tr.	6.58	.60	......	Tr.	100.65	44.50	41.32	11.75	1.76	......	3.05	102.38
28	62.23	17.65	2.35	.82	.62	1.38	.67	12.13	1.60	......	......	99.45	38.10	35.23	18.83	2.75	1.47	......	96.38
30	62.54	19.53	3.32	.82	.82	1.53	Tr.	9.08	1.66	......	......	99.30	45.01	35.39	9.05	3.87	1.47	......	94.79
39	57.73	21.24	4.01	.81	1.21	1.87	.31	10.45	2.74	......	Tr.	100.37	47.30	26.67	23.19	4.18	......	2.50	93.84
43	48.09	14.23	3.88	12.23	1.97	2.10	.10	14.93	1.00	......	Tr.	98.53	29.85	25.58	13.27	4.53	......	37.80	111.03[1]
45	74.67	14.54	1.66	.65	.63	1.59	.15	5.50	.70	......	......	100.09	31.90	52.90	10.75	1.99	1.16	......	98.80
46	58.97	19.27	5.58	.57	1.10	1.01	.21	11.16	2.08	......	......	99.94	45.10	32.94	7.68	6.53	1.02	......	93.27
47	54.30	15.02	9.48	4.08	2.86	2.64	.43	9.11	1.68	......	Tr.	99.60	28.83	18.20	19.22	11.08	......	12.58	99.91
48	72.89	16.87	.18	1.06	.81	2.24	2.80	1.89	.28	......	......	99.02	24.80	36.41	37.00	.21	1.90	......	100.32
49	63.92	15.90	4.10	2.53	2.26	.25	2.23	6.79	1.52	......	......	99.50	30.10	36.01	20.38	4.80	4.53	......	95.82
50	60.31	15.76	5.69	2.20	2.21	2.63	.78	7.72	1.94	......	Tr.	99.24	29.35	32.01	21.67	6.68	......	6.77	96.48
55	66.31	13.69	4.41	2.28	1.58	2.22	1.19	6.40	1.68	......	......	99.76	23.55	39.86	23.22	5.16	4.08	......	95.87
56	61.38	15.80	5.50	2.53	2.55	1.82	1.05	7.87	1.85	......	Tr.	100.29	30.60	33.99	19.65	6.43	......	7.80	97.87
57	61.05	20.18	3.47	1.14	1.14	2.18	Tr.	9.09	1.76	......	Tr.	100.01	45.10	31.70	12.90	4.06	......	3.51	97.27
58	72.50	17.11	.74	.84	.20	3.73	.26	3.01	.82	......	......	99.19	32.38	40.59	24.31	.83	1.50	......	99.61
66	61.30	15.03	4.67	2.45	2.23	3.54	.18	9.62	.77	......	Tr.	99.79	27.60	33.70	22.32	5.47	......	7.55	96.69
76	62.55	16.00	5.55	2.04	1.90	2.79	Tr.	7.33	1.36	......	Tr.	99.52	32.80	36.53	16.50	6.50	......	6.28	98.61
109	58.86	24.64	4.11	.24	.74	3.03	Tr.	8.50	.45	......	......	100.57	53.80	22.30	17.75	4.80	.43	......	99.08
115	63.00	21.76	2.29	.16	.81	1.51	Tr.	9.57	1.57	......	Tr.	100.67	50.80	33.55	8.87	2.69	......	.62	96.53
120	64.73	19.36	2.19	.81	1.97	.48	Tr.	10.42	.37	......	......	100.33	47.50	40.58	2.95	2.58	1.45	......	95.06
122	72.35	14.64	2.16	.81	1.01	2.94	Tr.	6.04	.29	......	Tr.	100.24	28.80	47.90	17.20	2.58	......	2.47	98.95
