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**STATE OF IDAHO**

D. W. DAVIS, *Governor*

**BUREAU OF MINES AND GEOLOGY**

FRANCIS A. THOMSON, *Secretary*

**A PRELIMINARY REPORT**  
**ON**  
**THE CLAYS OF IDAHO**

BY FRANK H. SKEELS

**CLAYS TESTED**

Under the Direction of

HEWITT WILSON

Consulting Ceramist, U. S. Bureau of Mines

(Published in Cooperation with the U. S. Bureau of Mines)



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# A PRELIMINARY REPORT ON THE CLAYS OF IDAHO

By FRANK H. SKEELS, with Clay Tests by HEWITT WILSON.

## INTRODUCTION

This report represents a cooperative investigation undertaken jointly by the U. S. Bureau of Mines and the State Bureau of Mines and Geology of Idaho.

It is preliminary in character and is to be followed later by a more complete report on the commercial possibilities of those clays which this investigation has demonstrated as being of particular merit. It is evident that Idaho has important clay resources which are only beginning to be developed.

Field work was begun by Mr. Skeels on August 21, 1919, and was carried on until November 1, 1919, when outside work was discontinued on account of snow.

The schedule of the field examinations was so arranged that the entire state was covered in a general way and as many deposits in each locality examined and sampled as was possible in the time available. A number of deposits of clay, shale and limestone thruout the state could not be visited at the time and these are consequently left for future examination and a later bulletin.

In connection with the field work on the clays, certain shales and limestones with cement-making possibilities were also examined and sampled. The data, however, are withheld from this bulletin with the expectation of publishing in the near future a separate bulletin covering the cement making resources of the state.

The testing of the clay samples was done under the direction of Mr. Hewitt Wilson, consulting ceramist, U. S. Bureau of Mines, in the laboratory of the School of Mines of the State University. The cone fusion tests were made in the ceramic laboratory of the College of Mines, University of Washington. All chemical analyses were made by Mr. J. H. Jonte, State Bureau analyst, unless otherwise stated.

The main body of the report is the work of Mr. Skeels, the tests and the conclusion drawn from them are to be credited to Mr. Wilson, to whom and to Dr. R. T. Stull of the Ceramics

Station of the U. S. Bureau of Mines at Columbus, Ohio, the State Bureau is deeply indebted for careful, painstaking and constructive criticism of the descriptive matter of the report. Without their careful scrutiny this bulletin would have lacked most of whatever merit it may possess.

The State Bureau acknowledges also its indebtedness to the brickmen of Idaho and of Spokane, as well as to the Chambers of Commerce throuout the state.

FRANCIS A. THOMSON,  
Secretary and Executive.

## PART I.

## NATURE AND ORIGIN OF CLAYS

**CLAY DEFINED.** Clay is one of the most abundant of natural materials. It is widely distributed and occurs in some form in almost every locality. On account of its properties, clay is capable of being used for a great many different purposes. Clays differ widely in both chemical and mineralogical composition.

The term clay as generally used is broad, and includes a large variety of materials, nearly all of which, when mixed with water, become plastic, can be molded into various shapes which they retain when dry, and when fired at 950° C. or higher become sufficiently hard and permanent to stand weathering conditions. Certain flint clays, however, exhibit no plastic qualities.

The economic or commercial value of a clay is based on its physical properties, and mainly on its plasticity, since this is the property first considered by the clay worker. All other properties simply determine the particular use of a certain clay.

**ORIGIN OF CLAYS.** Clays are always of secondary origin and are produced by the decomposition of various kinds of rocks. The character of the clay depends, of course, upon the presence or absence of certain minerals in the rock from which the particular clay is derived.

A **RESIDUAL CLAY** is one that occurs in the place of the original or parent rock from which it is formed. When formed by the decomposition of an igneous rock, there is in residual clay a gradual transition from the soft clay near the surface to the hard, unaltered, parent rock at depth. A residual clay generally contains fewer impurities than a clay that has been transported for a greater or less distance. In a residual clay above limestone, the change from clay to rock is plainly defined. Such a clay is formed, not from the limestone proper, but from the insoluble impurities contained in the limestone, and these accumulate directly above unchanged limestone as a result of the gradual decomposition of the latter by percolating surface waters.

A **TRANSPORTED CLAY** is one which has been removed, by water, ice or wind, from the place in which it was first formed, carried a greater or less distance, and then deposited. The final deposition may be in the bed of a stream, in a lake, in the ocean or on land surfaces. These clays are more or less stratified, with clays of different character mixed in the same deposit, and may cover either a wide or a comparatively narrow zone. The largest deposits are undoubtedly those formed in lakes or seas from silt-bearing water. Transported clays, although containing a larger amount of impurities, are more plentiful, and the value of the products derived from them is greater than that of the

products from residual clays. The difference in manner of deposition does not necessarily imply that the residual and transported clays differ in appearance, properties and uses. Except by noting the manner of occurrence it is sometimes hard to distinguish one from the other.

### PHYSICAL PROPERTIES OF CLAYS

As regards commercial or economic value, physical properties are the most important factor in determining the usefulness of a clay. Different clays used for the same purpose may differ chemically, likewise, of two clays having similar chemical analyses, one may be adapted for a certain purpose for which the other is unsuitable. From the above it is evident that the chemical analysis alone may not determine the usefulness of a clay.

The physical properties of a clay can be determined only by physical tests, although some physical properties may be predicted from chemical analysis. For convenience physical properties may be discussed under two heads, (1) those of raw clays, (2) those developed during burning.

#### I. Physical Properties of Raw Clays.

**OCCURRENCE.** Altho the occurrence of a clay is not a physical property, yet as regards economic value it is indispensable to know the size, condition, formation, strike and dip of a deposit, since these will have a considerable bearing on the methods to be used in extraction.

**COLOR.** The color of a raw clay will not always indicate the color of the finished product altho it will often give a good idea of what may be expected.

**SLAKING.** A substance that cracks, breaks, and separates into small particles when brought into contact with water, is said to slake. Some clays, as taken from the bank, when placed in water will crack and break into large pieces, which in turn will break up into smaller and smaller particles, while others will first swell and then slowly crumble away, while still others will disintegrate into a lumpy mass which may have to be pulverized. A clay that will slake readily can be handled with less expense than one which does not. Clays are often spread out and allowed to weather, which not only assists slaking, but may allow certain soluble salts that impair the value of the clay, to be leached away.

**STRENGTH.** The tensile strength of a clay enables it to resist being pulled apart when air dried. A good plastic strength is needed for molding, and the higher the strength when air dried the better it is for burning, and the less the loss from handling. It is one of the most important physical properties of a clay for it enables a clay to be used for purposes for which it could

not be used if without tensile strength. The most common method for determining the strength of dry and of fired clay samples is by transverse breaking tests.

**BONDING POWER.** This is the physical property that enables a clay to hold non-plastic material and make the whole mass plastic. It is a very important property in the manufacture of fire clay and other refractory wares. A method of obtaining an indication of the bonding power of a clay consists of mixing the clay with its weight of standard Ottawa silica sand 20 to 30 mesh, and determining the transverse strength of the dry mixture after molding into test bars.

**DRYING SHRINKAGE** results from the evaporation of the moisture separating the particles of a clay and the contraction of the colloidal matter, that abounds in most clays. It is a very important physical characteristic, since high shrinkage usually causes more or less distortion of the ware. High shrinkage can be lowered by "grogging" the clay. (Mixing with sand or other non-plastic material.)

**FINENESS OF GRAIN** can be determined roughly by the "feel" of the clay. This property has considerable bearing on plasticity, shrinkage and fusibility, and on the speed with which the ware may be dried. The finer the grains, the more plastic is the clay, which may be desirable; on the other hand the higher is the air and fire shrinkage, which is not desirable. The texture, or fineness of grain is an important factor in the burning of the ware. In a coarse grained ware there is less danger of injury to the ware during burning because the gases can escape more readily. From the foregoing, it is readily seen that fineness of grain has an important bearing on the value of a given clay.

**PLASTICITY** is one of the most important properties of clay; without it the ordinary clay wares produced by the wet process could not be manufactured. It is the property that permits a clay to be molded in any form desired. Plasticity is of lesser importance when the dry press process is used. The plasticity of most clays can be improved by weathering and by fine grinding. To develop the maximum degree of plasticity requires the addition of from 14% to 50% water to the dry clay, although 30% would more nearly represent the usual maximum water content.

## II. Properties Developed During Burning.

**DEHYDRATION.** Water Smoking. The so-called "Water smoking" occurs at or below 250° C. Decidedly important physical and chemical changes occur between 450° and 950° C. such as dehydration of the clay, dissociation of carbonates and sulphides if present, distillation and burning out of carbonaceous



matter, and oxidation of ferrous to ferric iron in the presence of excess air. This is a critical stage in burning certain low-grade clays and shales and it must be watched carefully before the temperature of the kiln is raised to the vitrification point.

**INCIPIENT VITRIFICATION.** The next change that takes place on firing is the softening, or fusing, of a part of the ingredients to such an extent that the whole mass is bound together, has almost completed its shrinkage, and has attained a hardness of approximately 6.0 or about equal to that of quartz. It has then reached the stage of incipient vitrification.

**VITRIFICATION.** When a clay has been heated from 25 degrees to 200 degrees C. above the first stage, it has become more dense, has finished shrinking and has hardened to 7.0. The grains have fused sufficiently to run together and close the natural pores of the mass, leaving the ware smooth with a slight lustre but no deformation. The clay has then reached the stage of complete vitrification.

**FUSION OR DEFORMATION.** When a clay has been heated to such a temperature that it softens, flows, and loses its form, it is said to be viscous, or to have reached its fusion point. The determination of the fusion or deformation point is important in determining the quality of the clay. A high fusion temperature is the principal requisite of a true fire clay. When a vitrified ware is desired the vitrification and fusion temperatures should be at least 100 degrees C. apart.

### CLAY MINERALS AND THEIR INFLUENCE

Altho clays contain a number of minerals, only a few important ones will be mentioned in this chapter.

KAOLINITE is generally considered as the base of all clays.\* It is a hydrous silicate of aluminum of definite composition ( $\text{Al}_2\text{O}_3$ ,  $2\text{SiO}_2$ ,  $2\text{H}_2\text{O}$ ) and contains 46.3 per cent silica, 39.8 per cent alumina and 13.9 per cent water.

Kaolin is an impure, amorphous form similar in composition to the mineral kaolinite. The commercial varieties, called kaolins or china clays, when purified are used for white ware and in paper manufacture. Unrefined kaolin may contain quartz, mica, beryl, tourmaline or undecomposed particles of feldspar from which most kaolin is supposed to have formed. Kaolins are usually soft, white, light cream, or grey clays having a sticky plasticity but feeble dry strength. Such material is found in all stages of kaolinization from the hard feldspar rock to the soft clay masses. The purest kaolins fuse at cone 35 or approximately  $1735^\circ\text{C}$ .

SILICA is silicon dioxide ( $\text{SiO}_2$ ). contains 46.7 per cent silicon and 55.3 per cent oxygen, and is usually present in clays. It occurs in very small grains, which may be either transparent, translucent and colorless, or superficially colored red or yellow by iron oxide.

The amount of silica (not necessarily quartz) in clays ranges from 34 per cent to 90 per cent. The proportion of silica greatly affects the plasticity, tensile strength, and shrinkage of a ware. The greater the proportion of silica present, the less the plasticity and tensile strength of the ware, which is undesirable; on the other hand, the greater the amount of silica, the less the shrinkage will be, which may be desirable. An excessive amount of quartz sand in clay is often a cause of cracking in firing and cooling. It is due to expansion on conversion of quartz at critical temperatures to tridymite or cristobalite on "heating up" or to sudden contraction at the critical temperature or partial reversion on "cooling down."

Altho silica fuses only at high temperatures, its addition to a basic clay lowers the fusion temperature; consequently a high per cent of silica is not desirable in a clay to be used as a refractory.

FELDSPAR. There are several kinds of feldspar. The ones usually found are, orthoclase (microcline), a potassium, aluminum silicate containing 18.4 per cent alumina and 16.9 per cent potassium oxide, and plagioclase, an aluminum silicate in which the potassium is replaced by either sodium or lime

\* There is a remarkable lack of unanimity as to the use of the words "Kaolin," "Kaolinite," "Clay Substance," and "Clayite." The usage of this report appears to correspond with that of the majority of American ceramists. F. A. T.

or both. Albite, the soda feldspar is also important. All feldspars, however, contain silica and alumina, with more or less sodium (soda), potassium (potash), or calcium (lime), and consequently they are the principal source of the fluxing elements\* found in clays.

The feldspars occur in various sized, colorless, red, pink, or white grains. They are softer than quartz and decompose more rapidly. When they have decomposed the product is kaolin, a mixture of so called kaolinite and sand. They resemble quartz in tending to decrease the amount of plasticity, tensile strength and air shrinkage. The feldspar content tends to lower the temperature of vitrification and fusion.

IRON exists in almost all clays either in the form of limonite, hematite, magnetite, siderite or pyrite, and is the principal cause of the color in clays.

Limonite, an oxide of iron, ( $\text{Fe}_2(\text{OH})_2\text{Fe}_2\text{O}_3$ ) contains 59.8 per cent iron, is soft, resists atmospheric agencies and causes the yellow or brown color found in clays. During burning under oxidizing conditions limonite changes to hematite, which is also an oxide of iron ( $\text{Fe}_2\text{O}_3$ ) with 70 per cent iron. It is responsible for the deep red color found in clays.

Magnetite, also an oxide of iron, ( $\text{Fe}_3\text{O}_4$ ) containing 72.4 per cent iron, is black in color, magnetic, and like hematite may change to limonite on weathering. Siderite, a carbonate of iron, ( $\text{FeCO}_3$ ) containing 62.1 per cent iron, is found in some clays and especially in shales. It is often blue or greenish blue in color, and on exposure to atmospheric agencies changes to limonite.

Pyrite, the disulphide of iron, ( $\text{FeS}_2$ ) containing 46.7 per cent iron, occurs in some clays. It is yellow in color, has a metallic lustre, and generally occurs in the form of cubes.

Iron compounds occur in two different forms, known as the ferrous and the ferric states. Limonite and hematite contain the iron in the ferric condition, magnetite contains iron in both states, and siderite and pyrite contain iron in the ferrous state.

The ferric iron in limonite and hematite gives to the clay brown, yellow and red colors, whereas the blue and blue-green colors come from the ferrous iron.

Regardless of the form of the iron in a clay, it will change when burned in an oxidizing atmosphere to the ferric state, unless the temperature is raised to the point of vitrification. According to Ries\*\* the color and depth of shade produced by iron

\* By fluxing elements is meant those substances which exercise a marked influence in lowering the fusion point of the clay. Potash and soda are especially active in this respect.

\*\* Geological Survey of New Jersey, Vol. I, p 57.

in burning clays will depend, upon: (1) the amount of iron in the clay; (2) the temperature of burning; (3) condition of the iron oxide: and (4) the condition of the kiln atmosphere.

Clays free from iron usually burn white, those with a little iron present burn cream or buff, and as the proportion of iron increases, the color changes to buff and then to red, if the lime and magnesia content is low.

LIME is a common constituent of most clays and the amount present is an important factor in determining the use of a clay. Lime usually occurs in the form of the carbonate, calcite, ( $\text{CaCO}_3$ ) containing 56 per cent lime, or calcium oxide; in the form of the hydrous sulphate, gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) containing 32.5 per cent calcium oxide; or as a silicate in the feldspar.

Calcite and gypsum are not harmful for many common uses if they are present in minute particles, evenly distributed, and in not too great amount.

Lime acts as a flux, lowers vitrification and fusion points, increases fire shrinkage, and makes slow, careful burning necessary. The soluble lime salts, principally the sulphate, may work to the surface causing a white coating or discoloration on the ware.

MAGNESIUM occurs in some clays in the form of carbonate, probably as the double carbonate of calcium and magnesium (dolomite), ( $\text{CaCO}_3 \cdot \text{MgCO}_3$ ), or as hydrous magnesium sulphate, ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ). The amount present, however, is usually very small. Magnesium compounds act as fluxes, soften slowly, and may have a slight bleaching action upon iron coloration.

ALKALIES occur usually in the form of silicates, rarely as some soluble potash or soda salt.

Manganese compounds and titanium compounds are frequent constituents of clays, but usually in minute amounts.

Hygroscopic water and organic matter are usually present and are of course eliminated in the burning process.

### CLASSIFICATION OF CLAYS

There are several different classifications of clays. One is based on origin; another on the uses to which the different clays are put. In another, chemical and mineralogical composition are used as a basis, and a fourth system is based on physical properties.

H. A. Wheeler's classification of clays is based on the purpose for which each is to be used.

#### I. WHITE WARE.

Kaolin

China clay

Ball clay

II. REFRACTORY.

Plastic fire clay

Flint clay

Refractory shale

III. POTTERS.

Plastic clay and shale of moderate fusibility

IV. VITRIFYING.

Paving brick clay and shale

Sewer pipe clay and shale

Roofing tile clay and shale

V. BRICK.

Common brick clay and shale

Terra cotta clay and shale

Drain tile clay and shale

VI. GUMBO.

Burnt ballast clay

VII. SLIPS.

Clays of easy fusibility

Hewitt Wilson, consulting ceramist for the U. S. Bureau of Mines, suggests the following classification for this section, based on uses.

A. WHITE WARE.

1. Kaolin or china clay

2. Ball clay

These clays form but a portion of the synthetic white ware composition used for table ware, floor and wall tile, chemical porcelain, electric insulators, etc. The kaolins are purified by washing. The ball clays are merely sorted during mining.

B. REFRACTORIES.

1. Plastic fire clays (unpurified kaolins of Idaho are used for refractory purposes.)

Kaolins and ball clays are also refractory clays.

2. Flint fire clays (not siliceous clays, but those fire clays having a natural, dense, "flinty" structure.)

C. CRUDE POTTERY WARE.

1. Plastic buff and red burning clays used for baking dishes, yellow bowls and general kitchen and household purposes.

2. Stoneware clays. Plastic buffburning clays fired to a high degree of vitrification for general household and chemical stoneware uses.

D. ART WARE.

1. Plastic white, buff and red burning clays for general

art purposes. The value of such ware depends primarily upon the artistic ornamentation.

E. STRUCTURAL WARE. (Buff, red or dark burning)

1. Common brick clays.
2. Face brick clays.
3. Paving brick clays.
4. Roofing tile clays.
5. Drain tile clays.
6. Sewer pipe clays.
7. Terra cotta clays.
8. Hollow building tile.

It is very difficult to classify clays owing to the fact that there is no definite line separating them chemically, mineralogically, according to their occurrence, or according to their uses, in fact clays grade gradually from the best on the one hand, to the poorest varieties on the other.

No one classification will suit all purposes. For example, bricks are made from clays that vary much in composition and have been formed in many different ways, yet in classifying according to uses all these clays would come under one head. Consequently, one classification may be satisfactory for one purpose, while another may be used when considering the subject from a different point of view.

### GENERAL DESCRIPTION OF CLAYS

**KAOLIN.** The kaolins are the purest clays known and are usually formed from the decomposition of feldspars. They are white, or nearly so, free from iron, of a rather soft texture, usually have very little plasticity, of low tensile strength, absorb a considerable amount of water and have a large amount of shrinkage.

The kaolins usually have quartz, feldspar and mica disseminated thruout the mass and the different properties of the kaolins vary according to the amount and physical conditions of these minerals present.

On account of their purity, the kaolins are used for the manufacture of fine china and porcelain ware. Because of their low plasticity and high shrinkage, they are not used alone but are mixed with other clays and with non-plastic materials.

#### Refractory Clays.

The clays that have the property of resisting high temperatures and are consequently valuable for the manufacture of materials that are to be subjected to such temperatures, are known as refractory clays. Resistance to high temperatures is the one essential property of these clays. The

portion of fluxes present, such as iron oxide, lime, magnesia, and the alkalis is small. Refractory clays vary within limits as regards their chemical composition. Some are plastic, others have no plasticity; some are fine grained; others are coarse grained; some are porous; others are dense and compact; but most refractory clays have a high shrinkage and some of the best grades show low tensile strength.

The non-plastic fire clays are hard and flint-like, and must be mixed with plastic clays. The plastic fire clays are not so compact in texture and will easily weather into a soft mass. Refractory clays are used in the manufacture of fire brick for furnaces, kilns, crucibles, gas retorts and glass pots.

The composition of a good grade of refractory fire clay\* is approximately  $\text{SiO}_2$ , 53.2 per cent;  $\text{Al}_2\text{O}_3$ , 31.72 per cent;  $\text{Fe}_2\text{O}_3$ , 1.16 per cent;  $\text{CaO}$ , 0.21 per cent;  $\text{MgO}$ , 0.08 per cent;  $\text{TiO}_2$ , 1.93 per cent;  $\text{Na}_2\text{O}$ , 0.30 per cent;  $\text{K}_2\text{O}$ , 0.97 per cent;  $\text{SO}_2$ , trace; ignition loss, 10.55 per cent.

**BALL CLAYS.** The clays used as ball clays have a high degree of plasticity, burn white or cream color (practically free from iron), are tough, have a strong tensile strength, and vitrify at low temperatures. They are used as a bond with non-plastic kaolins in the manufacture of white ware, also in the manufacture of graphite crucibles.