123	67.04	17.60	2.05	1.48	.98	.61	.22	5.32	2.99	......	Tr.	98.29	42.00	43.78	5.5	2.34	......	3.39	99.01
135	62.14	24.30	1.15	1.32	1.45	1.11	Tr.	6.39	2.80	......	Tr.	100.66	58.70	30.65	6.53	1.40	......	4.07	101.35
145	58.18	14.42	6.63	3.13	4.89	2.29	.31	6.53	3.50	......	......	99.88	28.80	34.20	16.15	7.72	......	9.95	96.92
147	56.91	29.04	3.92	1.90	2.64	.62	.23	4.20	.70	......	......	100.16	69.20	18.65	7.78	4.58	3.40	......	103.61
148	84.60	9.50	.27	......	1.0	.07	.50	3.88	.09	......	......	100.52	20.70	71.29	4.66	.30	......	......	96.95

149	59.34	10.91	9.14	2.63	3.08	2.12	.59	7.76	3.05	......	1.28	99.90	19.25	38.80	17.59	10.6	......	8.00	94.24
152	59.66	17.33	3.66	1.47	2.03	1.70	.25	9.15	3.11	......	.82	99.18	37.70	33.83	12.60	3.63	......	4.62	92.38
156	66.00	10.94	2.51	2.80	2.45	1.47	Tr.	8.95	3.78	......	1.14	100.04	23.30	49.45	8.86	2.93	......	8.62	93.16
158	56.92	24.16	4.34	.49	1.92	3.48	2.10	5.39	.57	......	......	99.37	42.80	22.38	38.50	5.03	.89	......	109.60
165	59.50	25.41	2.29	.65	1.65	3.13	Tr.	6.43	1.57	......	......	100.63	55.70	21.65	18.30	2.69	1.16	......	99.50
169	59.02	24.59	5.76	.39	......	.67	Tr.	9.37	.70	......	......	100.50	60.20	28.22	4.25	6.83	1.20	......	101.20
171	56.50	29.10	3.29	.60	Tr.	.25	Tr.	9.81	.70	......	Tr.	100.25	72.80	21.54	1.48	3.86	......	1.07	100.75
173	52.39	31.91	1.84	.99	......	Tr.	Tr.	11.34	.87	......	......	99.34	80.70	14.70	......	2.22	3.05	......	100.67
175	72.56	17.86	1.14	.49	.90	Tr.	.73	6.83	.57	......	Tr.	101.08	42.30	48.65	6.18	1.40	......	.89	99.42
192	63.14	23.46	.69	.49	.12	.38	.23	11.13	.74	......	Tr.	100.38	42.80	24.91	24.45	.88	......	1.54	94.58
203	48.80	35.70	5.20	1.05	Tr.	←—	10.25		—→	......	......	101.00	......	......	......	......	......	......	......
205	61.08	13.15	3.20	5.59	3.86	3.54	.62	9.39	1.20	......	Tr.	101.63	16.90	33.96	26.71	3.75	......	17.25	98.57
206	65.44	7.46	1.14	5.76	7.30	1.45	Tr.	11.02	.32	......	.42	100.21	14.90	52.80	8.86	1.41	......	17.80	95.77
209	52.57	17.80	6.85	4.77	3.95	5.22	.15	8.59	.95	......	Tr.	100.85	30.00	17.83	35.27	8.07	......	14.80	105.97
211	71.02	14.06	5.94	1.26	2.47	.65	.79	3.89	1.32	......	Tr.	101.40	32.00	49.57	10.90	6.90	......	4.00	103.37
213	52.63	23.15	1.60	3.62	2.75	4.13	Tr.	8.82	4.41	......	......	100.91	47.00	14.50	24.80	1.87	6.45	......	94.62