Ball clays are refractory, or at least No. 2 clays as regards resistance to high temperatures. Altho they vitrify at low temperatures they do not deform until high temperatures.

#### **Semi-Refractory Clays.**

These clays are not used for wares that are to be subjected to very high temperatures. Their physical properties vary within wide limits, yet they are all plastic so that they may be easily molded into any shape desired. These clays should vitrify at medium temperatures to give a dense body with low absorption, should have good tensile strength, so that they may be handled without breakage, and should have a low shrinkage to be capable of drying rapidly without warping or cracking.

**STONEWARE CLAYS.** The clays used for this ware vary within a given range, as regards some of their properties. A good stone ware clay should be highly plastic, free from coarse sand, (a good many stone ware clays are washed free of sand before using), as free from iron as possible, buff burning, capable of being dried and heated fairly rapidly, should give a rough and strong body when burned and should vitrify at least by cone 9, or approximately at  $1310^\circ\text{C}$ . The following analyses show the

\* U. S. Bureau of Standards Technological Paper No. 7.

composition of clays that are being used for the manufacture of stoneware.

|                                | I<br>Per Cent. | II<br>Per Cent. |
|--------------------------------|----------------|-----------------|
| SiO <sub>2</sub>               | 64.26          | 71.94           |
| Al <sub>2</sub> O <sub>3</sub> | 22.95          | 17.60           |
| Fe <sub>2</sub> O <sub>3</sub> | 1.28           | 2.35            |
| CaO                            | 0.45           | 0.62            |
| MgO                            | 0.37           | 0.56            |
| K <sub>2</sub> O               | 1.96           | 1.50            |
| H <sub>2</sub> O               | 6.74           | 5.27            |
| Moisture                       | 2.05           | 1.01            |

I. Zanesville, Ohio. Ohio Geol. Sur., Vol. VII, p. 74.

II. Calhoun, Mo. Missouri Geol. Sur., Vol. VII, p. 564.

**TERRA COTTA CLAYS.** Many kinds of clays can be used in the manufacture of this ware, but low grade fire clay is used nearly altogether. Terra Cotta clays should have good plasticity, medium shrinkage, be free from soluble salts, give a uniform buff color, burn to a dense body at medium temperature and should not warp nor crack. The following table shows the wide range in the composition of clays used in the manufacture of terra cotta.

|                                | I<br>Per Cent. | II(*)<br>Per Cent. |
|--------------------------------|----------------|--------------------|
| SiO <sub>2</sub>               | 68.30          | 44.20              |
| Al <sub>2</sub> O <sub>3</sub> | 21.27          | 38.66              |
| Fe <sub>2</sub> O <sub>3</sub> | 1.43           | 0.74               |
| CaO                            | 0.52           | ....               |
| MgO                            | 0.80           | ....               |
| Alkalies                       | 0.20           | 0.46               |
| H <sub>2</sub> O               | 7.55           | 14.55              |

I. Maryland Geol. Sur., Vol. IV, p. 435.

II. Missouri Geol. Sur., Vol. XI, p. 452.

#### Non-Refractory Clays.

The clays under this division have a wide range of physical properties, composition and appearance. They include the clays used in the manufacture of common structural materials and the common pottery clays.

**PAVING BRICK.** The clays used for the manufacture of paving brick range from surface clays, usually high in fluxes, to those that are low in fluxes and therefore semi-refractory. Impure shales which vitrify at medium temperature are generally used for such brick. The great range in the composition of the material that is used to make a good product, provided the material has certain physical properties, is illustrated by the following table by Wheeler.\*\*

\* Mr. Wilson objects to this clay as lying outside the limits of terra-cotta composition. F. A. T.

\*\* Missouri Geol. Survey, Vol XI, p 456.



|                                | Minimum<br>Per Cent. | Maximum<br>Per Cent. |
|--------------------------------|----------------------|----------------------|
| SiO <sub>2</sub>               | 49.0                 | 75.0                 |
| Al <sub>2</sub> O <sub>3</sub> | 11.0                 | 25.0                 |
| Fe <sub>2</sub> O <sub>3</sub> | 2.0                  | 9.0                  |
| CaO                            | 0.2                  | 3.5                  |
| MgO                            | 0.1                  | 3.0                  |
| Alkalies                       | 1.0                  | 5.0                  |
| Ignition loss                  | 3.0                  | 13.0                 |
| Moisture                       | 0.0                  | 3.0                  |

Paving brick clay should have good tensile strength, yield dense brick, have a low shrinkage, a slow rate of vitrification and a long fusion range, should be plastic enough to be worked by machinery and should burn to a tough strong body. Practically all paving brick fire to a dark red brown color.

**SEWER PIPE CLAYS.** The clays used for the manufacture of sewer pipe are similar to those used for paving brick. Impure fire clays and a mixture of fire clays, shale or clay are also used for sewer pipe. Sewer pipe is usually glazed with a salt glaze (sodium chloride) to give a vitreous surface. This also darkens the color of the pipe.

**ROOFING TILE CLAYS.** Clays used for the manufacture of roofing tile should fuse at a low temperature and produce a vitrified product. They should give a dense body when burned, should have low air and fire shrinkage, and should contain enough iron to give the red color usually desired.

**FLOWER POT CLAYS.** Flower pots are manufactured from the poorer grades of clay. They are burned at low temperatures and the ware is usually porous. They are sometimes glazed to give them a better appearance. The pots are generally red, due to the iron in the clays. When white pots are wanted, potter's clay is used. The clays should have good plasticity and fair tensile strength.

**BUILDING BRICK AND TILE CLAYS.** Building brick and tile clays are usually considered crude clays. They generally contain a high percentage of flux. They may not be suitable for vitrified ware because they may fuse at low temperatures and have a short heat range. They form the most important group of clays, however, because of the great bulk of the products made from them, they are widely distributed, there being but few localities that cannot produce clay from which a fair grade of brick may be made. Paving brick clays are often used for making structural brick and tile.

**COMMON BRICK AND DRAIN TILE.** The clays or shales used for making common brick and drain tile have a wide range of composition and physical properties. They are usually low grade

and may be sandy in places. They should burn to a dense hard body at low temperature, should mold easily, and dry and burn without cracking or excessive shrinkage. Their most common color is red or brown. While common brick should be dense and hard, yet most of them are still very porous. They are used for backing up the facing material.

**GUMBO CLAYS** do not differ chemically from the common brick, drain tile or paving brick clays, but physically they are very different. They are black, fine grained, very plastic, have high air and fire shrinkage, contain a high per cent of fluxing substances and can be burned at low temperatures. When burned they have the peculiar quality of breaking up into small particles and consequently they are used extensively for railroad ballast.

**SLIP CLAYS.** These clays have a large amount of impurities or fluxing substances, fuse at low temperatures, give a uniform color, often brown or buff, and when burned form a natural glaze on the ware without cracking or checking. They are fine grained, of uniform texture and have a low air shrinkage. Slip clay that can be used alone is found in only a few localities. (Examples; Albany slip clay from Albany, New York, and Michigan slip clay.)

A good slip clay makes a better glaze than the artificial glazes which have exactly the same chemical composition.

The slip is made into a thick liquid by mixing with water and then is either sprayed over the ware or the ware is dipped into the slip.

## USES OF AND HINTS FOR PROSPECTING AND TESTING CLAYS

On account of the general scantiness of knowledge concerning the uses of clay and the materials made from it, the following table is given:\*

### Uses of Clay.

"Domestic.—Porcelain, white earthenware, stoneware, yellow ware and rockingham ware for the table service and cooking; stoves of majolica; polishing brick, often known as bath brick; fire kindlers.

"Structural.—Brick, common, front, pressed, ornamental, hollow, glazed; adobe; terra cotta; roofing tile; glazed and caustic tile; fire proofing; terra cotta lumber; copings; fence posts; drain tile; paving brick; chimney flues; chimney pots; door knobs.

"Hygienic.—Urinals, closet bowls, sinks, wash-tubs; pitchers; sewer pipe, ventilating flues, fountain blocks, vitrified bricks.

"Decorative.—Ornamental pottery, terra cotta, majolica, garden furniture.

"Minor Uses.—Food adulterants, paint fillers, paper filling, electric insulators, pumps, filling cloth, scouring soap, packing horses' hoofs, chemical apparatus, condensing worms, ink blotters, ultramarine manufacture, emery wheels.

"Refractory Wares.—Crucibles and other assaying apparatus, gas retorts, fire brick, glass pots, saggars, stove and furnace brick, blocks and fire boxes, tuyeres, cupola bricks.

"Engineering Works.—Puddle; Portland cement, railroad ballast, water conduits, turbine wheels." (Electric insulators, chemical porcelain, spark plugs.)

### Prospecting.

In the hope of interesting people thruout the state in the future development of the clay industry a few hints regarding prospecting for and the testing of clays will be given.

Examination of the surface should be the first step. The character of the vegetation should be noted, for it is likely that the vegetation will be scant over a fat, heavy body of clay. The occurrence of springs along a hillside at about the same elevation may indicate a clay seam, for clays are not easily penetrated by percolating water. The material brought to the surface by squirrels and other burrowing animals may often show the character of the formation at depth. Gulches, gorges, stream banks and beds should be carefully examined, for they show

\* Ries, Maryland Geol. Survey, Vol. IV, pp 266-267.

not only the thickness of the deposit but the variation in different parts of the deposit as well. Cuts along the highways and railroads are a valuable source of information. Wells, excavations for buildings and diggings of all kinds should be examined. All or any of these may help to locate a clay deposit.

For examinations at depth, augers may be used, and a depth of twenty to twenty-five feet can easily be obtained. Digging pits will permit of a better inspection of a deposit than augering.

As regards commercial value the location of a clay deposit is important. If a deposit is far from transportation and requires a long truck or wagon haul, it is not of commercial value, unless it has exceptional merit.

When a good quality of clay is found in a favorable location, the extent of the deposit should be determined by close examination of the entire outcropping along its length and by boring or digging pits across the deposit, always noting the uniformity of the deposit, because clay deposits may vary considerably in a short distance.

The occurrence of a deposit is important. A deposit with a very heavy overburden of no value cannot always be profitably worked. With the exception of certain of the more valuable clays a deposit with a pronounced dip may not prove profitable because of the cost of slope mining. Likewise, a deposit which has been tipped up by faulting or folding, may be unprofitable, because that part exposed is only a small part, the balance below the surface requiring slope mining methods.

Deposits requiring tunnels are not of commercial value unless the clay is of the best quality. Consequently, having regard to commercial or economic consideration, it is readily seen that a prospector cannot be too careful in sizing up the occurrence of his clay deposit.

Altho a deposit may be examined and found to be commercially valuable there yet remain several important features. What will be the cost of labor, of the proper kind of fuel, and of freight rates and what are the market conditions? Some wares may sell at a profit large enough to stand shipping a long distance, whereas others can be used to supply only a local demand, which may be limited. Consequently the location of a plant is an important item to the clay worker.

Sampling a clay deposit should be done so as to get an average of the deposit, and as clay deposits vary considerably in different places, samples should be taken from all parts of the deposit. If the entire deposit is to be used the samples should be thoroly mixed, but if certain sections only are to be used, those sections should be sampled separately, taking into consideration the cost of separating them from the useless material.

### Testing.

After samples are procured, they should be tested, first, for their physical properties, and if their properties are satisfactory, a chemical analysis may be made later, if desired.

To aid a person not familiar with clay to obtain an idea of the value of a clay, a few tests, outlined by the West Virginia Geological Survey\* are given:

1. "A small lump of clay may be roasted in a blue gas flame, as in a gas (or gasoline) stove; if a red or brown color be given the clay, the percentage of iron is high, probably four per cent or more. Fire clays are low in iron."

2. "By tasting a bit of the clay, bitter salts, alum, epsom, may be detected, or they may occur as white coating on the outcrops of the clay in the bank. These salts are apt to form white-wash coats on the finished brick, injuring their appearance. By crushing the clay in the mouth the sand may be detected by grit against the teeth. A rough determination of the amount of such sand may be made."

3. "An approximate idea of plasticity may be obtained by working the moist clay with the fingers. This is a good test for pottery clay, moistening the clay and finding whether it can be worked into a definite shape and retain the form when dry, without cracking."

4. "A rough brick of small size can be made and easily dried and a rough determination made of its shrinkage. If it shrinks out of shape, cracks or crumbles when dry its value is very doubtful. For this test, the clay should be ground, thoroly tempered with water and dried slowly."

5. "If carbonates of lime are present, a few drops of hydrochloric acid may be added, and it will be detected by the effervescence or bubbling as the carbonic acid gas passes off. A better plan is to place a lump of clay in the small amount of acid, as the clay absorbs the liquid so rapidly the effervescence may be overlooked. Good fire brick clays are low in lime." (If the percentage of iron present be low and the percentage of lime higher, about three times that of the iron, the clay product will burn buff. If the high percentage of lime is due to lumps of lime carbonate, the brick on burning will spall or show cracks due to the slaking and swelling of the quicklime on exposure to the atmosphere. Lumps of lime do not cause cracking during burning. Cracking is due to slaking and swelling of the lime after they are taken from kiln. High lime content does not "ruin a clay," but may render the clay worthless for the manufacture of certain products. It is not

\* Grimsley, West Virginia Geological Survey Report, Vol. III, pp. 90-91.

always possible to predict the color of the burned product from the color of the clay. Red clays will usually burn red, blue clays may burn buff or red. Dark or black clays are usually high in organic matter, and may burn red or buff.)

6. "The slaking of clays or the crumbling down in tempering is tested by dropping a lump of clay into a cup of water. Some clays slake in a very few minutes, and so are easily tempered. Shales slake usually only after a long time, and require fine grinding."

The above tests are simple and easily carried out and while they are not conclusive they do give considerable information regarding the value of the clay for certain purposes.

For further information the reader is referred to the following publications which have been freely consulted in the preparation of this report:

"Clays, Occurrence Properties and Uses," by Heinrich Ries.

"Clays and Clay Industry of Washington," by Solon Shedd.

"Clays of Eastern Colorado," Bulletin No. 8, Colorado State Geological Survey, by G. Montague Butler.

"Tests on Clay Materials Available in Illinois Coal Mines," Bulletin No. 18, Engineering Experiment Station, University of Illinois, by R. T. Stull and R. K. Hursh.

"Preliminary Report on the Clays and Clay Industries of Oklahoma," Bulletin No. 7, Oklahoma Geological Survey, by L. C. Snider.

"Mining and Treatment of Feldspar and Kaolin in the Southern Appalachian Region," Bulletin No. 53, U. S. Bureau of Mines, by A. S. Watts.

Missouri Geological Survey, Vol. 11, by H. A. Wheeler.

### PROCEDURE OF TESTING.

By HEWITT WILSON

TREATMENT OF CRUDE KAOLINS. These samples in the dry condition were weighed, blunged with water to form a thin slip, and screened thru a 40-mesh screen to catch the coarse quartz and feldspar particles. The fine non-plastic portions were caught on a 200-mesh screen. The sum of the residues on both screens was determined by weighing and the per cent of kaolin material was calculated. After decantation and drying, the fines were treated the same as were the other clays.

ORIGINAL PROPERTIES. The clays as sampled were examined for original color, hardness, structure, and visible objectionable materials. The ease or rapidity with which lumps disintegrated in water was noted as the "Slaking Property." Carbonates were detected by the application of hydrochloric acid.

PREPARATION OF SAMPLES AND UNFIRED PROPERTIES. The samples were crushed to pass a 20-mesh screen, pugged with water to the best plastic consistency, and allowed to stand at least over night in a closed receptacle to insure an even distribution of the water content. The plastic material was then molded into briquettes  $4\frac{1}{4}$  by  $1\frac{1}{8}$  by  $1\frac{1}{8}$  inches and marked with two shrinkage marks, 100 millimeters apart. The samples were then dried slowly in air from four to six days and finally in an electric dryer at about 100 degrees centigrade to constant weight. The water of plasticity or the amount of water used for tempering was determined by finding the difference in weight between the plastic sample (weighed immediately after molding) and the dry sample. The per cent water of plasticity is expressed as percentage of the dried weight. The linear shrinkage is expressed as per cent of the original or plastic length.

FIRED PROPERTIES. The test pieces were placed in a refractory muffle and fired in a coal-burning test kiln, holding four muffles. A set of Orton pyrometric cones was placed with each group of trials. A platinum, platinum-rhodium thermocouple was used in regulating the temperature in the early stages of the firing, so that the rate would correspond with the recommendations of the Committee on Standards of the American Ceramic Society. Approximately 24 hours were needed to reach cone 9.

As quickly as the trials were drawn from the muffle after the proper temperature was reached, they were placed in an adjoining muffle which was held at a dull red heat. After all trials had been withdrawn, both kilns were allowed to cool slowly. This method of cooling gives better colors and body structures than quick cooling.

The test pieces were then examined and the linear shrinkage, absorption, color, hardness and defects noted for each temperature. The per cent absorption is the weight of water absorbed after two hours boiling, in terms of the dry fired weight.

Thru the courtesy of the Moscow Fire Brick Company a number of the more refractory clay samples were fired to cone 15 in a regular burn of one of their large commercial kilns. The samples were protected as before by a refractory muffle.

A cone fusion test was made of a number of the clays at the ceramic laboratory of the College of Mines, University of Washington. For this purpose a carbon resistance electric furnace was employed.

From the data procured, the possible value of each clay was outlined. It must be emphasized that the sampling and testing of these clays are but preliminary in character, and the deductions drawn are but indicative of the general type of the clays. The

specific economic value can only be determined by a more extensive investigation based on the results herein obtained.

#### Conclusions.

An examination of the following data will show that a wide variety of clay materials exists in the State of Idaho. From 32 deposits were taken a total of 88 samples; 28 of the deposits gave indications of useful clay materials. Two of these deposits contained white burning kaolin-like material together with brown, red or buff burning clays in the same outcrop; 13 gave buff or gray burning clays, and 13 gave red or brown burning clays. In quality, the clays grade from white ware and high refractory clays, thru the buff burning stoneware and terra cotta clays to the common red brick varieties.

There is this peculiarity. In most regions, red burning shales suitable for the bulk of the structural wares, constitute the majority of the clays. These shales have not been reported from the State of Idaho, and if absent must be replaced in the manufacturing industries by red burning clays of different origin, such as the basaltic clays.

A large quantity of residual fire-clay of good quality is found, portions of which are used at the present time for refractory wares, such as common fire brick, locomotive boiler and metallurgical furnace shapes, all of which are of such quality as to find a ready market. Such material unwashed, not only supplies a good class of refractory ware, but when the quartz, feldspar and mica impurities are removed by washing, a kaolin of excellent purity results. Fired to cone 15 several samples remained unvitriified and gave colors approaching that of pure white. Cone fusion tests of the washed material gave deformation points above that of the standard cone 34, or approximately 1740° C. However, when some samples were not washed, or were used in the natural condition their fusion temperature fell below that of cone 31, approximately 1685° C. At these high temperatures silica acts as a flux with kaolin, and when finely ground may lower the fusion point even to cone 26, approximately 1600° C. As the silica content may change the clay from a No. 1 to a No. 2 or No. 3 refractory material, keeping it as low as possible is advantageous.

A simple washing process similar to that performed in the laboratory would produce a high-grade kaolin material suitable for the whiteware industry and possibly for white paper clay. As the washed material is very refractory it could be used in the manufacture of superior refractory articles. It would be necessary to replace the non-plastic coarse quartz grains, which would be removed in washing, with grog made by calcining



some of this same washed material. Such a body should approximate the quality of some of the so-called "super-refractories" developed during the war for use in battleship boiler furnaces. In this case sawdust or other combustible material was probably also added to decrease the weight of the refractory.

An outline of such a washing process would include:

- (1) Blunging the clay with water to a thin slip;
- (2) Settling the sand and coarse mica in troughs and removing same by a sand wheel;
- (3) Screening the slip;
- (4) Concentrating or dewatering the slip by settling, decantation, filter pressing and drying, or allowing the concentrated slip to evaporate to dryness in a large shallow tank or field in the open.

Such methods are used in the Appalachian districts for refining kaolin for the whiteware industry of the eastern United States. Refined chemical methods which give a whiter and finer grained product are being slowly introduced at the present time.\*

Kaolins have been reported from 23 different states but at the present time the principal commercial deposits are operated in Florida, Georgia, North Carolina, Delaware and Pennsylvania. English kaolin is also used extensively in the United States. There are no whiteware companies operating in the Pacific Northwest, but it is reported that one is under construction at Warrenton, Oregon. Practically all whiteware and also most of the crude kitchen wares such as baking dishes and yellow bowls, come from eastern points. There is a stoneware plant at Spokane, Washington, and another at Portland, Oregon. Thus it is believed that there is a market sufficient to support a small company manufacturing yellow ware, whiteware or both.

An average whiteware body would contain the following:

|                       | Parts by weight. |
|-----------------------|------------------|
| Washed kaolin.....    | 35               |
| Sorted ball clay..... | 10               |
| Ground feldspar.....  | 20               |
| Ground silica .....   | 35               |

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100

Altho no true ball clays were found in this investigation, several of the light buff burning, very plastic, high-shrinkage clays could no doubt be used for this purpose. Our present ball

\* For further details see, Watts: Mining and Treatment of Feldspar and Kaolin in the Southeastern Appalachian Region, Bulletin 53, U. S. Bureau of Mines. Sproat; Purification of the Georgia Kaolins. Transactions of the American Ceramic Society. Volume 18, (1916).

clay supply comes from Kentucky, Tennessee, New Jersey and England.

Feldspar, having a degree of purity sufficient for whiteware requirements, has been reported from Latah county near these deposits. The principal present feldspar sources are in Maine, Pennsylvania and eastern Canada.

Silica could be obtained by finegrinding some of the purer grades of vein quartz common to this district, but it is a question if this could compete with the ground silica from Ottawa, Illinois.

The methods of preparing and blending the raw materials, the proper methods and cost of manufacture, including fuel and ways and means of placing the finished product on the market, should be thoroly investigated before one should engage in the manufacture of whiteware. Whiteware products require a high degree of technical ceramic skill, and the preliminary experiments with the synthetic body mixture should be thoroly performed.

**STRUCTURAL WARES.** In the majority of cases, mixing of two or more clays for buff, brown or red structural wares will be necessary. Owing to the residual or local character of most of the deposits, some of the clays are either lacking in the plastic properties or do not contain enough non-plastic material. They are either too fat and plastic or too sandy and weak. Shales and sedimentary clays deposited in large bodies of water are the natural mixtures of large quantities of material, and so give more of an average and uniform composition thruout the bank. Often if the clay from the entire face of a residual deposit is well mixed, a body of average working properties will be obtained, when the confinement of the mining operations to any one spot on the face would give clay of very inferior working properties. This is not a local disadvantage, however, as most clay wares are improved by mixing clays from several points in the same bank and even from other neighborhoods.

Great care should be taken in thoroly sampling such deposits to determine the extent and uniformity of the useful clay material. From the observation of many disastrous experiences it is necessary to emphasize also the necessity of having full sized samples taken from many points in the deposit, covering 10-20 years future growth of the plant, and thoroly tested by distinterested parties of reputable ceramic engineering ability before the erection of a plant.

## PART II.

LOCATION, OCCURRENCE, FIELD CHARACTERISTICS, ANALYSES  
AND ECONOMIC VALUE OF THE SAMPLES TESTED.

## BENEWAH COUNTY.

Benewah County is situated on the northwestern limits of the great granite batholith which occupies the greater part of the central portion of Idaho. The county covers a rather mountainous section of the state, but is favorably situated for the occurrence of clay deposits, since these are to be expected on or near the edges of the granite intrusion. Many deposits were seen thru-out this county which were not sampled owing to the lack of time and because of the doubtful commercial value under the present poor transportation facilities and market conditions.

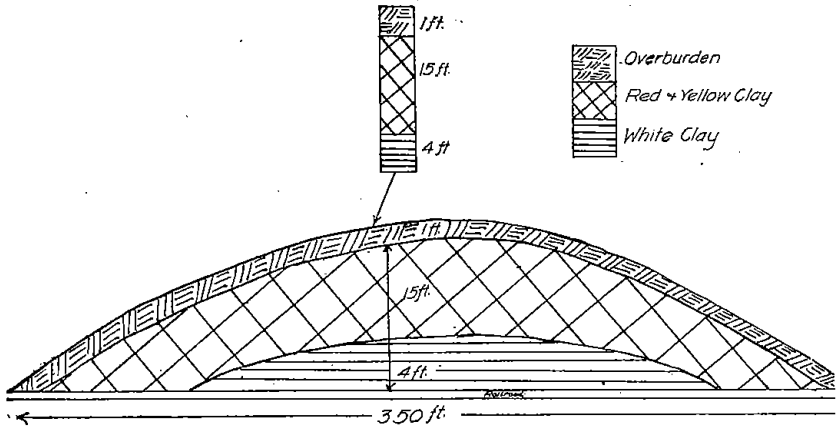


FIG. 1. •Longitudinal section of railroad cut one quarter mile east of St. Maries, showing position of samples No. 1 and No. 2.

## Sample No. 1.

*Location.* 100 feet from the east end of the railroad cut on the Chicago, Milwaukee & St. Paul Railroad, one-quarter mile east of the station of St. Maries.

*Occurrence.* A 19-foot exposure of a transported deposit of yellow and white clay, striking east and west\*, flat, and well stratified, under an overburden of two feet.

*Field Characteristics.* A fine grained, medium hard, sandy clay, gray and yellow in color, showing mica.

*General Properties.* Water of plasticity 29.5%, general plasticity fair, slakes very rapidly, dry linear shrinkage 7% without cracking or warping.

\*The use of the word "strike" for a flat deposit may be open to some question. As here applied it may be taken to mean the direction of the major axis, or greatest length of the deposit.—F. A. T.

*Fire Properties*

| Cone No. ....         | 010       | 06          | 02         | 1+         |
|-----------------------|-----------|-------------|------------|------------|
| Color .....           | Red Brown | Red Brown   | Brown Red  | Brown Red  |
| Hardness .....        | Soft      | Medium Hard | Steel Hard | Steel Hard |
|                       | Per Cent  | Per Cent    | Per Cent   | Per Cent   |
| Absorption .....      | 22.9      | 21.8        | 15.7       | 12.1       |
| Fire Shrinkage .....  | .....     | 2.0         | 5.0        | 5.0        |
| Total Shrinkage ..... | 7.0       | 9.0         | 12.0       | 12.0       |
| Condition .....       | Good      | Good        | Good       | Good       |

*Analysis.* Approximately the same as No. 3.

*Probable Economic Value.* Common brick and possibly drain tile when used alone. Its good red color would aid in face brick and other common structural wares.

Mix with No. 2 to secure a more vitrified product.

**Sample No. 2.**

*Location.* General location same as sample No. 1. Sample taken beneath sample No. 1.

*Occurrence.* Same as sample No. 1.

*General Properties.* Water of plasticity 32.4%, general plasticity good, slakes very readily, dry linear shrinkage 7%, without cracking or warping.

*Fire Properties*

| Cone No. ....         | 01         | 06         | 04         | 02         | 3          |
|-----------------------|------------|------------|------------|------------|------------|
| Color .....           | Buff Brown | Buff Brown | Buff Brown | Red Brown  | Red Brown  |
| Hardness .....        | Soft       | Steel Hard | Steel Hard | Steel Hard | Steel Hard |
|                       | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....      | 22.2       | 18.6       | 5.3        | 4.3        | 3.6        |
| Fire Shrinkage .....  | 1.0        | 3.0        | 9.5        | 10.0       | 11.0       |
| Total Shrinkage ..... | 8.0        | 10.0       | 16.5       | 17.0       | 18.0       |
| Condition .....       | Good       | Good       | Good       | Cracked    | Cracked    |

*Analysis.* Same as No. 3.

*Probable Economic Value.* Common structural wares, common brick, face brick and possibly roofing, drain tile and sewer pipe.

**Sample No. 3.**

*Location.* In east end of small cut on the Chicago, Milwaukee & St. Paul Railroad, six miles west of St. Maries.

*Occurrence.* A 16-foot exposure (8 feet of white clay underlain by 8 feet of yellow clay) striking north and south, flat, well stratified and covered by one foot of overburden.

*Field Characteristics.* A fine grained, medium soft, white clay, without any visible objectionable material.

*General Properties.* Water of plasticity 30%, general plasticity good, slakes readily, dry linear shrinkage 5% without warping or cracking.

*Fire Properties*

| Cone No. ....         | 01         | 3          | 6          | 9          | 15                             |
|-----------------------|------------|------------|------------|------------|--------------------------------|
| Color .....           | Med. Buff  | Med. Buff  | Gray Buff  | Dark Gray  | Gray Brown                     |
| Hardness .....        | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard                     |
|                       | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent                       |
| Absorption .....      | 7.1        | 7.0        | 2.6        | 0.5        | 10.7                           |
| Fire Shrinkage .....  | 5.0        | 6.0        | 7.0        | 8.0        | 2.0                            |
| Total Shrinkage ..... | 10.0       | 11.0       | 12.0       | 13.0       | 7.0                            |
| Condition .....       | Good       | Good       | Good       | Good       | Bloated badly; partially fused |

*Analysis.* SiO<sub>2</sub> 71.3%; Al<sub>2</sub>O<sub>3</sub> 11.4%; Fe<sub>2</sub>O<sub>3</sub> 1.7%; CaO 1.0%; MgO 0.7%; Ignition Loss 5.1%.

*Probable Economic Value.* Could be used for a portion of a crude pottery, stoneware or terra cotta body; also for buff face brick.

#### Sample No. 4.

*Location.* General location same as No. 3, sample taken from beneath No. 3.

*Occurrence.* Same as sample No. 3.

*Field Characteristics.* A fine grained, medium soft, gray and yellow clay, without visible objectionable material.

*General Properties.* Water of plasticity 25.1% general plasticity good, slakes readily, dry linear shrinkage 5% without warping or cracking.

#### Fire Properties

| Cone No. ....        | 01         | 3          | 6          | 9          | 15                                 |
|----------------------|------------|------------|------------|------------|------------------------------------|
| Color .....          | Light Gray | Light Gray | Med. Gray  | Med. Gray  | Mottled Light Gray                 |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard                         |
|                      | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent                           |
| Absorption .....     | 13.0       | 11.6       | 8.2        | 7.0        | 4.1                                |
| Fire Shrinkage ..... | 4.0        | 6.0        | 7.5        | 8.0        | .....                              |
| Total Shrinkage..... | 9.0        | 10.0       | 12.5       | 13.0       | 12.3                               |
| Condition .....      | Good       | Good       | Good       | Good       | Dark gray interior, no deformation |

*Cone Fusion.* Cone No. 30. Approximately 1675°C.

*Analysis.* SiO<sub>2</sub> 67.3%; Al<sub>2</sub>O<sub>3</sub> 16.7%; Fe<sub>2</sub>O<sub>3</sub> 1.7%; CaO 2.0%; MgO 0.2%; Ignition Loss 9.3%.

*Probable Economic Value.* Could be used for a portion of a crude pottery, stoneware or terra cotta body, buff face brick, or No. 2 refractory.

#### Sample No. 5.

*Location.* In a cut on the Chicago, Milwaukee & St. Paul Railroad, eight miles west of St. Maries. Sample taken in center of the cut.

*Occurrence.* A 20-foot exposure 100 feet long, striking east and west, flat, well stratified, and lying between a steeply inclined bed of quartzite on the east and a bed of quartzite boulders on the west.

*Field Characteristics.* A fine graded, medium hard, pink clay with white streaks.

*General Properties.* Water of plasticity 34%, general plasticity fine, slakes readily, dry linear shrinkage 8% without warping or cracking.

#### Fire Properties

| Cone No.              | 010      | 06       | 02         | 3          | 6          | 15                      |
|-----------------------|----------|----------|------------|------------|------------|-------------------------|
| Color                 | Buff     | Buff     | Buff       | Med. Buff  | Med. Buff  | Dark Brown              |
|                       | Red      | Red      | Brown      | Brown      | Brown      | Slag Spots              |
| Hardness              | Soft     | Soft     | Steel Hard | Steel Hard | Steel Hard | Steel Hard              |
|                       | Per Cent | Per Cent | Per Cent   | Per Cent   | Per Cent   | Per Cent                |
| Absorption .....      | .....    | 19.1     | 13.9       | 7.9        | 6.8        | 11.1                    |
| Fire Shrinkage .....  | .....    | 3.0      | 4.0        | 8.0        | 9.0        | 6.5                     |
| Total Shrinkage ..... | .....    | 8.0      | 11.0       | 12.0       | 16.0       | 14.5                    |
| Condition .....       | Good     | Good     | Good       | Good       | Good       | Bloated, black interior |

*Probable Economic Value.* Dark burning structural wares such as face brick, common brick, drain tile, etc.

**Sample No. 6.**

*Location.* General location same as sample No. 5. Sample taken beneath No. 5.

*Occurrence.* Same as sample No. 5.

*Field Characteristics.* A fine grained, soft, gray clay, without any visible objectionable material.

*General Properties.* Water of plasticity 37%, general plasticity fine, slakes readily, dry linear shrinkage 11% without warping or cracking.

*Fire Properties*

| Cone No. ....       | 010           | 06         | 02         | 3          | 6          |
|---------------------|---------------|------------|------------|------------|------------|
| Color .....         | Buff Brown    | Buff Brown | Deep Buff  | Deep Buff  | Deep Buff  |
| Hardness .....      | Med. Hard     | Med. Hard  | Steel Hard | Steel Hard | Steel Hard |
|                     | Per Cent      | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....    | 19.4          | 17.0       | 5.8        | 3.1        | 2.0        |
| Fire Shrinkage .... | .....         | 1.0        | 6.0        | 10.0       | 11.0       |
| Total Shrinkage.... | 11.0          | 12.0       | 17.0       | 21.0       | 22.0       |
| Condition .....     | Some cracking | Ditto      | Ditto      | Good       | Good       |

*Cone Fusion.* Cone No. 30 minus. Approximately 1665°C.

*Probable Economic Value.* Buff burning structural wares such as face brick, or as a portion of a crude pottery or terra cotta body. Would give better results if mixed with No. 5 for structural wares. The addition of grog is needed to control shrinkage.

No. 2 grade refractory clay.

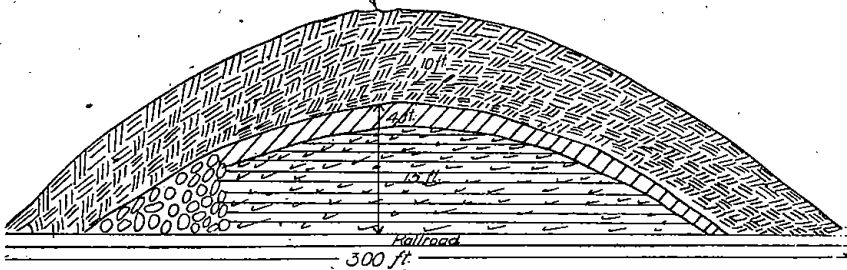
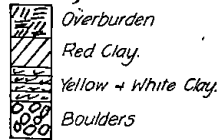
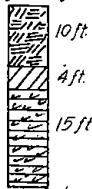


FIG. 2. Longitudinal section of railroad cut two miles west of St. Maries, showing position of samples No. 7 and No. 8.

**Sample No. 7.**

*Location.* In the east end of cut on the Chicago, Milwaukee & St. Paul Railroad, two miles west of St. Maries. Sample taken over the entire face in the center of the cut.

*Occurrence.* A 19-foot exposure, 100 feet long, of red and yellow clay, strikes easterly and westerly, flat and well stratified, with the east end of the deposit against a bed of quartzite boulders.

*General Properties.* Water of plasticity 32.2%, general plasticity fine, slakes very readily, dry linear shrinkage 9% without warping or cracking.

*Fire Properties*

| Cone No. ....       | 010       | 06        | 02         | 1+         | 6          |
|---------------------|-----------|-----------|------------|------------|------------|
|                     | Bright    | Bright    | Bright     | Bright     | Bright     |
| Color .....         | Brown Red | Brown Red | Brown Red  | Brown Red  | Brown Red  |
| Hardness .....      | Soft      | Hard      | Steel Hard | Steel Hard | Steel Hard |
|                     | Per Cent  | Per Cent  | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....    | 20.1      | 14.5      | 9.8        | 7.3        | 6.1        |
| Fire Shrinkage .... | 1.0       | 3.0       | 8.0        | 8.0        | 9.0        |
| Total Shrinkage.... | 10.0      | 12.0      | 17.0       | 17.0       | 18.0       |
| Condition .....     | Good      | Good      | Good       | Good       | Good       |

*Probable Economic Value.* Red burning structural wares, such as, common and face brick, drain tile, roofing tile and sewer pipe.

**Sample No. 8.**

*Location.* General location same as sample No. 7. Sample taken near east end of the cut.

*Occurrence.* Same as sample No. 7.

*Field Characteristics.* A medium fine grained, medium soft gray clay, with brown streaks.

*General Properties.* Water of plasticity 34.4%, general plasticity good, slakes very readily, dry linear shrinkage 7% without warping or cracking.

*Fire Properties*

| Cone No. ....       | 010       | 06        | 02        | 3         | 6        |
|---------------------|-----------|-----------|-----------|-----------|----------|
|                     | Red Brown | Red Brown | Red Brown | Red Brown | Bright   |
| Color .....         | Soft      | Soft      | Med. Hard | Hard      | Hard     |
| Hardness .....      | Per Cent  | Per Cent  | Per Cent  | Per Cent  | Per Cent |
| Absorption .....    | 24.6      | 24.1      | 20.7      | 19.4      | 17.5     |
| Fire Shrinkage .... | 2.0       | 3.0       | 4.0       | 5.0       | 6.0      |
| Total Shrinkage.... | 9.0       | 10.0      | 11.0      | 12.0      | 13.0     |
| Condition .....     | Good      | Good      | Good      |           |          |

*Analysis.* SiO<sub>2</sub> 59.9%; Al<sub>2</sub>O<sub>3</sub> 24.6%; Fe<sub>2</sub>O<sub>3</sub> 6.6%; CaO 0.8%; MgO 0.4%; Ignition Loss 8.9%.

*Probable Economic Value.* Would require a higher temperature than usual for structural products, but color is excellent for red burning brick and tile. Could not use for vitrified structural wares. Blend with No. 7 for better vitrification.

**CASSIA COUNTY.**

Cassia County is far to the south of the granite batholith in the more recent sedimentary formation, and good clay deposits are likely to be rare under such conditions.

**Sample No. 9.**

*Location.* Three miles southeast of Declo, and one mile south of the Oregon Short Line Railroad, along the foothills. Sample near top of exposure.

*Occurrence.* A 20-foot bed, striking east and west, dipping 20 degrees to the north and lying on top of limestone.

*Field Characteristics.* A fine grained, hard, dark gray shale without visible objectionable materials.

*General Properties.* Lacked molding properties and a brick was not made.

NOTE.—This sample was included in the clay examinations because attempts had been made to use it for brick.

**Sample No. 10.**

*Location.* Same as sample No. 9. Sample taken from the bottom of the bed immediately above the lime.

*Occurrence.* Same as sample No. 9.

*Field Characteristics.* A medium fine grained, medium hard, gray shale.

*General Properties.* Water of plasticity 27.8%, general plasticity fine, slakes readily, dry linear shrinkage 7% with slight warping but no cracking.

*Fire Properties*

|                       | 010       | 06        | 02         | 1+                              |
|-----------------------|-----------|-----------|------------|---------------------------------|
| Cone No. ....         | 010       | 06        | 02         | 1+                              |
| Color .....           | Red Brown | Red Brown | Deep Brown | Deep Brown                      |
| Hardness .....        | Soft      | Med. Hard | Steel Hard | Steel Hard                      |
|                       | Per Cent  | Per Cent  | Per Cent   | Per Cent                        |
| Absorption .....      | 20.5      | 18.7      | 7.1        | 1.7                             |
| Fire Shrinkage .....  | 7.0       | 5.0       | 9.0        | 10.0                            |
| Total Shrinkage ..... | 7.0       | 12.0      | 16.0       | 17.0                            |
| Condition .....       | Good      | Good      | Good       | Glazed surface but not deformed |

*Analysis.* SiO<sub>2</sub> 62.9%; Al<sub>2</sub>O<sub>3</sub> 15.0%; Fe<sub>2</sub>O<sub>3</sub> 3.9%; CaO 3.0%; MgO 0.25%; Ignition Loss 8.5%.

*Probable Economic Value.* Red burning structural wares, such as common, face and possibly paving brick (?) and roofing tile, drain tile and sewer pipe.

**Sample No. 11.**

*Location.* In surface pits on the northern edge of the town of Burley.

*Occurrence.* Deposits cover a 10-acre tract to the depth of six feet and underlaid by gravel. It is reported that holes have



been drilled to a depth of 200 feet, finding blue clay and gravel mixed for the entire distance.

*Field Characteristics.* A medium fine grained, medium soft, yellowish gray clay.. Visible objectionable material, calcium carbonate.

*General Properties.* Water of plasticity 31.9%, general plasticity fair, slakes readily, dry linear shrinkage 10% with bad cracking and warping.

*Fire Properties*

|                 |           |                   |            |
|-----------------|-----------|-------------------|------------|
| Cone No.....    | 010       | 06                | 02         |
| Color.....      | Lt. Brown | Lt. Brown         | Gray       |
| Hardness.....   | Hard      | Hard              | Steel Hard |
| Condition ..... |           | Cracked to pieces |            |

*Analysis.* SiO<sub>2</sub> 37.6%; Al<sub>2</sub>O<sub>3</sub> 4.1%; Fe<sub>2</sub>O<sub>3</sub> 3.7%; CaO 18.1%; MgO 0.2%; Ignition Loss 26.7%.

*Probable Economic Value.* No value for clay wares owing to high lime content and excessive cracking.

## KOOTENAI COUNTY.

Kootenai County lies toward the northwestern limits of the granite. It has good transportation facilities and market conditions and from a geological standpoint the conditions are favorable for the occurrence of good clay deposits.