218	60.81	16.22	3.88	2.64	.47	2.20	.85	9.38	1.37	......	......	97.82	31.40	32.82	20.26	4.57	4.83	......	93.88
220	50.60	35.59	.91	.32	1.18	.47	Tr.	10.07	1.86	......	......	101.00	88.50	6.27	2.96	1.05	.53	......	99.31
224	66.42	21.19	2.98	2.35	1.03	2.83	1.83	5.15	......	......	......	100.80	38.20	17.20	32.28	3.49	4.20	......	95.37
225	61.69	19.55	3.65	1.25	2.32	2.40	1.04	9.50	2.34	......	......	101.40	38.30	28.47	23.04	4.33	2.24	......	96.38
226	60.91	18.77	4.39	1.36	3.24	2.19	1.05	7.16	1.40	......	......	100.47	37.00	29.02	21.93	5.15	2.50	......	95.60
231	67.09	17.67	2.88	2.20	Tr.	1.85	Tr.	7.22	1.44	......	.20	100.51	39.70	41.48	10.98	3.39	......	6.78	102.33
235	50.93	32.79	1.46	.66	Tr.	Tr.	Tr.	11.28	1.32	......	Tr.	98.44	83.00	13.20	......	1.75	......	1.25	99.20
241	61.39	25.97	1.33	1.35	......	.46	.46	9.77	.46	......	......	100.73	62.50	30.16	6.62	1.64	......	2.50	103.42
256	70.67	15.70	3.65	.76	.87	1.30	Tr.	5.91	1.09	......	Tr.	99.95	36.20	49.09	7.68	4.98	......	2.34	100.29
257	75.07	13.93	1.37	1.13	1.56	1.45	Tr.	5.84	1.39	......	Tr.	101.74	31.22	54.65	9.46	1.64	......	3.40	100.35
258	72.16	15.58	1.37	1.06	1.01	1.22	.63	5.20	1.67	......	Tr.	99.90	33.60	48.40	12.20	1.64	......	3.40	99.24
267	71.44	18.72	1.38	.41	.56	.11	.037	6.15	.55	......	......	99.39	46.80	48.90	1.00	1.62	.72	......	99.13
268	73.32	13.26	3.54	.51	.49	.29	.35	6.54	.72	......	......	99.02	35.40	55.57	24.69	4.14	.91	......	100.71
269	66.46	18.49	3.26	.41	Tr.	.28	Tr.	9.00	.61	......	......	98.51	46.10	43.86	1.66	3.82	.72	......	96.16
270	66.45	21.65	1.65	.57	.78	.11	1.13	7.63	.61	......	......	100.58	49.70	35.90	10.83	1.99	1.02	......	99.44
271	70.86	13.93	5.92	.65	.91	.44	.47	7.08	.25	......	......	100.51	32.60	51.44	6.61	6.93	1.16	......	98.74
272	63.29	20.93	2.42	1.05	.97	1.65	Tr.	8.76	.76	......	Tr.	99.83	48.40	34.48	9.75	2.82	......	3.08	98.53
273	60.66	19.84	3.26	2.15	1.00	3.16	.18	8.80	.80	......	......	99.85	40.50	28.54	20.68	3.86	3.94	......	97.52
274	63.05	13.83	3.42	3.83	1.00	2.61	......	11.60	1.40	......	......	100.74	27.70	40.20	15.40	3.98	6.80	......	94.08
275	73.17	16.63	.62	1.45	Tr.	1.50	.23	6.07	1.90	......	......	100.42	37.00	49.07	8.65	.70	2.68	......	98.10

[1] Some of the lime should have been calculated to calcite.