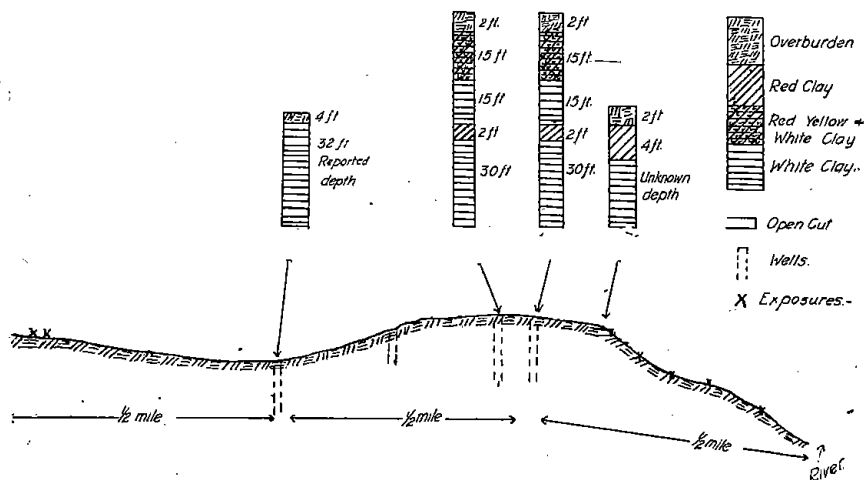


FIG. 3. Cross-section sketch of vicinity of Mooney's ranch, near Coeur d'Alene. Samples in order from right to left of view above are No. 12, 14, 15 and 19.

## Sample No. 12.

*Location.* Four miles northeast of Coeur d'Alene, one mile southeast of the electric station of Hunter, on the hillside one-half mile from the south bank of the Spokane River and 100 feet west of a very large basalt outcrop. Sample was of the white material.

*Occurrence.* An unknown depth of white material under four feet of red material, all of which is covered by two feet of overburden. A small exposure in an open cut from which no strike could be obtained. The bed appears flat. A 10-foot auger hole was put down from the bottom of the cut and disclosed white material the full distance. Altho the country rock is basalt the clay is derived from the decomposition of granite.

*Field Characteristics.* A fine grained, sandy, medium soft, gray clay, well stratified and without visible objectionable materials.

*General Properties.* Water of plasticity 31.5%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

| Cone No.        | <i>Fire Properties</i> |                 |           |           |              |                                   |                |  |
|-----------------|------------------------|-----------------|-----------|-----------|--------------|-----------------------------------|----------------|--|
|                 | 02                     | 1+              | 3         | 6         | 9+           | 15                                |                |  |
| Color           | Light Red Brown        | Light Red Brown | Red Brown | Red Brown | Spotted Gray | Dk. Brown                         | Glazed surface |  |
| Hardness        | Soft                   | Soft            | Hard      | Hard      | Hard         | Steel Hard                        | Steel Hard     |  |
| Absorption      | Per Cent               | Per Cent        | Per Cent  | Per Cent  | Per Cent     | Per Cent                          | Per Cent       |  |
| Fire Shrinkage  | 22.1                   | .....           | 20.9      | 19.0      | 17.0         | 1.2                               | 1.2            |  |
| Total Shrinkage | 3.0                    | 3.0             | 4.0       | 4.0       | 6.0          | 7.3                               | 7.3            |  |
| Condition       | 10.0                   | 10.0            | 11.0      | 11.0      | 13.0         | 14.3                              | 14.3           |  |
|                 | Good                   | Good            | Good      | Good      | Good         | Slight deformation, dark interior |                |  |

*Cone Fusion.* Cone No. 20-23. Approximately 1510°C.

*Analysis.* Similar to No. 19.

*Probable Economic Value.* This clay alone develops its strength at temperatures prohibitive to common structural wares. It would give its best service when used with a clay of lower vitrification temperature, for dark structural products.

#### Sample No. 13.

*Location.* Same as No. 12 but sample is of both red and gray material over 6-foot face.

*Occurrence.* Same as sample No. 12.

*Field Characteristics.* A fine grained, sandy, gray and brown, medium hard, and well stratified bed, showing mica.

*General Properties.* Water of plasticity 84.9%, general plasticity fair, slakes very readily, dry linear shrinkage 8%, cracking and warping, none.

| Cone No.        | <i>Fire Properties</i> |           |           |           |
|-----------------|------------------------|-----------|-----------|-----------|
|                 | 01                     | 3         | 6         | 9         |
| Color           | Buff Red               | Red Brown | Red Brown | Brown Red |
| Hardness        | Med. Hard              | Med. Hard | Med. Hard | Hard      |
|                 | Per Cent               | Per Cent  | Per Cent  | Per Cent  |
| Absorption      | 19.4                   | 17.7      | 15.1      | 12.7      |
| Fire Shrinkage  | 4.0                    | 4.5       | 3.5       | 5.5       |
| Total Shrinkage | 12.0                   | 12.5      | 11.5      | 13.5      |
| Condition       | Good                   | Good      | Good      | Good      |

*Analysis.* Similar to No. 14.

*Probable Economic Value.* Common brick, face brick and drain tile.

#### Sample No. 14.

*Location.* General location same as sample No. 12, but sample taken from dump of well 200 feet south of the open cut.

*Occurrence.* Dump is from well reported to have been dug to depth of 32 feet and then drilled to an added depth of 30 feet. Log of well shows: 2' feet overburden, 15 feet red and yellow material, balance of well (30 feet) in white material. Derived from the decomposition of granite.

*Field Characteristics.* A fine grained, medium hard, gray clay, without visible objectionable materials.

*General Properties.* Water of plasticity 28.3%, general plasticity fine, dry linear shrinkage 12%, slakes very readily and does not crack nor warp.

*Fire Properties*

| Cone No.        | 010       |      | 06        |            | 02        |            | 3         |            | 6         |            | 15    |            |
|-----------------|-----------|------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-------|------------|
|                 | Med. Buff | Hard | Med. Buff | Steel Hard | Deep Buff | Steel Hard | Deep Buff | Steel Hard | Deep Buff | Steel Hard | Brown | Steel Hard |
| Color           |           |      |           |            |           |            |           |            |           |            |       |            |
| Hardness        |           |      |           |            |           |            |           |            |           |            |       |            |
| Absorption      | 18.9      | 16.5 | 16.5      | 4.9        | 2.4       | 2.4        | 2.3       | 1.5        |           |            |       |            |
| Fire Shrinkage  | 3.0       | 3.0  | 3.0       | 9.0        | 10.0      | 10.0       | 10.0      | 9.0        |           |            |       |            |
| Total Shrinkage | 15.0      | 15.0 | 15.0      | 21.0       | 22.0      | 22.0       | 22.0      | 21.0       |           |            |       |            |
| Condition       | Good      | Good | Good      | Cracked    | Cracked   | Cracked    | Cracked   | Few cracks |           |            |       |            |

*Analysis.* SiO<sub>2</sub> 51.2%; Al<sub>2</sub>O<sub>3</sub> 19.6%; Fe<sub>2</sub>O<sub>3</sub> 3.4%; CaO 2.0%; MgO 0.04%; Ignition Loss 10.6%.

*Probable Economic Value.* Buff burning structural ware if mixed with non-plastic material or a clay of lower shrinkage. Face brick, and a possible portion of a crude pottery or terra cotta body. Should not use this clay alone on account of excessive shrinkage.

**Sample No. 15.**

*Location.* General location same as sample No. 13. Sample taken from dump of well 30 feet east of sample No. 14.

*Occurrence.* Same as sample No. 14 and log of well same as No. 14.

*Field Characteristics.* A hard, fine grained, gray and light brown clay, showing mica.

*General Properties.* Water of plasticity 25.7%, general plasticity fair, slakes readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No.        | 01     |             | 3           |             | 6      |        | 9+      |           |
|-----------------|--------|-------------|-------------|-------------|--------|--------|---------|-----------|
|                 | Bright | Bright      | Bright      | Bright      | Bright | Bright | Spotted | Dark Gray |
| Color           |        |             |             |             |        |        |         |           |
| Hardness        |        |             |             |             |        |        |         |           |
| Absorption      | 12.9   | 10.6        | 10.6        | 6.6         | 6.6    | 6.6    | 3.5     |           |
| Fire Shrinkage  | 6.0    | 6.5         | 6.5         | 10.0        | 10.0   | 10.0   | 10.0    |           |
| Total Shrinkage | 11.0   | 11.5        | 11.5        | 15.0        | 15.0   | 15.0   | 15.0    |           |
| Condition       |        | Black spots | Black spots | Black spots | Good   | Good   | Good    | Good      |

*Analysis.* Similar to No. 14.

*Probable Economic Value.* Red burning face brick, common brick and drain tile, would have to be burned at too high a temperature for the common vitrified structural wares.

**Sample No. 16.**

*Location.* Two miles northeast of Coeur d'Alene on A. C. Power's ranch. Sample from well and dump located 200 yards north of residence.

*Occurrence.* A 9-foot exposure of red and yellow material under 5 feet of overburden, flat and well stratified. Under the red and yellow material and just below the water level a white material can be seen, but on account of the depth of water in the well it could not be sampled.

*Field Characteristics.* A medium fine grained, sandy, yellowish gray, and medium soft clay, showing mica particles.

*General Properties.* Water of plasticity 31%, general plas-

ticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

#### Fire Properties

| Cone No.        | 010      | 06       | 02        | 1+        | 6         | 15             |
|-----------------|----------|----------|-----------|-----------|-----------|----------------|
| Color           | Buff     | Buff     | Buff      | Buff      | Buff      | Dk. Brown      |
| Hardness        | Soft     | Soft     | Med. Hard | Med. Hard | Med. Hard | almost Blk.    |
|                 | Per Cent | Per Cent | Per Cent  | Per Cent  | Per Cent  | Per Cent       |
| Absorption      | 23.7     | 22.7     | 18.4      | 17.3      | 11.8      | 9.4            |
| Fire Shrinkage  | 0.0      | 1.0      | 4.0       | 4.0       | 4.0       | 7.5            |
| Total Shrinkage | 7.0      | 8.0      | 11.0      | 11.0      | 11.0      | 14.5           |
| Condition       | Good     | Good     | Good      | Good      | Good      | Glazed surface |

*Probable Economic Value.* Porous common brick and possibly drain tile.

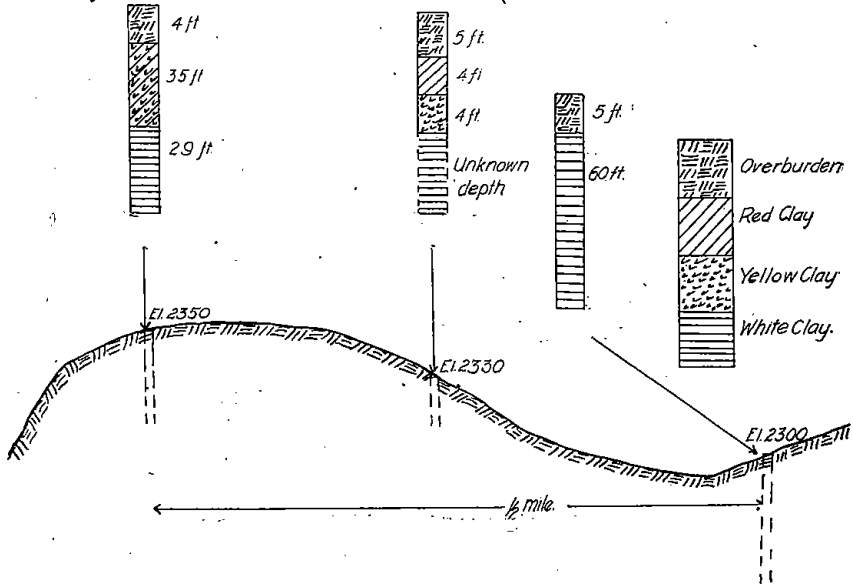


Fig. 4. Cross-section sketch looking NE. thru Stanley Hill near Coeur d'Alene. Samples in order from right to left are No. 17, 16, and 18.

#### Sample No. 17.

*Location.* One-half mile east of sample No. 16. From dump of well immediately in the rear of Stanley's house. Well is walled up and covered entirely.

*Occurrence.* Well is covered but owner reports that it was put down 60 feet, entirely in the white clay and water was struck after passing through the clay.

*Field Characteristics.* A coarse grained, medium soft, gray white clay with no visible objectionable material.

*General Properties.* Water of plasticity 33.5%, general plasticity good, slakes quickly, dry linear shrinkage 4% without warping, but little cracking.

*Fire Properties*

|                      |           |                   |           |          |            |
|----------------------|-----------|-------------------|-----------|----------|------------|
| Cone No. ....        | 01        | 3                 | 6         | 9+       | 15         |
| Color .....          | Deep Buff | Deep Buff         | Deep Buff | Buff     | Brown Gray |
| Hardness .....       | Med. Hard | Med. Hard         | Med. Hard | Hard     | Soft       |
|                      | Per Cent  | Per Cent          | Per Cent  | Per Cent | Per Cent   |
| Absorption .....     | 31.3      | 28.9              | 27.0      | 20.8     | 33.0       |
| Fire Shrinkage ..... | .....     | .....             | .....     | .....    | .....      |
| Total Shrinkage..... | 4.0       | 4.0               | 4.0       | 4.0      | 2.5        |
| Condition .....      |           | Small body cracks |           | Good     | Funky      |

*Cone Fusion.* Cone 20 Minus. Approximately 1520°C.

*Probable Economic Value.* This clay could possibly be used for buff face brick and one of the clays in a terra cotta or crude pottery body. Needs mixing with a clay which vitrifies at a lower temperature. It is not a refractory clay.

**Sample No. 18.**

*Location.* One-quarter mile west of sample No. 16 and taken from the dump of a caved well immediately east of house.

*Occurrence.* Well reported to be 60 feet deep with the bottom 29 feet in white clay. Did not go through the clay but abandoned the well.

*Field Characteristics.* A fine grained, hard, yellowish gray clay without visible objectionable material.

*General Properties:* Water of plasticity 40.3%, general plasticity good, slakes slowly, dry linear shrinkage 7% with cracking.

*Fire Properties*

|                      |                                    |            |            |                  |
|----------------------|------------------------------------|------------|------------|------------------|
| Cone No. ....        | 01                                 | 3          | 6          | 15               |
| Color .....          | Gray White                         | Gray White | Gray White | Light Buff Brown |
| Hardness .....       | Steel Hard                         | Steel Hard | Steel Hard | Steel Hard       |
|                      | Per Cent                           | Per Cent   | Per Cent   | Per Cent         |
| Absorption .....     | 13.7                               | 8.5        | 6.3        | .....            |
| Fire Shrinkage ..... | 11.0                               | 13.0       | 15.0       | .....            |
| Total Shrinkage..... | 18.0                               | 20.0       | 22.0       | .....            |
| Condition .....      | All badly cracked with yellow seum |            |            |                  |

*Probable Economic Value.* A small portion could possibly be used in a crude pottery or terra cotta or buff burning face brick body but its value when used alone is very doubtful because of cracking and high shrinkage.

**Sample No. 19.**

*Location.* General location same as samples No. 12, 13, 14, and 15. Sample taken one-quarter mile west of wells and pit, on the east end of Mooney's ranch.

*Occurrence.* A 4-foot exposure of material in a hole reported to have been dug to a depth of 16 feet and then drilled to a further depth of 30 feet, now partly caved. Neither strike nor dip could be determined, but apparently the material crops, or can be found near the surface in numerous places for a distance of one-half mile west of the exposure. This deposit is derived from the decomposition of granite.

*Field Characteristics.* A fine grained, medium hard, white massive clay, without visible objectionable material.

*General Properties.* Water of plasticity 30.3%, general plas-

ticity fine, slakes readily dry linear shrinkage 8% without cracking or warping.

#### Fire Properties

| Cone No. ....       | 01         | 3          | 6          | 9+         | 15   |
|---------------------|------------|------------|------------|------------|--|
| Color.....          | Light Buff | Med. Buff  | Med. Buff  | Gray Buff  | Light Brown                                |
| Hardness .....      | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard                                 |
|                     | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent                                   |
| Absorption .....    | 16.7       | 10.5       | 9.1        | 5.3        | 1.0  |
| Fire Shrinkage .... | 6.0        | 6.5        | 7.0        | 9.0        | 9.0  |
| Total Shrinkage.... | 14.0       | 14.5       | 15.0       | 17.0       | 17.0                                       |
| Condition .....     | Good       | Good       | Good       | Good       | Blue gray interior; vitreous, some warpage |

*Cone Fusion.* Cone No. 30. Approximately 1675°C.

*Analysis.* SiO<sub>2</sub> 58.4%; Al<sub>2</sub>O<sub>3</sub> 29.6%; Fe<sub>2</sub>O<sub>3</sub> 1.9%; CaO 1.55%; MgO 0.04%; Ignition Loss 9.1%.

*Probable Economic Value.* Buff burning structural wares, such as face brick, and if buff color is not objectionable, for drain tile and sewer pipe. A portion could be used in crude pottery and terra cotta bodies.

No. 2 Refractory.

#### Sample No. 19a.

*Location.* In a cut on the O. W. R. & N. Rail road, one-quarter mile south of the station of Chatcolet. Sample taken 300 feet from the south end of the cut.

*Occurrence.* A 30-foot exposure, striking north and south, flat and well stratified and under an overburden 5 feet in depth. On the top of the clay deposit is a 20-foot bed of soft sandy shale.

*Field Characteristics.* A fine grained medium hard, yellow clay with red streaks.

*General Properties.* Water of plasticity 32.3%, general plasticity fair, slakes very readily, dry linear shrinkage 6% without warping or cracking.

#### Fire Properties

| Cone No. ....       | 010      | 06       | 02       | 3          | 6          |
|---------------------|----------|----------|----------|------------|------------|
| Color.....          | Brown    | Brown    | Dark     | Buff Brown | Buff Brown |
| Hardness .....      | Soft     | Soft     | Hard     | Steel Hard | Steel Hard |
|                     | Per Cent | Per Cent | Per Cent | Per Cent   | Per Cent   |
| Absorption .....    | 24.6     | 21.8     | 15.2     | 10.9       | 7.0        |
| Fire Shrinkage .... | 1.0      | 2.5      | 4.0      | 5.0        | 8.0        |
| Total Shrinkage.... | 7.0      | 8.5      | 10.0     | 13.0       | 16.0       |
| Condition .....     | Good     | Good     | Good     | Good       | Good       |

*Probable Economic Value.* Common brick, drain tile and face brick.

#### Sample No. 19b.

*Location.* General location same as sample No. 30. Sample taken near the south end of the cut over a 60-foot face.

*Occurrence.* Same as sample No. 19a.

*Field Characteristics.* A fine grained, medium hard, brown yellow clay.

*General Properties.* Water of plasticity 31.1%, general plasticity fair, slakes very readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....       | 010              | 06                 | 02                 | 1+                 | 3                  |
|---------------------|------------------|--------------------|--------------------|--------------------|--------------------|
| Color .....         | Bright<br>Red    | Buff Brown<br>Soft | Buff Brown<br>Hard | Buff Brown<br>Hard | Buff Brown<br>Hard |
| Hardness .....      | Soft             | Per Cent           | Per Cent           | Per Cent           | Per Cent           |
| Absorption .....    | Per Cent<br>23.9 | 23.9               | 19.1               | 15.9               | 14.9               |
| Fire Shrinkage .... | 1.0              | 1.5                | 5.0                | 6.0                | 7.0                |
| Total Shrinkage.... | 6.0              | 6.5                | 10.0               | 11.0               | 12.0               |
| Condition .....     | Good             | Good               | Good               | Good               | Good               |

*Probable Economic Value.* Common brick, face brick and drain tile.



## LATAH COUNTY.

Latah County, like Benewah County, is on the northwestern edge of the granite batholith. From a geological standpoint, there is but little to choose between the two counties as far as clay occurrence is concerned. From a commercial standpoint, however, Latah County is the better situated because of its more open country, less mountainous terrain, better transportation facilities and better market conditions. Several deposits and many indications of deposits were seen but not examined or sampled because of lack of time.

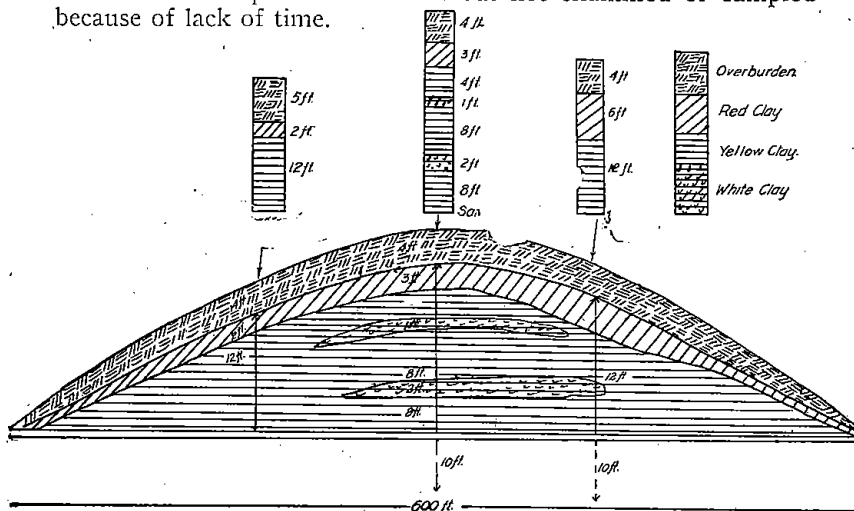


FIG. 5. Longitudinal sketch of railroad cut, near Stanford. Samples in order from right to left are No. 22, 20, and 24.