TABLE III—Concluded

	Ultimate Analysis (In percentages)												Rational Analysis (In percentages)						
Sample Number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on Ignition	Moisture	CO_2	SO_3	Total	Kaolin	Quartz	Feldspar	Limonite	Calcite	Gypsum	Total
276	65.17	16.73	3.07	4.64	.90	1.80	.27	6.52	1.42	......	......	100.52	24.80	45.05	13.28	3.63	8.24	......	95.00
277	66.50	19.52	2.33	.91	Tr.	2.66	.18	6.79	1.90	......	Tr.	100.79	41.00	36.04	17.78	2.69	......	2.78	100.29
278	60.79	16.88	3.12	3.73	1.00	2.05	.54	10.50	1.87	......	......	100.48	35.10	33.44	16.64	3.63	6.62	......	95.43
279	53.17	17.36	2.74	3.22	3.65	2.31	.28	13.39	1.85	......	......	97.97	36.50	25.63	16.28	3.16	5.73	......	87.30
280	64.86	20.00	2.55	1.95	2.30	3.02	.24	5.01	2.37	......	......	102.30	41.40	32.71	19.94	3.04	3.49	......	100.58
281	65.77	12.69	3.16	1.14	.95	2.79	2.19	7.18	3.39	......	......	99.26	35.30	35.20	18.56	3.74	1.97	......	94.77
282	73.23	13.98	2.12	1.83	.80	1.07	.18	5.95	1.75	......	......	100.91	31.80	53.41	7.70	2.46	3.22	......	98.59
283	66.53	17.18	3.62	1.50	1.45	2.16	.15	6.73	1.65	......	......	100.97	34.30	41.18	14.34	4.20	2.68	......	96.70
284	63.61	17.43	3.37	2.11	......	.98	.05	8.88	3.17	......	......	99.60	41.00	40.28	6.34	3.98	3.76	......	95.36
285	69.05	14.78	2.72	2.93	.72	.42	.18	7.20	2.14	......	......	100.14	35.60	49.77	4.09	3.16	5.18	......	98.80
286	73.61	13.56	2.44	1.39	.38	1.09	.36	5.65	1.90	......	......	100.38	29.90	53.37	9.58	2.93	2.50	......	98.38
287	63.69	16.20	3.90	2.77	1.15	2.73	......	7.11	3.04	......	......	100.59	33.60	37.65	16.20	4.57	5.02	......	97.04
288	68.02	13.90	3.65	2.28	.90	1.52	.28	8.73	.49	......	Tr.	99.77	29.80	46.85	11.40	4.27	......	7.08	99.40
289	71.69	10.89	2.91	2.93	1.03	1.78	.23	6.27	1.36	......	......	100.09	21.60	53.38	12.63	3.41	5.24	......	96.26
290	69.48	12.44	4.56	2.11	.61	1.36	.30	7.49	1.61	......	......	99.96	26.50	50.16	10.62	5.38	3.77	......	96.43
291	71.30	13.56	4.39	.98	.82	1.24	.19	6.44	1.46	......	......	100.38	30.10	51.40	8.97	5.15	1.75	......	97.37
292	64.66	18.96	4.44	1.22	1.26	.12	.27	8.62	.65	......	......	100.20	46.51	40.92	3.00	5.27	2.18	......	97.88
293	51.23	33.26	.54	.91	......	.17	.31	13.14	.53	......	......	100.09	82.40	10.35	2.73	.63	1.63	......	97.74
294	66.03	16.50	4.10	1.30	.91	.40	.18	7.99	1.85	......	......	99.26	39.70	44.82	4.90	4.82	2.32	......	96.56
295	63.14	15.21	3.39	3.20	2.61	2.70	.78	7.32	.84	......	......	99.19	27.78	35.35	22.62	3.98	5.72	......	95.46
310	63.48	13.16	4.44	5.22	.53	1.63	.93	7.43	1.83	......	Tr.	98.65	25.00	40.19	17.53	5.20	......	16.01	103.93
313	58.77	18.33	6.37	1.95	.91	3.13	.46	8.71	2.02	......	Tr.	100.65	35.80	27.34	22.40	7.45	......	6.00	98.99
314	34.92	9.73	4.21	10.00	15.10	1.22	.62	19.82	2.52	......	......	99.50	18.65	17.94	12.49	4.93	49.43[1]	......	103.44
316	60.36	14.82	1.38	7.74	1.29	.61	.20	11.24	1.95	......	......	99.58	35.00	40.55	5.30	1.61	13.85	......	96.31