## Sample No. 20.

*Location.* In a cut 600 feet long on the Idaho, Washington & Montana Railroad, near Stanford station, six miles northwest of Deary. Sample taken from near center of cut and on the north side of the track.

*Occurrence.* A 24-foot exposure of red, yellow and white material striking easterly and westerly, flat and well stratified and under an overburden of from two to six feet. Drilled 10 feet below the track level finding white material the entire distance. It is reported to have been drilled to a depth of 100 feet in three distinct places, in the center, and on the north and south limits of a 40-acre tract, the entire distance being in the white material.

*Field Characteristics.* A medium fine grained, sandy, medium hard, gray clay with mica visible.

*General Properties.* Water of plasticity 29.8%, general plasticity good, slakes readily, dry linear shrinkage 8% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01         | 3          | 6          | 9+         | 15                               |
|----------------------|------------|------------|------------|------------|----------------------------------|
| Color .....          | Brown Buff | Brown Buff | Light Buff | Light Buff | Mottled                          |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Brown                            |
|                      | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Steel Hard                       |
| Absorption .....     | 10.7       | 9.3        | 8.0        | 4.5        | 7.5                              |
| Fire Shrinkage ..... | 4.0        | 4.5        | 3.5        | 4.5        | 4.5                              |
| Total Shrinkage....  | 12.0       | 12.5       | 11.5       | 12.5       | 12.5                             |
| Condition .....      | Good       | Good       | Good       | Good       | Dark interior,<br>no deformation |

*Cone Fusion.* Cone No. 29. Approximately 1650°C.

*Analysis.* (by University of North Dakota) SiO<sub>2</sub> 51.7%; Al<sub>2</sub>O<sub>3</sub> 34.7%; Fe<sub>2</sub>O<sub>3</sub> 3.48%; CaO 1.2%; MgO 0.5%.

*Probable Economic Value.* Buff colored face brick, and possibly building tile. May be used in a crude pottery, terra cotta or stoneware body.

No. 2 refractory clay.

**Sample No. 21.**

*Location.* General location same as sample No. 20. Sample from beneath No. 20 at bottom of deposit.

*Occurrence.* Same as No. 20.

*Field Characteristics.* A fine grained, hard, white clay with yellow streaks, and showing mica.

*General Properties.* Water of plasticity 32.2%, general plasticity fine, slakes very readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....    | 01         | 3          | 6          | 9          | 15   |
|------------------|------------|------------|------------|------------|--|
| Color .....      | Light      | Light      | Light      | Gray Buff  | Mottled  |
| Hardness .....   | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard   |
|                  | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption ..... | 22.7       | 17.0       | 13.0       | 7.0        | 6.8  |
| Condition .....  | Good       | Good       | Good       | Good       | Few slag spots,<br>dark interior<br>but not deformed |

*Analysis.* Similar to No. 23.

*Probable Economic Value.* Similar to No. 20.

**Sample No. 22.**

*Location.* General location same as No. 21. Sample taken near east end of cut over 9-foot face.

*Occurrence.* Same as sample No. 20.

*Field Characteristics.* A fine grained, sandy, medium hard, gray and brown clay, showing mica particles.

*General Properties.* Water of plasticity 32.8%, general plasticity good, slakes very readily, dry linear shrinkage 7% without cracking or warping.

| Cone No.        | Fire Properties |            |           |            |            |   |
|-----------------|-----------------|------------|-----------|------------|------------|---|
|                 | 101             | 06         | 02        | 3          | 6          | 15  |
| Color           | Buff Brown      | Light Buff | Gray Buff | Gray Buff  | Gray Buff  | Light Brown                                     |
| Hardness        | Soft            | Soft       | M. Hard   | Steel Hard | Steel Hard | Steel Hard                                      |
|                 | Per Cent        | Per Cent   | Per Cent  | Per Cent   | Per Cent   | Per Cent  |
| Absorption      | 22.2            | 20.8       | 14.5      | 11.0       | 9.7        | 0.2   |
| Fire Shrinkage  | 2.0             | 3.0        | 4.0       | 4.0        | 6.0        | 7.5   |
| Total Shrinkage | 9.0             | 10.0       | 11.0      | 11.0       | 13.0       | 14.5  |
| Condition       | Good            | Good       | Good      | Good       | Good       | Near vitreous and dark interior, no deformation |

*Analysis.* Similar to No. 23.

*Probable Economic Value.* Similar to No. 20.

#### Sample No. 23.

*Location.* General location same as No. 21. Sample taken beneath No. 20.

*Occurrence.* Same as sample No. 20.

*Field Characteristics.* A fine grained, soft, white and brown clay, showing mica.

*Field Characteristics.* A fine grained, soft, white and brown clay, showing mica.

*General Properties.* Water of plasticity 30%, general plasticity fair, slakes readily, dry linear shrinkage 6% without cracking or warping.

| Cone No.        | Fire Properties |             |             |             |          |  |
|-----------------|-----------------|-------------|-------------|-------------|----------|--|
|                 | 02              | 1+          | 3           | 6           | 9        | 15   |
| Color           | Light Brown     | Light Brown | Light Brown | Light Brown | .....    | Light Brown                                  |
| Hardness        | Hard            | Hard        | Hard        | Hard        | .....    | Hard Steel Hard                              |
|                 | Per Cent        | Per Cent    | Per Cent    | Per Cent    | Per Cent | Per Cent                                     |
| Absorption      | .....           | 16.7        | 15.9        | 12.2        | 6.2      | 8.2  |
| Fire Shrinkage  | .....           | 2.0         | 5.0         | 5.0         | 7.0      | 3.5  |
| Total Shrinkage | .....           | 8.0         | 11.0        | 11.0        | 12.0     | 9.5  |
| Condition       | Good            | Good        | Good        | Good        | Good     | Near vitreous, dark interior, no deformation |

*Analysis.* (by University of North Dakota) SiO<sub>2</sub> 53.9%; Al<sub>2</sub>O<sub>3</sub> 34.4%; Fe<sub>2</sub>O<sub>3</sub> 0.9%; CaO 0.2%; MgO 0.4%; Ignition Loss 10.2%.

*Probable Economic Value.* Requires rather high temperature for even porous structural ware. Needs mixing with other clays.

#### Sample No. 24.

*Location.* Same as sample No. 20. Sample taken from west end of cut and near the top of the deposit.

*Occurrence.* Same as sample No. 20.

*Field Characteristics.* A fine grained, medium hard, gray clay, showing mica.

*General Properties.* Water of plasticity 31.3%, general plasticity fine, slakes readily, dry linear shrinkage 8% without cracking or warping.

| Cone No.        | Fire Properties |            |            |            |                                |
|-----------------|-----------------|------------|------------|------------|--------------------------------|
|                 | 01              | 3          | 6          | 9+         | 15                             |
| Color           | Buff            | Buff       | Buff       | Dark Gray  | Mottled Brown                  |
| Hardness        | Steel Hard      | Steel Hard | Steel Hard | Steel Hard | Steel Hard                     |
|                 | Per Cent        | Per Cent   | Per Cent   | Per Cent   | Per Cent                       |
| Absorption      | 8.6             | 6.5        | 6.4        | 2.7        | 5.7                            |
| Fire Shrinkage  | 7.0             | 7.5        | 8.0        | 8.0        | 7.0                            |
| Total Shrinkage | 15.0            | 15.5       | 16.0       | 16.0       | 15.0                           |
| Condition       | Good            | Good       | Good       | Good       | Dark interior, slight swelling |

*Analysis.* Similar to No. 23.

*Probable Economic Value.* Similar to No. 20.

**Sample No. 25.**

*Location.* Same as sample No. 20.

*Occurrence.* Same as sample No. 20.

*Field Characteristics.* A coarse grained, medium hard, gray and yellow clay, showing mica.

*General Properties.* Water of plasticity 26%, general plasticity good, slakes readily, dry linear shrinkage 6% without cracking or warping.

*Fire Properties*

| Cone No.        | 02       | 1+       | 3          | 6          | 9+         | 15                     |
|-----------------|----------|----------|------------|------------|------------|------------------------|
| Color           | Buff     | Buff     | Buff       | Buff       | Buff       | Mottled Brown          |
| Hardness        | Hard     | Hard     | Steel Hard | Steel Hard | Steel Hard | Steel Hard             |
|                 | Per Cent | Per Cent | Per Cent   | Per Cent   | Per Cent   | Per Cent               |
| Absorption      | 28.3     | 24.1     | 22.2       | 15.4       | 11.5       | 4.1                    |
| Fire Shrinkage  | 1.0      | 1.0      | 4.0        | 4.0        | 4.0        | 6.0                    |
| Total Shrinkage | 7.0      | 7.0      | 11.0       | 11.0       | 11.0       | 12.0                   |
| Condition       | Good     | Good     | Good       | Good       | Good       | Dark interior but good |

*Analysis.* Similar to No. 23.

*Probable Economic Value.* Similar to No. 24.

**Sample No. 26.**

*Location.* One-half mile east of Deary in a cut on the Idaho, Washington & Montana Railroad. Sample taken on the north side of the cut, near the center and over 11 foot face.

*Occurrence.* An 11-foot exposure of a gray material with yellow streaks, striking easterly and westerly, flat, well stratified and under a 5-foot overburden. Is on the top of a small knoll, set off by itself in the edge of the valley near the foothills and is not very extensive. There are a great number of clay exposures in the surrounding country, and it is possible that the continuation of this exposure could be picked up in the foothills to the north. This clay is derived from granite.

*Field Characteristics.* A fine grained, medium soft, gray and yellow clay showing mica.

*General Properties.* Water of plasticity 34.6%, general plasticity fine, slakes slowly, dry linear shrinkage 7% without warping or cracking.

*Fire Properties*

| Cone No.        | 01         | 3          | 6          | 9               | 15                            |
|-----------------|------------|------------|------------|-----------------|-------------------------------|
| Color           | Gray Buff  | Gray Buff  | Gray Buff  | Light Gray Buff | Mottled Brown                 |
|                 | Per Cent   | Per Cent   | Per Cent   | Per Cent        | Per Cent                      |
| Hardness        | Steel Hard | Steel Hard | Steel Hard | Steel Hard      | Steel Hard                    |
| Absorption      | 10.8       | 10.8       | 6.5        | 4.4             | 2.5                           |
| Fire Shrinkage  | 7.0        | 9.0        | 9.0        | 9.0             | 9.5                           |
| Total Shrinkage | 14.0       | 16.0       | 16.0       | 16.0            | 16.5                          |
| Condition       | Good       | Good       | Good       | Good            | Dark interior but no swelling |

*Probable Economic Value.* Buff colored face brick, possibly structural hollow ware such as building blocks, crude pottery, terra cotta or even stoneware.

**Sample No. 27.**

*Location.* General location same as sample No. 26. Sample taken near west end of cut over 11-foot exposure.

*Occurrence.* Same as sample No. 26.

*Field Characteristics.* A fine grained, medium soft, gray and brown clay.

*General Properties.* Water of plasticity 31.2%, general plasticity fine, slakes very readily, dry linear shrinkage 7% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01         | 3          | 6                 | 9+         | 15         |
|----------------------|------------|------------|-------------------|------------|------------|
|                      |            |            |                   | Light      | Mottled    |
| Color .....          | Pink Gray  | Pink Gray  | Light Gray        | Gray Buff  | Light Buff |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard        | Steel Hard | Steel Hard |
|                      | Per Cent   | Per Cent   | Per Cent          | Per Cent   | Per Cent   |
| Absorption .....     | 18.6       | 14.0       | 8.3               | 6.8        | 4.5        |
| Fire Shrinkage ..... | 8.0        | 8.0        | 11.0              | 11.0       | 11.5       |
| Total Shrinkage....  | 13.0       | 15.0       | 18.0              | 18.0       | 18.5       |
| Condition .....      |            |            | All badly cracked |            |            |

*Analysis.* Similar to No. 26.

*Probable Economic Value.* Similar to No. 26 if precautions can be taken to prevent cracking.

**Sample No. 28.**

*Location.* Same as sample No. 26. Sample taken near the east end of the cut.

*Occurrence.* Same as sample No. 26.

*Field Characteristics.* A fine grained, medium soft, gray clay.

*General Properties.* Water of plasticity 25%, general plasticity fine, slakes readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01         | 3          | 6          | 9+         |
|----------------------|------------|------------|------------|------------|
|                      |            |            |            |            |
| Color .....          | Light Gray | Light Gray | Gray White | Gray White |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard | Steel Hard |
|                      | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....     | 17.5       | 14.4       | 12.3       | 9.6        |
| Fire Shrinkage ..... | 7.0        | 9.0        | 10.0       | 14.0       |
| Total Shrinkage....  | 12.0       | 14.0       | 15.0       | 19.0       |
| Condition .....      | Cracked    | Cracked    | Cracked    | Cracked    |

*Analysis.* Similar to 26.

*Probable Economic Value.* Similar to No. 27. Precautions should be taken to overcome cracking.

**Sample No. 29.**

*Location.* In a cut on the Idaho, Washington & Montana Railroad, 200 yards west of the station of Deary. Sample taken 30 feet east of the west end and on the north side of the cut, over a face of 10 feet.

*Occurrence.* A 22-foot exposure striking east and west, flat, well stratified, with yellow streaks thruout the gray, and under an overburden of 10 feet. Occurs near the bottom of the slope on the south side of the range, and is a transported clay derived from granite.

*Field Characteristics.* A coarse grained, medium soft, gray clay, with yellow streaks, showing mica.

*General Properties.* Water of plasticity 41.6%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping. This sample was washed for kaolin. Screened thru 200 mesh removing 63% sand.

*Fire Properties*

| Cone No. ....         | 02<br>Light | 1+         | 3          | 6          | 9          |
|-----------------------|-------------|------------|------------|------------|------------|
| Color .....           | Pink Buff   | Light Buff | Light Buff | Light Buff | Light Buff |
| Hardness .....        | Hard        | Hard       | Steel Hard | Steel Hard | Steel Hard |
|                       | Per Cent    | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....      |             | 17.1       | 15.1       | 12.2       | 8.1        |
| Fire Shrinkage .....  | 8.0         | 8.0        | 8.0        | 11.0       | 11.0       |
| Total Shrinkage ..... | 15.0        | 15.0       | 15.0       | 18.0       | 18.0       |
| Condition .....       | Cracked     | Cracked    | Cracked    | Cracked    | Cracked    |

*Cone Fusion.* Come No. 30-31. Approximately 1675°C.

*Analysis.* Similar to No. 30.

*Probable Economic Value.* Crude pottery, stoneware, terra cotta clay. When grogged or mixed with sandier clays could be also used for buff structural wares. Shows fair refractory qualities.

**Sample No. 30.**

*Location.* General location same as sample No. 29. Sample taken over 15-foot face beneath No. 29.

*Occurrence.* Same as sample No. 29.

*Field Characteristics.* A coarse grained, soft, white and brown clay, showing mica particles.

*General Properties.* Water of plasticity 27.6%, general plasticity good, slakes very readily, dry linear shrinkage 6% without cracking or warping.

*Fire Properties*

| Cone No.        | 010      | 06       | 02        | 1+                   | 6          | 15  |
|-----------------|----------|----------|-----------|----------------------|------------|---|
| Color           | Buff     | Buff     | Buff      | Buff                 | Buff       | Dark  |
| Hardness        | Brown    | Brown    | Brown     | Brown                | Brown      | Brown   |
|                 | Soft     | Soft     | Med. Hard | Steel Hard           | Steel Hard | Steel Hard  |
|                 | Per Cent | Per Cent | Per Cent  | Per Cent             | Per Cent   | Per Cent  |
| Absorption      | 23.0     | 22.6     | 19.3      | 16.6                 | 14.2       | 2.1   |
| Fire Shrinkage  | 1.0      | 2.0      | 4.0       | 5.0                  | 6.0        | 5.5   |
| Total Shrinkage | 7.0      | 8.0      | 10.0      | 11.0                 | 12.0       | 11.5  |
| Condition       | Good     | Good     | Good      | Small surface cracks |            | Dark interior showing white siliceous grains, dense structure |

*Analysis.* (by University of North Dakota) SiO<sub>2</sub> 52.7%; Al<sub>2</sub>O<sub>3</sub> 21.2%; FeO 14.6%; CaO 1.4%; MgO 1.6%; Ignition Loss 8.8%.

*Probable Economic Value.* Common and face brick, possibly drain tile, and building brick. Must be fired to a higher temperature than is commonly used for these products to develop good structure.

**Sample No. 31.**

*Location.* General location same as sample No. 21. Sample taken 30 feet west of east end of cut over face of 20 feet.

*Occurrence.* Same as sample No. 21.

*Field Characteristics.* A coarse grained, medium soft, gray clay with brown streaks.

*General Properties.* Water of plasticity 23.1%, general plasticity, fair, slakes very readily, dry linear shrinkage 4% without cracking or warping.

| Cone No.        | <i>Fire Properties</i> |            |            |            |            |  |
|-----------------|------------------------|------------|------------|------------|------------|--|
|                 | 010                    | 06         | 02         | 3          | 6          | 15                                     |
| Color           | Buff                   | Light Buff | Light Buff | Light Buff | Light Buff | Spotted Gray                           |
| Hardness        | Brown Soft             | Brown Soft | Brown Soft | Brown Hard | Brown Hard | Brown Steel Hard                       |
| Absorption      | 20.6                   | 23.0       | 19.5       | 17.2       | 12.9       | 2.9                                    |
| Fire Shrinkage  | 1.0                    | 1.0        | 3.0        | 3.0        | 3.0        | 7.5                                    |
| Total Shrinkage | 5.0                    | 5.0        | 7.0        | 7.0        | 7.0        | 11.5                                   |
| Condition       | Good                   | Good       | Good       | Good       | Good       | Vitreous gray interior, good structure |

*Analysis.* Similar to No. 22.

*Probable Economic Value.* Alone, it needs a higher temperature of firing for structural wares than is commonly used. If mixed with a small quantity of clay which vitrifies at a low temperature, it would be better suited for the structural wares.

#### Sample No. 32.

*Location.* Six miles east of Troy on main wagon road. Sample taken in west end of pit over face of eight feet at top of deposit.

*Occurrence.* A pit 100 feet long by 50 feet wide and 24 feet deep with one foot of overburden. The bed strikes easterly and westerly, is flat and well stratified. The pit is on a small knoll near the bottom of the slope on the south side of the mountain range. Clay is exposed in a great many places throughout the surrounding country. It is reported that several deposits have been examined and found to be of commercial value. The clay is derived from granite.

*Field Characteristics.* A coarse grained, medium hard, gray clay, showing mica.

*General Properties.* Water of plasticity 41.1%, general plasticity fine, slakes readily, dry linear shrinkage 7% without cracking or warping. This sample was washed for kaolin. Screened thru 200 mesh removing 61% sand.

| Cone No.        | <i>Fire Properties</i> |                          |            |            |            |
|-----------------|------------------------|--------------------------|------------|------------|------------|
|                 | 01                     | 3                        | 6          | 9+         | 15         |
| Color           |                        | Approaching nearly white |            |            |            |
| Hardness        | Steel Hard             | Steel Hard               | Steel Hard | Steel Hard | Steel Hard |
|                 | Per Cent               | Per Cent                 | Per Cent   | Per Cent   | Per Cent   |
| Absorption      | 20.2                   | 16.3                     | 19.4       | 13.9       | 10.2       |
| Fire Shrinkage  | 8.0                    | 8.0                      | 10.0       | 10.0       | 15.5       |
| Total Shrinkage | 15.0                   | 15.0                     | 17.0       | 17.0       | 22.5       |
| Condition       |                        | Few small cracks         |            |            |            |

*Analysis of Unwashed Clay.* (by Anaconda Copper Mining Co.) SiO<sub>2</sub> 58.2; Al<sub>2</sub>O<sub>3</sub> 27%; Fe<sub>2</sub>O<sub>3</sub> 1.9%; CaO 0.4%; MgO 0.0%; Ignition Loss 2.2%.

*Probable Economic Value.* Refractory wares when mixed with grog, white ware and possibly paper clay.

### Sample No. 33.

*Location.* General location same as sample No. 32, Sample taken over 8-foot face immediately beneath sample No. 32.

*Occurrence.* Same as sample No. 32.

*Field Characteristics.* A fine grained, medium soft, white clay.

*General Properties.* Water of plasticity 27.4% general plasticity fine, slakes very readily, dry linear shrinkage 6% without warping but some cracking.

### Fire Properties

| Cone No. ....         | 01                                    | 3          | 6          | 9+         | 15                        |
|-----------------------|---------------------------------------|------------|------------|------------|---------------------------|
| Color .....           | Gray White                            | Gray White | Gray White | Gray White | Light Gray,<br>near White |
| Hardness .....        | Med. Hard                             | Med. Hard  | Steel Hard | Steel Hard | Steel Hard                |
|                       | Per Cent                              | Per Cent   | Per Cent   | Per Cent   | Per Cent                  |
| Absorption .....      | 25.9                                  | 22.1       | 18.0       | 11.4       | 12.0                      |
| Fire Shrinkage .....  | 3.0                                   | 5.0        | 7.0        | 8.0        | 7.5                       |
| Total Shrinkage ..... | 9.0                                   | 11.0       | 13.0       | 14.0       | 13.5                      |
| Condition .....       | Fine checking due to quartz particles |            |            |            |                           |

*Analysis.* (by Anaconda Copper Mining Co.) SiO<sub>2</sub> 57.5%; Al<sub>2</sub>O<sub>3</sub> 40.9%; Fe<sub>2</sub>O<sub>3</sub> 0.5%; CaO 0.4%; MgO 0.5%; Ignition Loss 2%.

*Probable Economic Value.* Refractory wares. The removal of the quartz and partial substitution of grog made of the fired clay would increase the refractoriness.

### Sample No. 34.

*Location.* General location same as No. 32. Sample taken over 8-foot face immediately over No. 33.

*Occurrence.* Same as sample No. 32. The bottom of the pit is quite yellow and lies on a bed of gravel.

*Field Characteristics.* A medium fine grained, medium soft, yellow and white clay, showing mica.

*General Properties.* Water of plasticity 28.3%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

### Fire Properties

| Cone No. ....         | 010      | 06       | 02             | 1+       | 3        |
|-----------------------|----------|----------|----------------|----------|----------|
| Color .....           |          |          | Deep brown red |          |          |
| Hardness .....        | Soft     | Soft     | Hard           | Hard     | Hard     |
|                       | Per Cent | Per Cent | Per Cent       | Per Cent | Per Cent |
| Absorption .....      | 33.9     | 25.4     | 22.0           | 20.7     | 17.0     |
| Fire Shrinkage .....  |          | 0.5      | 3.0            | 3.0      | 3.0      |
| Total Shrinkage ..... | 7.0      | 7.5      | 10.0           | 10.0     | 10.0     |
| Condition .....       | Good     | Good     | Good           | Good     | Good     |

*Analysis.* Similar to No. 30.

*Probable Economic Value.* Common brick and drain tile. Better product could be produced by mixing with a clay of lower



temperature of vitrification. The color is a very good brown red, excellent for structural wares.

#### Sample No. 35.

*Location.* General location same as No. 32. Sample is over 6-foot face near the top in east end of pit.

*Occurrence.* Same as sample No. 32. The east end of pit, however, shows a light yellow color and is covered by a 3-foot overburden.

*Field Characteristics.* A fine grained, medium soft, white clay with light yellow streaks and showing mica.

*General Properties.* Water of plasticity 21.8%, general plasticity fine, slakes very readily, dry linear shrinkage 6% without cracking or warping.

| <i>Fire Properties</i> |                     |                          |                         |                    |   |
|------------------------|---------------------|--------------------------|-------------------------|--------------------|---|
| Cone No. ....          | 01                  | 3                        | 6                       | 9+                 | 15                                      |
| Color.....             | Light<br>Brown Buff | Light Buff<br>Steel Hard | Gray Buff<br>Steel Hard | Gray<br>Steel Hard | Light Brown<br>Steel Hard               |
| Hardness .....         | Steel Hard          | Per Cent                 | Per Cent                | Per Cent           | Per Cent                                |
| Absorption .....       | 19.4                | 17.7                     | 14.8                    | 12.0               | 8.3                                     |
| Fire Shrinkage .....   | 3.0                 | 3.0                      | 3.0                     | 5.0                | 5.5                                     |
| Total Shrinkage.....   | 9.0                 | 9.0                      | 9.0                     | 11.0               | 11.5                                    |
| Condition .....        | Good                | Good                     | Cracked                 | Cracked            | Near<br>vitrification,<br>gray interior |

*Analysis.* Similar to No. 30.

*Probable Economic Value.* Buff colored face brick, hollow building block, terra cotta. When mixed with No. 32 the plasticity of the latter would be improved for a lower grade refractory. When washed, it might be used for crude pottery and stoneware.

#### Sample No. 36.

*Location.* General location same as sample No. 32. Sample taken in east end of pit and beneath sample No. 35.

*Occurrence.* Same as sample No. 32.

*Field Characteristics.* A coarse grained, medium soft, white clay, showing mica.

*General Properties.* Water of plasticity 43.7%, general plasticity fair, slakes readily, dry linear shrinkage 8% without cracking or warping. Sample was washed for kaolin. Screened thru 200 mesh removing 66.8% sand.

| <i>Fire Properties</i> |                   |          |          |          |          |
|------------------------|-------------------|----------|----------|----------|----------|
| Cone No. ....          | 02                | 1+       | 3        | 6        | 15       |
| Color.....             | Nearly pure white |          |          |          |          |
| Hardness .....         | All steel hard    |          |          |          |          |
|                        | Per Cent          | Per Cent | Per Cent | Per Cent | Per Cent |
| Absorption .....       | 23.0              | 16.0     | 21.6     | 19.4     | 9.1      |
| Fire Shrinkage .....   | 6.0               | 6.0      | 6.0      | 9.0      | 12.0     |
| Total Shrinkage.....   | 14.0              | 14.0     | 14.0     | 17.0     | 20.0     |
| Condition .....        | Badly cracked     |          |          |          |          |

*Probable Economic Value.* White ware or possibly paper clay. Refractory clay.

**Sample No. 37.**

*Location.* General location same as No. 32. Sample taken 18 feet beneath surface, over face of six feet.

*Occurrence.* Same as No. 33. Yellow material in bottom.

*Field Characteristics.* A medium fine grained, medium hard, yellow clay with white streaks, showing mica.

*General Properties.* Water of plasticity 28.3%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without warping or cracking.

*Fire Properties*

| Cone No. ....        | 010      | 06       | 02             | 1+       | 3        |
|----------------------|----------|----------|----------------|----------|----------|
| Color .....          |          |          | Deep brown red |          |          |
| Hardness .....       | Soft     | Soft     | Hard           | Hard     | Hard     |
|                      | Per Cent | Per Cent | Per Cent       | Per Cent | Per Cent |
| Absorption .....     | 33.9     | 25.4     | 22.0           | 20.7     | 17.0     |
| Fire Shrinkage ..... | .....    | 0.5      | 3.0            | 3.0      | 3.0      |
| Total Shrinkage..... | 7.0      | 7.5      | 10.0           | 10.0     | 10.0     |
| Condition .....      | Good     | Good     | Good           | Good     | Good     |

*Analysis.* Similar to No. 30.

*Probable Economic Value.* Common brick and drain tile. Better product could be produced by mixing with a clay of lower temperature of vitrification. The color is a very good brown red, excellent for structural wares.

**Sample No. 38.**

*Location.* On the brow of a hill 100 feet south of the kilns of the Troy Fire Brick Co. Sample is over a face of three feet at the top of the bed under three feet of overburden.

*Occurrence.* A six-foot bed of so-called "shale" striking north and south and flat. It is reported to be used for mixing with fire clay to make an exceptionally hard brick.

*Field Characteristics.* Apparently a sill of fine grained igneous rock highly decomposed.

*General Properties.* Could not be moulded into a brick.

**Sample No. 38a.**

*Location.* Sample is over a three-foot face immediately Beneath No. 38.

*Occurrence, Field Characteristics and Dry Properties.* Similar to No. 38.

NOTE.—These samples of "shale" were tested because it was reported this material had been used in a mixture to produce an extra hard fire brick.

**Sample No. 39.**

*Location.* Six miles east of Moscow and one mile north of the Northern Pacific Railroad station of Joel.

*Occurrence.* A 10-foot exposure in a pit 20 feet long, 15 feet wide and 10 feet deep, under an overburden of two feet. It is a very irregular massive deposit without strike or dip. The

south end of the pit is a deep red in color, while the north end is bluish purple. A 10-foot auger hole in the center of the pit shows blue clay in the bottom. The deeper the deposit is opened the more prominent become the feldspar crystals in the red clay groundmass. The main deposit is derived from granite. The red color comes from a layer of basalt on the surface.

*Field Characteristics.* A medium coarse grained, soft, very deep red clay showing some feldspar crystals.

*General Properties.* Water of plasticity 29%, general plasticity fine, slakes very readily, dry linear shrinkage 4% without cracking or warping.

| Cone No.        | Fire Properties              |          |          |          |          |            |
|-----------------|------------------------------|----------|----------|----------|----------|------------|
|                 | 010                          | 06       | 02       | 1+       | 3        | 15         |
| Color           | Bright Brown                 | Brown    | Brown    | Brown    | Brown    | Dark Brown |
| Hardness        | Red                          | Red      | Red      | Red      | Red      | Red        |
|                 | Soft                         | Soft     | Soft     | Soft     | Soft     | Soft       |
|                 | Per Cent                     | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent   |
| Absorption      | 27.2                         | 31.2     | 31.2     | 17.7     | 15.7     | 14.8       |
| Fire Shrinkage  | 3.0                          | 4.0      | 6.5      | 8.0      | 9.0      | 8.5        |
| Total Shrinkage | 7.0                          | 8.0      | 10.5     | 12.0     | 13.0     | 12.5       |
| Condition       | Checked due to quartz grains |          |          |          |          |            |

*Cone Fusion.* Cone No. 36. Approximately 1575°C.

*Analysis.* Similar to No. 40.

*Probable Economic Value.* On account of the disruptive effect of the quartz grains during firing, the value of this clay when used alone is doubtful. Mixed with other clays it may be used for common brick, drain tile or face brick.

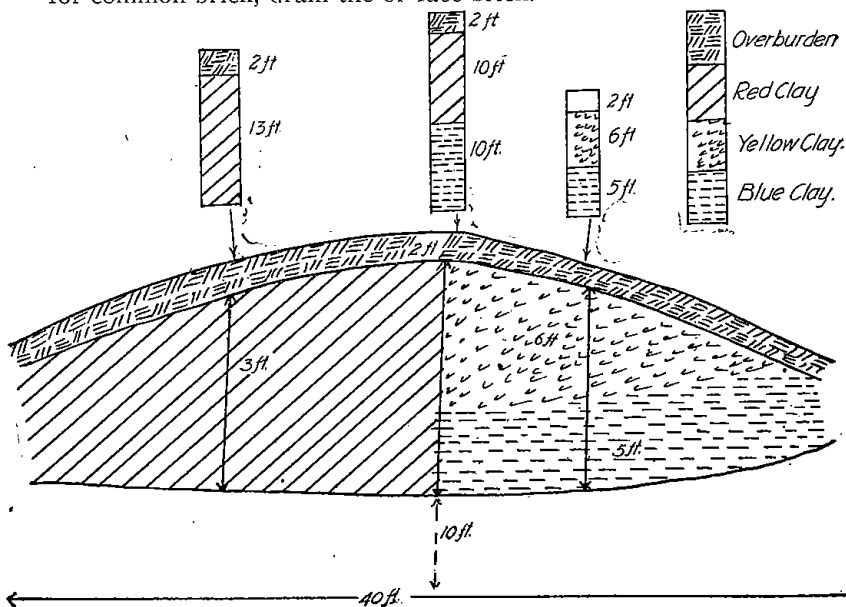


Fig. 6. Longitudinal sketch of clay pit A at Joel. Samples in order from left to right are No. 39, 40, and 42.

**Sample No. 40.**

*Location.* General location same as No. 39. Sample taken over five foot face beneath No. 39.

*Occurrence.* Same as No. 39.

*Field Characteristics.* A medium grained, medium soft, deep red clay.

*General Properties.* Water of plasticity 31.3%, general plasticity fine, slakes very readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....         | 010          | 06           | 02           | 1+       | 3        |
|-----------------------|--------------|--------------|--------------|----------|----------|
|                       | Bright Brown | Bright Brown | Bright Brown | Brown    | Brown    |
| Color .....           | Red          | Red          | Red          | Red      | Red      |
| Hardness .....        | Soft         | Soft         | Soft         | Hard     | Hard     |
|                       | Per Cent     | Per Cent     | Per Cent     | Per Cent | Per Cent |
| Absorption .....      | 28.4         | 29.0         | 22.7         | 19.7     | 16.5     |
| Fire Shrinkage .....  | 3.0          | 3.5          | 5.0          | 6.0      | 6.0      |
| Total Shrinkage ..... | 8.0          | 8.5          | 10.0         | 11.0     | 11.0     |

*Analysis.* SiO<sub>2</sub> 54.4%; Al<sub>2</sub>O<sub>3</sub> 28.5%; Fe<sub>2</sub>O<sub>3</sub> 8.2%; CaO 1.7%; MgO 0.2%; Ignition Loss 8.3%.

*Probable Economic Value.* Similar to No. 39.

The bright brown red color of these two clays is very good.

**Sample No. 41.**

*Location.* General location same as No. 39. Sample taken over a four-foot face immediately beneath No. 40.

*Occurrence.* Same as sample No. 39.

*Field Characteristics.* A medium coarse grained, medium soft, deep red clay.

*General Properties.* Water of plasticity 30.3%, general plasticity fine, slakes very readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....         | 010                           | 06           | 02           | 1+       | 3        |
|-----------------------|-------------------------------|--------------|--------------|----------|----------|
|                       | Bright Brown                  | Bright Brown | Bright Brown | Brown    | Brown    |
| Color .....           | Red                           | Red          | Red          | Red      | Red      |
| Hardness .....        | Soft                          | Soft         | Hard         | Hard     | Hard     |
|                       | Per Cent                      | Per Cent     | Per Cent     | Per Cent | Per Cent |
| Absorption .....      | 28.4                          | 29.0         | 22.7         | 14.7     | 16.5     |
| Fire Shrinkage .....  | 3.0                           | 3.5          | 5.0          | 6.0      | 6.0      |
| Total Shrinkage ..... | 8.0                           | 8.5          | 10.0         | 11.0     | 11.0     |
| Condition .....       | Checking due to quartz grains |              |              |          |          |

*Analysis.* Similar to No. 40.

*Probable Economic Value.* Similar to No. 40.

**Sample No. 42.**

*Location.* General location same as No. 39. Sample taken near the top in the center over a six-foot face.

*Occurrence.* Same as No. 39.

*Field Characteristics.* A coarse grained, medium hard, light red clay.

*General Properties.* Water of plasticity 29.2%, general plasticity fair, slakes very readily, dry linear shrinkage 6% without cracking or warping.

| Cone No.        | <i>Fire Properties</i> |           |          |          |          |  |
|-----------------|------------------------|-----------|----------|----------|----------|--|
|                 | 010                    | 06        | 02       | 3        | 6        | 15   |
| Color           | Light Red              | Light Red | Purple   | Purple   | Purple   | Mottled  |
| Hardness        | Brown                  | Brown     | Brown    | Brown    | Brown    | Brown  |
|                 | Soft                   | Soft      | Soft     | Soft     | Soft     | Soft   |
|                 | Per Cent               | Per Cent  | Per Cent | Per Cent | Per Cent | Per Cent   |
| Absorption      | 25.2                   | 30.4      | 25.0     | 22.8     | 21.2     | 22.4   |
| Fire Shrinkage  | 2.0                    | 3.5       | 2.0      | 3.0      | 4.0      | 3.0  |
| Total Shrinkage | 8.0                    | 9.5       | 8.0      | 9.0      | 10.0     | 9.0  |
| Condition       | Good                   | Good      | Good     | Good     | Good     | Very soft,<br>loose sandy<br>texture, slight<br>swelling |

*Analysis.* Similar to No. 40.

*Probable Economic Value.* Too high a temperature is required to produce a strong structure for common structural wares.

#### Sample No. 43.

*Location.* General location same as No. 39. Sample taken in center beneath No. 42.

*Occurrence.* Same as sample No. 39.

*Field Characteristics.* A medium fine grained, soft, purple and red clay.

*General Properties.* Water of plasticity 38%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

| Cone No.        | <i>Fire Properties</i> |           |              |              |                 |  |
|-----------------|------------------------|-----------|--------------|--------------|-----------------|--|
|                 | 010                    | 06        | 02           | 3            | 15              |  |
| Color           | Red Brown              | Red Brown | Purple Brown | Purple Brown | Dark Brown      |  |
| Hardness        | Soft                   | Soft      | Soft         | Soft         | Soft, Sandy     |  |
|                 | Per Cent               | Per Cent  | Per Cent     | Per Cent     | Per Cent        |  |
| Absorption      | 27.8                   | 27.7      | 27.6         | 26.0         | 30.4            |  |
| Fire Shrinkage  | 1.0                    | 1.0       | 1.0          | 2.0          | 0.5             |  |
| Total Shrinkage | 7.0                    | 8.0       | 8.0          | 9.0          | 7.5             |  |
| Condition       | Good                   | Good      | Good         | Good         | Slight swelling |  |

*Cone Fusion.* Cone No. 20-23. Approximately 1510°C.

*Analysis.* Similar to No. 40.

*Probable Economic Value.* Similar to No. 42. A low grade fire clay.

#### Sample No. 44.

*Location.* General location same as No. 39. Sample taken in center pit under No. 43.

*Occurrence.* Same as sample No. 39.

*Field Characteristics.* A medium fine grained, soft, purple and red clay with feldspar crystals prominent.

*General Properties.* Water of plasticity 38%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

| Cone No.        | <i>Fire Properties</i> |           |              |              |                 |  |
|-----------------|------------------------|-----------|--------------|--------------|-----------------|--|
|                 | 010                    | 06        | 02           | 3            | 15              |  |
| Color           | Red Brown              | Red Brown | Purple Brown | Purple Brown | Dark Brown      |  |
| Hardness        | Soft                   | Soft      | Soft         | Soft         | Soft, Sandy     |  |
|                 | Per Cent               | Per Cent  | Per Cent     | Per Cent     | Per Cent        |  |
| Absorption      | 27.8                   | 27.7      | 27.6         | 26.0         | 30.4            |  |
| Fire Shrinkage  | 1.0                    | 1.0       | 1.0          | 2.0          | 0.5             |  |
| Total Shrinkage | 7.0                    | 8.0       | 8.0          | 9.0          | 7.5             |  |
| Condition       | Good                   | Good      | Good         | Good         | Slight swelling |  |

*Analysis.* Similar to No. 40.

*Probable Economic Value.* Similar to No. 42.

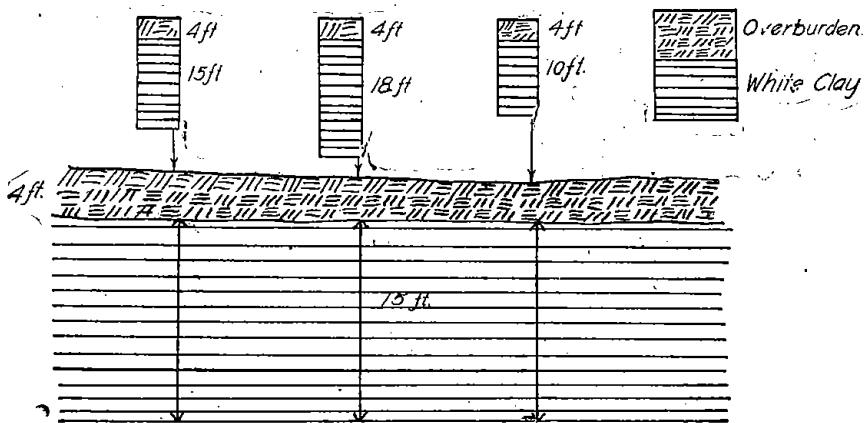


FIG. 7. Longitudinal sketch of clay pit B at Joel. Samples in order from right to left are No. 45, 49, and 52.

**Sample No. 45.**

*Location.* One hundred yards north of previously described pit where samples No. 39 and No. 42 were taken. General location same as No. 39.

*Occurrence.* A 22-foot exposure in a pit 100 feet long by 50 feet wide and 22 feet deep. It is a very irregular residual deposit and shows neither strike nor dip, and is derived from the decomposition of granite. The east end of the pit produces a finer grained and softer clay. The farther the pit is opened westerly, the coarser the grains and the harder the clay. It is reported that a hole has been drilled to a depth of 60 feet, the entire distance being in coarse white clay. White clay is exposed in several places over a 40-acre tract surrounding pit and in many other places in the surrounding country.

*Field Characteristics.* A fine grained, medium soft, gray clay, showing mica.

*General Properties.* Water of plasticity 37.5%, general plasticity good, slakes readily, dry linear shrinkage 5% without cracking or warping. Sample washed for kaolin. Screened thru 200 mesh removing 67% sand.

*Fire Properties*

| Cone No.        | 01                          | 3             | 6             | 9+            | 15           |
|-----------------|-----------------------------|---------------|---------------|---------------|--------------|
| Color           | Light Pink                  | Light Pink    | Nearly White  | Nearly White  | Cream White  |
| Hardness        |                             |               |               |               | Steel Hard   |
| Absorption      | Per Cent 29.3               | Per Cent 24.3 | Per Cent 22.5 | Per Cent 16.8 | Per Cent 6.7 |
| Fire Shrinkage  | 7.0                         | 7.0           | 7.0           | 7.0           |              |
| Total Shrinkage | 12.0                        | 12.0          | 12.0          | 12.0          |              |
| Condition       | Some cracking in all bricks |               |               |               |              |

*Probable Economic Value.* Possible white ware clay. When mixed with good grog, it would make high grade refractory ware.

**Sample No. 46.**

*Location.* General location same as No. 45. Sample taken in east end of pit beneath No. 45.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A fine grained, medium soft, gray colored clay without visible objectionable materials.