317	74.25	11.48	1.02	5.05	.78	1.97	Tr.	4.43	.97	......	......	99.95	23.70	55.70	11.60	1.19	......	15.50	107.69
320	24.85	8.41	.79	32.68	1.06	1.22	Tr.	30.04	.55	......	Tr.	99.60	17.90	11.81	7.22	.92	58.49	......	96.34
323	74.90	12.07	4.08	.73	.65	2.46	Tr.	3.74	.83	......	......	99.46	23.80	59.25	14.50	4.78	1.30	......	103.63
330	61.49	15.51	3.59	3.74	2.35	2.87	Tr.	9.43	.86	......	......	99.84	31.30	35.90	16.95	4.20	......	11.50	99.85
332	60.01	14.45	3.75	5.29	1.41	3.15	Tr.	10.36	1.27	......	.43	100.12	28.00	34.82	18.60	4.49	......	16.30	102.21
334	59.36	18.40	5.20	.98	1.23	2.03	Tr.	10.42	1.57	......	Tr.	99.19	39.50	31.01	15.40	6.08	......	3.02	95.01

353	61.91	18.00	5.01	4.24	1.49	1.40	2.54	3.60	.35	......	......	100.13[1]	31.50	27.25	7.60	......	......	5.86	102.04
387	59.47	21.26	3.59	1.65	Tr.	2.00	Tr.	9.45	2.87	......	......	100.29	48.40	29.39	11.84	4.20	3.40	......	97.23
390	59.97	21.52	4.38	4.13	Tr.	2.22	.58	9.21	.85	......	Tr.	100.86	45.80	25.69	47.97	2.15	......	12.93	104.54
394	65.02	20.25	3.20	1.15	2.64	1.29	.45	4.78	2.44	......	......	101.22	45.50	35.76	11.94	3.74	2.15	......	99.09
396	63.44	16.28	4.51	.82	1.38	2.12	1.02	3.85	5.69	......	......	99.17	30.10	34.52	22.35	5.38	2.52	......	94.87
407	65.34	14.56	3.69	2.87	.59	2.31	.53	8.03	.89	......	Tr.	98.81	28.50	40.25	18.14	4.33	......	8.94	100.16
421	63.67	17.20	3.85	.99	Tr.	2.45	.78	8.01	2.08	......	Tr.	99.03	33.20	37.95	21.56	4.45	......	3.08	100.24
426	74.49	16.37	1.63	.66	.21	1.40	Tr.	5.00	.40	......	Tr.	100.16	37.60	51.65	8.30	1.87	......	2.16	101.58
445	50.35	16.47	2.68	7.42	Tr.	1.55	.44	16.62	1.81	......	1.60	98.94	35.60	25.30	12.80	3.14	......	22.80	99.72
466	58.85	15.56	3.20	4.30	3.00	3.25	Tr.	6.90	2.09	......	2.82	99.70	30.18	30.10	19.55	3.74	......	13.25	96.82
467	50.36	19.38	2.17	7.95	1.50	2.88	.15	14.32	.60	......	......	97.81	40.45	19.55	18.47	2.58	......	24.50	105.55
468	38.30	13.90	2.66	17.36	2.46	2.05	.24	21.95	.75	......	2.27	101.94	26.00	4.35	14.34	3.11	......	53.80	101.60
469	58.83	18.77	3.48	3.11	2.14	2.50	.97	9.00	1.49	......	Tr.	100.35	36.60	26.55	23.05	4.09	......	9.55	99.84
470	56.05	28.84	1.91	......	1.00	3.73	.08	7.96	.99	......	......	100.66	62.20	13.23	27.78	2.22	......	......	105.43
471	63.15	21.48	2.12	1.22	.31	3.16	.12	7.80	1.90	......	Tr.	101.26	45.30	29.31	19.77	2.48	......	3.73	100.59
480	68.40	13.93	2.62	2.87	.44	.89	.94	7.74	.36	......	......	98.19	28.80	46.21	12.94	3.40	5.20	......	96.55
482	35.10	11.48	1.87	21.61	.68	1.72	.42	25.18	.27	......	.32	98.65	22.80	15.69	13.80	2.22	......	66.50	101.09
494	59.08	20.53	3.62	.66	......	1.51	.23	11.39	2.08	......	Tr.	99.10	46.80	30.22	10.83	6.45	......	2.04	96.34
504	62.00	15.50	4.30	2.18	.44	2.81	.62	7.42	2.00	......	......	97.27	28.90	34.24	21.86	5.03	......	6.78	96.81

[1]Dolomite.

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