*General Properties.* Water of plasticity 24.8%, general plasticity good, slakes slowly, dry linear shrinkage 4% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01        | 3         | 6            | 15                             |
|----------------------|-----------|-----------|--------------|--------------------------------|
| Color .....          | Pink Gray | Pink Gray | Spotted Gray | Spotted Light Gray, near White |
| Hardness .....       | Soft      | Soft      | Soft         | Hard                           |
|                      | Per Cent  | Per Cent  | Per Cent     | Per Cent                       |
| Absorption .....     | 23.4      | 22.1      | 21.2         | 12.4                           |
| Fire Shrinkage ..... | 3.0       | 2.0       | 2.0          | 6.0                            |
| Total Shrinkage..... | 6.0       | 6.0       | 6.0          | 10.0                           |
| Condition .....      | Good      | Good      | Good         | Granular texture good          |

*Analysis.* SiO<sub>2</sub> 64.9%; Al<sub>2</sub>O<sub>3</sub> 25.15%; Fe<sub>2</sub>O<sub>3</sub> 1.9%; CaO 1.2%; MgO 1.05%; Ignition Loss 6.8%.

*Probable Economic Value.* Refractory ware unwashed. A possible white ware clay if washed.

**Sample No. 47.**

*Location.* General location same as No. 45. Sample taken from beneath No. 46.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A fine grained, soft, gray clay showing mica.

*General Properties.* Water of plasticity 36.9%, general plasticity good, slakes quickly, dry linear shrinkage 5% without cracking or warping. Sample washed for kaolin. Screened thru 200 mesh removing 63% sand.

*Fire Properties*

| Cone No. ....       | 01            | 3          | 6            | 9+           | 15         |
|---------------------|---------------|------------|--------------|--------------|------------|
| Color .....         | Light Pink    | Light Pink | Nearly White | Nearly White | Pure White |
| Hardness .....      | Hard          | Hard       | Steel Hard   | Steel Hard   | Steel Hard |
|                     | Per Cent      | Per Cent   | Per Cent     | Per Cent     | Per Cent   |
| Absorption .....    | 31.4          | 26.7       | 24.5         | 17.9         | 12.9       |
| Fire Shrinkage .... | 4.0           | 6.0        | 9.5          | 9.5          | .....      |
| Total Shrinkage...  | 9.0           | 11.0       | 14.5         | 14.5         | .....      |
| Condition .....     | Some cracking |            |              |              |            |

*Probable Economic Value.* May be used as a white ware clay or paper clay when washed. Refractory possibilities.

**Sample No. 48.**

*Location.* General location same as No. 45. Sample taken in east end of the pit beneath No. 47.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A fine grained, soft, gray clay, showing mica.

*General Properties.* Water of plasticity 36.1%, general plasticity fine, slakes very readily, dry linear shrinkage 3% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01                    | 3                     | 6          | 15                          |
|----------------------|-----------------------|-----------------------|------------|-----------------------------|
| Color .....          | Spotted<br>Pink White | Spotted<br>Pink White | Gray White | Spotted Gray,<br>near White |
| Hardness .....       | Soft                  | Soft                  | Soft       | Soft                        |
|                      | Per Cent              | Per Cent              | Per Cent   | Per Cent                    |
| Absorption .....     | 20.9                  | 20.3                  | 19.8       | 18.2                        |
| Fire Shrinkage ..... | 3.0                   | 2.0                   | 2.0        | .....                       |
| Total Shrinkage..... | 6.0                   | 5.0                   | 5.0        | .....                       |
| Condition .....      | Good                  | Good                  | Good       | Good                        |

*Analysis.* Similiar to No. 46.

*Probable Value.* Refractory ware.

**Sample No. 49.**

*Location.* General locations same as No. 45. Sample taken from center of pit over five-foot face.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A coarse grained, medium hard, white clay. Visible objectionable material, manganese (dendritic markings).

*General Properties.* Water of plasticity 47%, general plasticity good, slakes readily, dry linear shrinkage 8% without cracking or warping.

*Fire Properties*

| Cone No. ....       | 02                | 1          | 3                    | 6                    | 15                   |
|---------------------|-------------------|------------|----------------------|----------------------|----------------------|
| Color .....         | Light Pink        | Light Pink | Nearly<br>Pure White | Nearly<br>Pure White | Nearly<br>Pure White |
| Hardness .....      | Soft              | Soft       | Hard                 | Hard                 | Steel Hard           |
|                     | Per Cent          | Per Cent   | Per Cent             | Per Cent             | Per Cent             |
| Absorption .....    | 35.7              | .....      | 26.8                 | 21.5                 | 12.4                 |
| Fire Shrinkage .... | 5.0               | 7.0        | 8.0                  | 8.0                  | .....                |
| Total Shrinkage.... | 13.0              | 15.0       | 16.0                 | 16.0                 | 17.5                 |
| Condition .....     | All show cracking |            |                      |                      |                      |

*Cone Fusion.* Cone No. 34-35. Approximately 1775°C.

*Analysis.* Similar to No. 46.

*Probable Economic Value.* Very refractory clay. May be useful in a white ware body or possibly as a paper clay.

**Sample No. 50.**

*Location.* General location same as No. 4. Sample taken from center of pit beneath No. 49.

*Occurrence.* A coarse grained, medium hard, white clay with red spots, without visible objectionable materials.

*General Properties.* Water of plasticity 24.2%, general plasticity fair, slakes slowly, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01                     | 3         | 6            | 15          |
|----------------------|------------------------|-----------|--------------|-------------|
| Color .....          | Pink Gray              | Pink Gray | Spotted Gray | Light Cream |
| Hardness .....       | Soft                   | Soft      | Soft         | Soft        |
|                      | Per Cent               | Per Cent  | Per Cent     | Per Cent    |
| Absorption .....     | 24.6                   | 23.7      | 22.8         | 19.4        |
| Fire Shrinkage ..... | .....                  | .....     | .....        | .....       |
| Total Shrinkage..... | 8.0                    | 8.0       | 8.0          | .....       |
| Condition .....      | Good                   | Good      | Good         | Sandy       |
|                      | All have sandy texture |           |              | few spots   |



*Analysis.* Similar to No. 46.

*Probable Economic Value.* Refractory ware.

**Sample No. 51.**

*Location.* General location same as No. 45. Sample taken in center of pit beneath No. 50.

*Occurrence.* A coarse grained, medium hard, white clay without visible objectionable materials.

*General Properties.* Water of plasticity 21.5%, general plasticity good, slakes very slowly, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01                         | 3                     | 6          | 15                       |
|----------------------|----------------------------|-----------------------|------------|--------------------------|
| Color .....          | Spotted<br>Pink White      | Spotted<br>Pink White | Gray White | Light Gray<br>near White |
| Hardness .....       | Soft                       | Soft                  | Soft       | Soft                     |
| Absorption .....     | Per Cent                   | Per Cent              | Per Cent   | Per Cent                 |
| Fire Shrinkage ..... | 22.7                       | 21.8                  | 20.5       | 14.1                     |
| Total Shrinkage..... | 1.0                        | 2.0                   | 2.0        | -----                    |
| Condition .....      | 6.0                        | 7.0                   | 7.0        | -----                    |
|                      | Good                       | Good                  | Good       | Good                     |
|                      | -----Granular texture----- |                       |            |                          |

*Analysis.* Similar to No. 46.

*Probable Economic Value.* Refractory wares, unwashed. Possible white ware clay if washed.

**Sample No. 52.**

*Location.* General location same as No. 45. Sample taken in west end of pit near the top.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A coarse grained, medium hard, gray clay showing red streaks, without visible objectionable materials.

*General Properties.* Water of plasticity 22.6%, general plasticity good, slakes very slowly, dry linear shrinkage 5% without warping, some cracking.

*Fire Properties*

| Cone No. ....        | 01                      | 3         | 6            |
|----------------------|-------------------------|-----------|--------------|
| Color .....          | Pink Gray               | Pink Gray | Spotted Gray |
| Hardness .....       | Soft                    | Soft      | Soft         |
| Absorption .....     | Per Cent                | Per cent  | Per Cent     |
| Fire Shrinkage ..... | 22.6                    | 21.2      | 19.8         |
| Total Shrinkage..... | 2.0                     | 2.0       | 3.0          |
| Condition .....      | 7.0                     | 7.0       | 8.0          |
|                      | -----Some cracking----- |           |              |

*Analysis.* Similar to No. 46.

*Probable Economic Value.* Refractory wares.

**Sample No. 53.**

*Location.* General location same as No. 45. Sample taken in west end of pit beneath No. 52.

*Occurrence.* Same as sample No. 45.

*General Properties.* Water of plasticity 23.4%, general plasticity good, slakes slowly, dry linear shrinkage 4% without warping, but some cracking.

*Fire Properties*

| Cone No.        | 01                | 3                 | 6            | 15                      |
|-----------------|-------------------|-------------------|--------------|-------------------------|
| Color           | Spotted Pink Gray | Spotted Pink Gray | Spotted Gray | Spotted Gray near White |
| Hardness        | Soft              | Soft              | Soft         | Hard                    |
| Absorption      | 24.4              | 21.3              | 20.0         | 12.4                    |
| Fire Shrinkage  | 2.0               | 2.0               | 3.0          | -----                   |
| Total Shrinkage | 6.0               | 6.0               | 7.0          | -----                   |
| Condition       | Some cracking     |                   |              | Good                    |

*Analysis.* Similar to No. 46.

*Probable Economic Value.* Refractory wares unless washed.

**Sample No. 54.**

*Location.* General location same as No. 45. Sample taken in west end of pit beneath No. 53.

*Occurrence.* Same as No. 45.

*Field Characteristics.* A coarse grained, medium hard, gray clay with red streaks. Visible objectionable materials, quartz.

*General Properties.* Water of plasticity 38.7%, general plasticity fine, slakes slowly, dry linear shrinkage 5% without cracking or warping. Sample washed for kaolin removing 53% sand.

*Fire Properties*

| Cone No.        | 2             | 1             | 3             | 6                            | 9  | 15                                      |
|-----------------|---------------|---------------|---------------|------------------------------|--|---|
| Color           | Lt. Pink Hard | Lt. Pink Hard | Lt. Pink Hard | Nearly Pure White Steel Hard | Steel White Steel Hard                         | Lt. Cream, nearly Pure White Steel Hard |
| Hardness        | Per Cent      | Per Cent      | Per Cent      | Per Cent                     | Per Cent                                       | Per Cent                                |
| Absorption      | 29.4          | 7.0           | 25.0          | 24.8                         | 21.2   | 4.3                                     |
| Fire Shrinkage  | 5.0           | 7.0           | 7.0           | 10.0                         | 11.0   | 16.0                                    |
| Total Shrinkage | 10.0          | 12.0          | 15.0          | 15.0                         | 16.0   | 21.0                                    |
| Condition       | Cracked badly |               |               |                              | Vitreous fracture, blue stained edges, cracked |   |

*Probable Economic Value.* White ware and possibly paper clay.

**Sample No. 55.**

*Location.* One-half mile north of Onaway along the state highway. Sample taken from dump.

*Occurrence.* According to reports, the half filled open cut exposed a deposit of white clay which to some extent has been mined and shipped. It is also, reported to have been drilled to a depth of 20 feet, in various places, the entire holes being in white clay. The same character of material that was secured from the dump has been exposed in numerous places in the surrounding gulches and road cuts.

*Field Characteristics.* A fine grained, hard, white clay, without visible objectionable materials.

*General Properties.* Water of plasticity 20.2%, general plasticity good, slakes readily, dry linear shrinkage 7% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01         | 3          | 6          | 9          | 15            |
|----------------------|------------|------------|------------|------------|---------------|
| Color.....           | Gray White | Gray White | Gray White | Light Buff | Buff Brown    |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Spotted       |
|                      | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent      |
| Absorption .....     | 13.7       | 12.8       | 11.7       | 7.8        | .....         |
| Fire Shrinkage ..... | 4.0        | 4.0        | 6.0        | 6.0        | 8.5           |
| Total Shrinkage..... | 11.0       | 11.0       | 13.0       | 13.0       | 15.5          |
| Condition .....      | Good       | Good       | Good       | Cracked    | Dark interior |

*Analysis.* (by Anaconda Copper Mining Co.) SiO<sub>2</sub> 53.2%; Al<sub>2</sub>O<sub>3</sub> 35.2%; Fe<sub>2</sub>O<sub>3</sub> 1.16%; CaO 1.5%; MgO 1.5%.

*Probable Economic Value.* Buff burning face brick and building tile. May be used in a crude pottery or terra cotta body. Refractory possibilities.

**Sample No. 56.**

*Location.* Same as No. 55.

*Occurrence.* Same as No. 55.

*Field Characteristics.* A fine grained, medium hard, white clay without visible objectionable materials.

*General Properties.* Water of plasticity 27.1%, general plasticity good, slakes very readily, dry linear shrinkage 7% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01         | 3          | 6          | 9          | 15         |
|----------------------|------------|------------|------------|------------|------------|
| Color.....           | Light Buff | Light Buff | Light Buff | Light Buff | Spotted    |
| Hardness .....       | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Buff Brown |
|                      | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....     | 15.2       | 14.5       | 12.0       | 10.9       | 5.9        |
| Fire Shrinkage ..... | 3.0        | 3.0        | 5.0        | 6.0        | 6.7        |
| Total Shrinkage..... | 10.0       | 10.0       | 12.0       | 13.0       | 13.7       |
| Condition .....      | Good       | Good       | Good       | Good       | Good       |

*Analysis.* Similar to No. 55.

*Probable Economic Value.* Similar to No. 55.

**Sample No. 57.**

*Location.* Sample from pit immediately behind clay plant at west end of Potlatch.

*Occurrence.* A deposit covering several acres, which has been mined to a depth of three to four feet. It shows neither strike, dip nor marks of stratification, and is a residual deposit probably derived from the basalt.

*Field Characteristics.* A medium fine grained, medium soft, light brown clay.

*General Properties.* Water of plasticity 28%, general plasticity fine, slakes very readily, dry linear shrinkage 8% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 010        | 00         | 02         | 1          |
|----------------------|------------|------------|------------|------------|
| Color.....           | Bright Red | Bright Red | Deep Red   | Deep       |
| Hardness .....       | Soft       | Hard       | Steel Hard | Bright Red |
|                      | Per Cent   | Per Cent   | Per Cent   | Steel Hard |
| Absorption .....     | 17.6       | 17.2       | 11.6       | 5.9        |
| Fire Shrinkage ..... | 1.0        | 1.0        | 3.0        | 5.0        |
| Total Shrinkage..... | 9.0        | 9.0        | 11.0       | 13.0       |
| Condition .....      | Good       | Good       | Good       | Good       |

*Probable Economic Value.* Common brick, face brick, drain tile and possibly sewer pipe and vitrified wares.

#### Sample No. 58.

*Location.* In a cut on the Spokane & Inland Empire Railroad at Ayer station.

*Occurrence.* A residual deposit of gray colored clay derived from granite.

*Field Characteristics.* A coarse grained, medium soft, gray clay.

*General Properties.* Brick was not made.

*Analysis.* (by Anaconda Copper Mining Co.)  $\text{SiO}_2$  70.4%;  $\text{Fe}_2\text{O}_3$  1.49%;  $\text{Al}_2\text{O}_3$  20.3%.

#### Sample No. 59.

*Location.* In artesian well on the campus of the University of Idaho.

*Occurrence.* The log of the new well now being dug (January, 1920), shows: 40 feet of overburden, 37 feet of white clay, 19 feet of soft white clay.

*Field Characteristics.* A fine grained, hard white clay, without visible objectionable material and probably derived from granite.

*General Properties.* Water of plasticity 37.5%, general plasticity fine, slakes readily, dry linear shrinkage 8% without cracking or warping.

#### Fire Properties

| Cone No.        | 010                             | 06        | 02         | 3          | 9                              | 15          |
|-----------------|---------------------------------|-----------|------------|------------|--------------------------------|-------------|
|                 | Gray                            |           | Light      |            | Deep                           | Mottled     |
| Color           | Buff                            | Gray Buff | Brown Buff | Deep Buff  | Buff                           | Light Brown |
| Hardness        | Hard                            | Med. Hard | Steel Hard | Steel Hard | Steel Hard                     | Steel Hard  |
|                 | Per Cent                        | Per Cent  | Per Cent   | Per Cent   | Per Cent                       | Per Cent    |
| Absorption      | 23.3                            | 23.2      | 13.8       | 5.4        | 2.8                            | 4.4         |
| Fire Shrinkage  | 3.0                             | 4.0       | 9.0        | 12.0       | 12.0                           | .....       |
| Total Shrinkage | 11.0                            | 12.0      | 17.0       | 20.0       | 20.0                           | .....       |
| Condition       | -----Considerable Cracking----- |           |            |            | Vitreous, small surface cracks |             |

*Cone Fusion.* Cone No. 28 plus. Approximately 1625°C.

*Analysis.*  $\text{SiO}_2$  63.8%;  $\text{Al}_2\text{O}_3$  19.8%;  $\text{Fe}_2\text{O}_3$  5.3%;  $\text{CaO}$  2.8%;  $\text{MgO}$  1.05%; Ignition Loss 10.2%.

*Probable Economic Value.* Care must be taken to overcome cracking of ware. Otherwise it might be used in a face brick, crude pottery or terra cotta body.

#### Sample No. 60.

*Location.* Three miles north of Tekoa along the wagon road, close to the Idaho-Washington state line, on top of a small knoll which was snow swept at the time of examination.

*Occurrence.* Surface was snow covered. It was reported that in digging a well on a school section near this locality, 30 feet of white clay was found.

*Field Characteristics.* A fine grained, hard, red and white clay.

*General Properties.* Water of plasticity 31.4%, general plasticity fine, slakes readily, dry linear shrinkage 7% without cracking or warping.

*Fire Properties*

| Cone No. ....         | 010       | 06         | 02         | 1+         | 3          |
|-----------------------|-----------|------------|------------|------------|------------|
|                       |           |            | Bright     | Bright     | Bright     |
| Color .....           | Red-Brown | Red-Brown  | Red-Brown  | Red-Brown  | Red-Brown  |
| Hardness .....        | Hard      | Steel Hard | Steel Hard | Steel Hard | Steel Hard |
|                       | Per Cent  | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....      | 27.4      | 11.4       | 6.6        | 6.2        | 2.1        |
| Fire Shrinkage .....  | 3.0       | 6.0        | 9.0        | 10.0       | 10.0       |
| Total Shrinkage ..... | 10.0      | 13.0       | 16.0       | 17.0       | 17.0       |
| Condition .....       | Good      | Good       | Good       |            |            |

*Probable Economic Value.* Common brick, drain tile, face brick and hollow building block. Possible for the vitrified wares such as sewer pipe and roofing tile.

**Sample No. 61.**

*Location.* Two and one-half miles north of Tekoa and along the roadside in a small pit.

*Occurrence.* Ground was covered with snow at time of visit and only one exposure could be seen. White clay is reported to have been found in numerous places in this vicinity.

*Field Characteristics.* A fine grained, medium hard, white clay, without visible objectionable materials.

*General Properties.* Water of plasticity 22.5%, general plasticity fine, slakes readily, dry linear shrinkage 6% without cracking or warping.

*Fire Properties*

| Cone No. ....         | 01          | 3          | 6          | 9+         | 15            |
|-----------------------|-------------|------------|------------|------------|---------------|
|                       | Light Brown | Light      |            | Light      |               |
| Color .....           | Buff        | Brown Buff | Light Buff | Gray Buff  | Light Brown   |
| Hardness .....        | Hard        | Steel Hard | Steel Hard | Steel Hard | Steel Hard    |
|                       | Per Cent    | Per Cent   | Per Cent   | Per Cent   | Per Cent      |
| Absorption .....      | 13.5        | 12.8       | 11.8       | 10.6       | 9.9           |
| Fire Shrinkage .....  | 1.5         | 3.0        | 3.0        | 3.0        | 2.5           |
| Total Shrinkage ..... | 7.5         | 9.0        | 9.0        | 9.0        | 8.5           |
| Condition .....       | Good        | Good       | Good       | Good       | Sandy texture |

*Economic Value.* Face brick, and possibly hollow building tile. May be used in crude pottery or terra cotta body.

**LEWIS AND IDAHO COUNTIES.**

Lewis and Idaho counties lie mainly within the area of the granite batholith. A careful examination of this area would probably uncover many deposits of excellent clay, few of which, however, would be of commercial value at this time because of the lack of transportation facilities.

**Sample No. 62.**

*Location.* In a pit immediately behind the clay plant on Booth's ranch, at the western edge of the town of Nezperce. Sample taken from the north end of the pit.

*Occurrence.* Deposit exposed in a pit 50 feet long by 30 feet wide and 15 feet deep, under three feet of overburden. The deposit strikes north and south, is flat and well stratified. The north end of the pit shows a clean face of sand underlaid by eight feet of white clay. As the pit is opened to the south the sand and white clay gradually grade into red, white, yellow, blue and green clay and in the extreme south end of the pit the entire face is composed of this mixed material. It is a transported deposit derived from granite with the later addition of a decomposed scarp of basalt.

*Field Characteristics.* A fine grained, medium hard gray clay without any visible objectionable materials.

*General Properties.* Water of plasticity 36.7%, general plasticity good, slakes slowly, dry linear shrinkage 11% without cracking or warping.

*Fire Properties*

| Cone No. ....       | 01       | 3          | 6          | 9-L        | 15         |
|---------------------|----------|------------|------------|------------|------------|
|                     |          |            |            | Light      |            |
| Color .....         | Buff     | Buff.      | Buff       | Brown Buff | Brown      |
| Hardness .....      | Hard     | Steel Hard | Steel Hard | Steel Hard | Steel Hard |
|                     | Per Cent | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....    | 14.3     | 13.1       | 12.9       | 10.5       | 12.6       |
| Fire Shrinkage .... | 5.0      | 5.0        | 5.0        | 6.0        | 6.0        |
| Total Shrinkage.... | 16.0     | 16.0       | 16.0       | 17.0       | 17.0       |
| Condition .....     | Good     | Good       | Good       | Good       | Good       |

*Cone Fusion.* Cone No. 23-26. Approximately 1600°C.

*Probable Economic Value.* As part of a crude pottery or terra cotta body. Porous, buff colored face brick.

**Sample No. 63.**

*Location.* Eighteen miles east of Kamiah and 3½ miles south of the post-office of Glenwood, in a heavily timbered country.

*Occurrence.* A residual deposit of a grayish white clay under an overburden of from two to five feet, and of unknown extent. It has been exposed on a hillside over an area of at least half an acre and the thickness is unknown. It is plowed,

loaded onto wagons, hauled to the railroad and sold for medical purposes.

*Field Characteristics.* A fine grained, sandy, soft, light brown clay without visible objectionable materials.

*General Properties.* Water of plasticity 47.6%, general plasticity poor, slakes very readily, dry linear shrinkage 8% without cracking or warping.

| Cone No.       | <i>Fire Properties</i> |            |            |            |  |                        |
|----------------|------------------------|------------|------------|------------|--|------------------------|
|                | 01                     | 06         | 02         | 3          | 6  | 15                     |
| Color          | Brown Buff             | Light Buff | Light Buff | Light Buff | Light Buff                                     | Mottled                |
| Hardness       | Soft                   | Soft       | Soft       | Soft       | Soft   | Lt. Brown<br>Very Soft |
| Absorption     | Per Cent               | Per Cent   | Per Cent   | Per Cent   | Per Cent                                       | Per Cent               |
| Fire Shrinkage | 46.3                   | .....      | 45.0       | 42.0       | .....  | 45.9                   |
| Condition      | 8.0                    | 8.0        | 10.0       | 11.0       | .....  | .....                  |
|                | Good                   | Good       | Good       | Good       | Disintegrated<br>when given<br>absorption test | Good                   |

*Analysis.* (by Anaconda Copper Mining Co.) SiO<sub>2</sub> 61.3%; Al<sub>2</sub>O<sub>3</sub> 23.4%; Fe<sub>2</sub>O<sub>3</sub> 0.5%; CaO 2.3%; MgO 0.8%.

*Probable Economic Value.* Too soft and porous for structural wares at their common temperatures of firing. Medicinal properties not investigated.

**POWER COUNTY.**

Power County, like Cassia County, is situated far to the south of the granite and the occurrence of extensive clay deposits does not appear probable.

**Sample No. 64.**

*Location.* Five miles southwest of American Falls and on the south side of Snake River. Sample from an open cut.

*Occurrence.* An open cut exposed a 12-foot face of material, flat, well stratified and under an overburden of three feet. It is exposed in a small shaft close to the open cut, and in the creek bed and in every instance is lying on limestone. All of the exposures are near the bottom of the slope of a small knoll. It is likely that this deposit may cover some five acres of ground.

*Field Characteristics.* A fine grained, medium hard, purple clay.

*General Properties.* Water of plasticity 51%, general plasticity good, slakes readily, dry linear shrinkage 2% with warping and considerable cracking.

*Fire Properties*

| Cone No. ....         | 010                    | 06                     | 02                       | 1+                     | 3                      |
|-----------------------|------------------------|------------------------|--------------------------|------------------------|------------------------|
| Color .....           | Bright<br>Brown        | Bright<br>Brown        | Bright<br>Brown          | Dark Red<br>Brown      | Dark Red<br>Brown      |
| Hardness .....        | Steel Hard<br>Per Cent | Steel Hard<br>Per Cent | Steel Hard<br>Per Cent   | Steel Hard<br>Per Cent | Steel Hard<br>Per Cent |
| Absorption .....      | 18.6                   | 16.5                   | 11.3                     | 5.0                    | 3.0                    |
| Fire Shrinkage .....  | 10.0                   | 5.0                    | 7.0                      | 9.0                    | 9.0                    |
| Total Shrinkage ..... | 12.0                   | 13.0                   | 15.0                     | 17.0                   | 17.0                   |
| Condition .....       | Cracked                | Cracked                | (Part of surface glazed) |                        |                        |

*Probable Economic Value.* Crude structural wares such as common brick drain tile, etc. Trouble will be experienced from cracking.

**Sample No. 65.**

*Location.* Same as No. 64. Sample taken 10 feet west of No. 64.

*Field Characteristics.* A medium fine grained, hard, yellow and pink clay.

*Dry Properties.* Water of plasticity 43.6%, general plasticity fair, slakes readily, dry linear shrinkage 8% with cracking and warping.

*Fire Properties*

Brick cracked too badly to permit further testing.



SHOSHONE COUNTY.

Shoshone County is situated entirely in a timbered, mountainous section of the state. While clay deposits other than those described may be present, they would, with few exceptions, be hard to locate and would on account of poor transportation facilities and market conditions, in all probability not be of commercial value at this time.

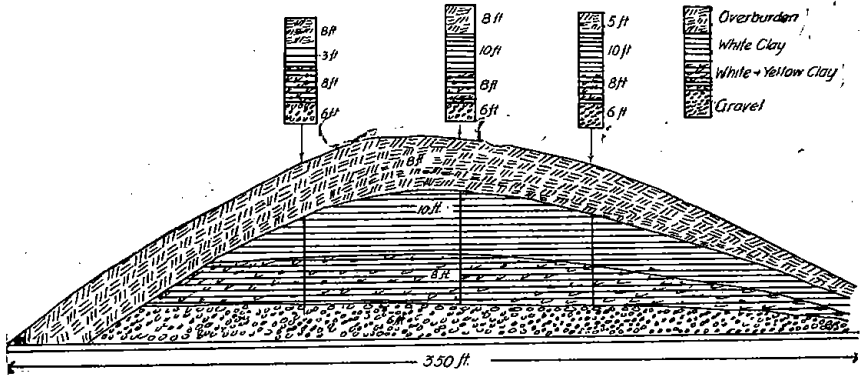


FIG. 8. Longitudinal sketch of railroad cut near Cataldo. Samples in order from left to right are No. 66, 68, and 70.

Sample No. 66.

*Location.* In a cut on the O.-W. R. & N. Railroad, two miles west of Cataldo. Sample taken on the south side of the cut, near the center and over a 10-foot face.

*Occurrence.* A 26-foot face in an exposure 450 feet long under an overburden of five feet; strikes east and west. is flat, well stratified and sandy. There are three distinct strata, 10 feet of white clay immediately under the overburden, eight feet of light yellow clay and a bed of gravel.

*Field Characteristics.* A fine grained, medium soft clay, light cream in color. Visible objectionable material, none.

*General Properties.* Water of plasticity 32.8%, general plasticity fine, slakes readily, dry linear shrinkage 8% without cracking or warping.

Fire Properties

| Cone No. ....      | 01                   | 3                    | 6               | 9+              | 15                                |
|--------------------|----------------------|----------------------|-----------------|-----------------|-----------------------------------|
| Color .....        | Medium<br>Brown Buff | Medium<br>Brown Buff | Gray            | Gray            | Light Brown<br>and Gray           |
| Hardness .....     | Steel Hard           | Steel Hard           | Steel Hard      | Steel Hard      | Steel Hard                        |
| Absorption .....   | Per Cent<br>8.6      | Per Cent<br>3.3      | Per Cent<br>0.0 | Per Cent<br>0.0 | Per Cent<br>0.33                  |
| Fire Shrinkage ... | 7.0                  | 7.0                  | 12.0            | 12.0            | 6.5                               |
| Total Shrinkage... | 15.0                 | 15.0                 | 20.0            | 20.0            | 14.5                              |
| Condition .....    | Good                 | Good                 | Good            | Good            | Gray interior,<br>slight bloating |

*Cone Fusion.* Cone No. 23. Approximately 1550°C.

*Analysis.* (by the Bunker Hill & Sullivan Co.) SiO<sub>2</sub> 61.2%; Al<sub>2</sub>O<sub>3</sub> 24.8%; Fe<sub>2</sub>O<sub>3</sub> 2.15%; CaO 0.5%; MgO 0.1%.

*Probable Economic Value.* This clay needs the addition of a non-plastic material or clay of more sandy nature to produce structural wares such as buff face brick or hollow building block. Could also be used in crude pottery, stoneware or terra cotta bodies. Suggest mixing with No. 71.

**Sample No. 67.**

*Location.* General location same as No. 66. Sample taken beneath No. 66.

*Occurrence.* Same as No. 66.

*Field Characteristics.* A fine grained, soft, cream colored, sandy clay.

*General Properties.* Water of plasticity 18.1%, general plasticity fair, slakes readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No.        | 02         | 1+       | 3        | 6          | 9+         | 15                                     |
|-----------------|------------|----------|----------|------------|------------|--|
| Color           | Light Buff | Buff     | Buff     | Deep Buff  | Gray       | Brown                                  |
| Hardness        | Hard       | Hard     | Hard     | Steel Hard | Steel Hard | Steel Hard                             |
|                 | Per Cent   | Per Cent | Per Cent | Per Cent   | Per Cent   | Per Cent                               |
| Absorption      | 13.8       | -----    | 12.0     | 12.0       | 7.0        | 3.4                                    |
| Fire Shrinkage  | -----      | 2.0      | 2.0      | 2.0        | 6.0        | 3.5                                    |
| Total Shrinkage | 5.0        | 7.0      | 7.0      | 7.0        | 11.0       | 8.5                                    |
| Condition       | Good       | Good     | Good     | Good       | Good       | Bloated Gray interior, partially fused |

*Analysis.* (by Bunker Hill & Sullivan Co.) SiO<sub>2</sub> 61.2%; Al<sub>2</sub>O<sub>3</sub> 25.8%; Fe<sub>2</sub>O<sub>3</sub> 2.0%; CaO 0.7%; MgO 1.0%.

*Probable Economic Value.* Buff colored face brick and structural ware. Possibly part of crude pottery or terra cotta body.

**Sample No. 68.**

*Location.* General location same as No. 66. Sample taken from top of exposure in the east end of the cut.

*Occurrence.* Same as No. 66.

*Field Characteristics.* A chalk-like, soft, yellow and white clay without visible objectionable materials.

*General Properties.* Water of plasticity 30.2%, general plasticity good, slakes quickly, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No.        | 01         | 3          | 6          | 9+         | 15            |
|-----------------|------------|------------|------------|------------|---------------|
| Color           | Light      | Medium     | Light      |            |               |
| Color           | Buff Brown | Brown Buff | Brown Buff | Dark Gray  | Dark Gray     |
| Hardness        | Steel Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard    |
|                 | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent      |
| Absorption      | 15.1       | 11.0       | 4.9        | 0.0        | 0.24          |
| Fire Shrinkage  | 6.0        | 6.0        | 11.0       | 11.0       | 8.0           |
| Total Shrinkage | 11.0       | 11.0       | 16.0       | 16.0       | 13.0          |
| Condition       | Good       | Good       | Good       | Good       | Badly bloated |

*Analysis.* Similar to No. 66.

*Probable Economic Value.* Suggested possible uses similar to No. 66.

**Sample No. 69.**

*Location.* General location same as No. 66. Sample taken from east end of the cut beneath No. 68.

*Occurrence.* Same as No. 66.

*Field Characteristics.* A fine grained, soft, sandy clay, very light cream in color without any visible objectionable materials.

*General Properties.* Water of plasticity 19.3%, general plasticity fair, slakes very readily, dry linear shrinkage 3% without cracking or warping.

*Fire Properties*

| Cone No.<br>Color | 02                     | 1+                     | 3                | 6                | 9                | 15                               |
|-------------------|------------------------|------------------------|------------------|------------------|------------------|----------------------------------|
|                   | Light Buff<br>Per Cent | Light Buff<br>Per Cent | Buff<br>Per Cent | Buff<br>Per Cent | Gray<br>Per Cent | Brown<br>Per Cent                |
| Hardness          | Hard                   | Hard                   | Hard             | Hard             | Steel Hard       | Steel Hard                       |
| Absorption        | 16.7                   | .....                  | 14.1             | 13.0             | 5.1              | 7.9                              |
| Fire Shrinkage    | 2.0                    | .....                  | 4.0              | 5.0              | 7.0              | 5.5                              |
| Total Shrinkage   | 5.0                    | .....                  | 7.0              | 8.0              | 10.0             | 8.5                              |
| Condition         | Good                   | Good                   | Good             | Good             | Good             | Badly bloated,<br>few slag spots |

*Analysis.* Similar to No., 67.

*Probable Economic Value.* Similar to preceding.

**Sample No. 70.**

*Location.* General location same as No. 66. Sample taken in west end of the cut over the entire deposit.

*Field Characteristics.* A fine grained, medium soft, white and brown clay.

*General Properties.* Water of plasticity 30.4%, general plasticity fine, slakes readily, dry linear shrinkage 5% without cracking or warping.

*Fire Properties*

| Cone No. ....        | 01                  | 3          | 6          | 9+         | 15                                     |
|----------------------|---------------------|------------|------------|------------|--|
|                      | Light<br>Buff Brown | Gray       | Deep Gray  | Deep Gray  | Mottled Brown<br>and Gray              |
| Color.....           | Buff Brown          | Gray       | Deep Gray  | Deep Gray  | Mottled Brown<br>and Gray              |
| Hardness .....       | Steel Hard          | Steel Hard | Steel Hard | Steel Hard | Steel Hard                             |
|                      | Per Cent            | Per Cent   | Per Cent   | Per Cent   | Per Cent                               |
| Absorption .....     | 5.4                 | 0.6        | 0.0        | 0.0        | 0.08                                   |
| Fire Shrinkage ..... | 9.5                 | 11.0       | 11.0       | 11.0       | 8.0                                    |
| Total Shrinkage..... | 14.5                | 16.0       | 16.0       | 16.0       | 13.0                                   |
| Condition .....      | Good                | Good       | Good       | Good       | Slight swelling,<br>dark gray interior |

*Probable Economic Value.* Possible uses similar to No. 66.

**Sample No. 71.**

*Location.* General location same as No. 66. Sample taken in west end of the cut.

*Occurrence.* Same as No. 66.

*Field Characteristics.* A fine grained, soft, sandy, reddish pink clay. Visible objectionable material, none.

*Dry Properties.* Water of plasticity 26.3%, general plasticity good, slakes readily, dry linear shrinkage 7% without cracking or warping.

| Cone No. ....        | <i>Fire Properties</i> |            |            |          |          |
|----------------------|------------------------|------------|------------|----------|----------|
|                      | 010                    | 06         | 02         | 3        | 6        |
| Color .....          | Buff Brown             | Buff Brown | Buff Brown | Buff     | Buff     |
|                      | Per Cent               | Per Cent   | Per Cent   | Per Cent | Per Cent |
| Hardness .....       | Soft                   | Soft       | Hard       | Hard     | Hard     |
| Absorption .....     | 20.8                   | 20.7       | 17.7       | 13.8     | 8.9      |
| Fire Shrinkage ..... | 7.0                    | 1.0        | 3.0        | 4.0      | 4.0      |
| Total Shrinkage..... | 7.0                    | 8.0        | 10.0       | 11.0     | 11.0     |
| Condition .....      | Good                   | Good       | Good       | Good     | Cracked  |

*Analysis.* Similar to No. 67.

*Probable Economic Value.* Common brick, drain tile. When mixed with No. 66, 68 or 70 it may be possible to produce such ware as face brick, hollow building tile and probably sewer pipe.

## WASHINGTON COUNTY.

Washington County is situated near the south-western corner of the granite area and the greater portion of the county is covered by the more recent river and lake deposits. A close examination in the northern part of this county might disclose more promising clay deposits than were examined for this report.

**Sample No. 72.**

*Location.* One mile north of Weiser in center of large pit.

*Occurrence.* A 20-foot exposure of a very sandy material showing neither strike nor dip but well stratified. On the hillside immediately above this pit is an exposure of a bed of sand filled with concretions and well stratified but with the different beds twisted and turned in many shapes and forms.

*Field Characteristics.* A medium fine grained, medium soft, yellow brown clay.

*General Properties.* Water of plasticity 47%, general plasticity good, slakes readily, dry linear shrinkage 16% without cracking or warping.

|                       | <i>Fire Properties</i> |           |            |            |
|-----------------------|------------------------|-----------|------------|------------|
|                       | 010                    | 06        | 02         | 1+         |
| Cone No. ....         | Red Brown              | Red Brown | Brown      | Deep Brown |
| Color .....           | Hard                   | Hard      | Steel Hard | Steel Hard |
| Hardness .....        | Per Cent               | Per Cent  | Per Cent   | Per Cent   |
| Absorption .....      | 15.4                   | 28.3      | 2.2        | 1.6        |
| Fire Shrinkage .....  | 5.0                    | 8.0       | 16.5       | 16.0       |
| Total Shrinkage ..... | 21.0                   | 24.0      | 32.5       | 33.0       |
| Condition .....       | Badly cracked          |           |            |            |

*Probable Economic Value.* Alone, this sample would have little value on account of the cracking and excessive shrinkage. A small amount could possibly be used in a mixture for common structural wares.

**Sample No. 73.**

*Location.* General location same as No. 72. Sample taken from west end of the pit.

*Occurrence.* Same as No. 72.

*Field Characteristics.* A fine grained, medium soft, yellow brown clay.

*Dry Properties.* Water of plasticity 47%; general plasticity fine, slakes readily, dry linear shrinkage 16% without cracking or warping.

*Fire Properties*

Identical with No. 72.

*Probable Economic Value.* See No. 72.

**Sample No. 74.**

*Location.* Ten miles west of Weiser along the main line of the Oregon-Washington Railroad & Navigation Co. General sample taken from the hillside.

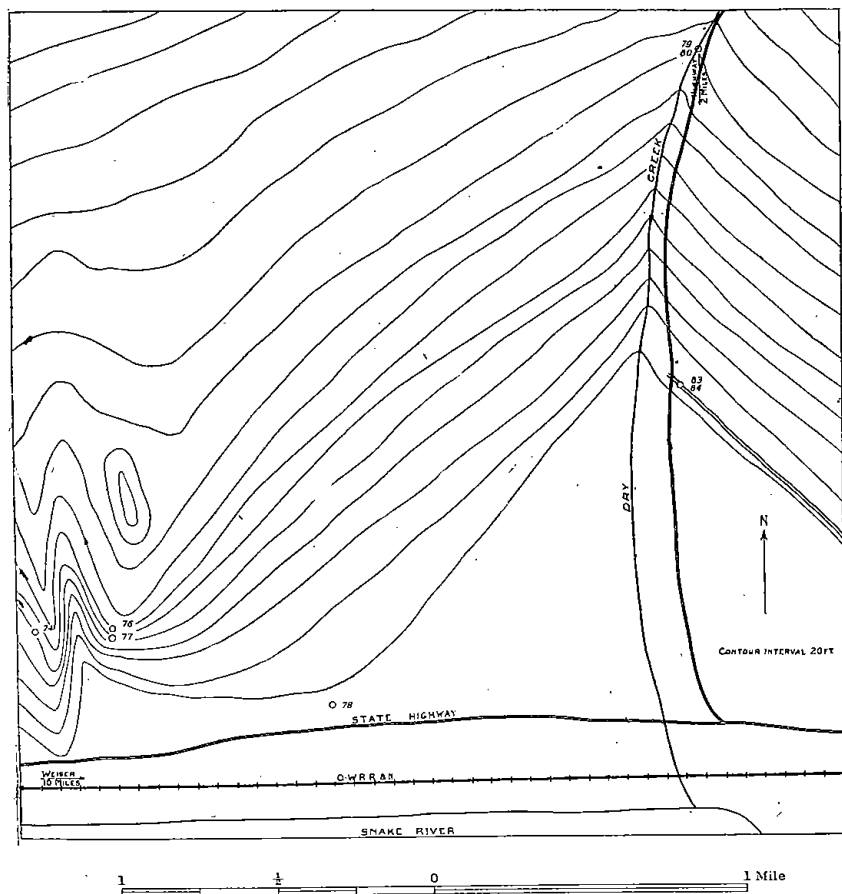


FIG. 9. Sketch Map showing location of clay samples taken west of Weiser. Topography has sketch value only. Numbers indicate samples.

*Occurrence.* A deposit covering some hundreds of acres, over which there is no vegetation and no excavations or openings except those made by burrowing animals. It is reported that many samples have been taken from this locality, examined, tested and analyzed and found to be of commercial value, especially when the various materials were mixed.

*Field Characteristics.* A fine grained, sandy, soft, gray clay.

*General Properties.* Water of plasticity 21.1%, general plasticity fair, slakes very readily, dry linear shrinkage 7% without cracking or warping.

| Cone No. ....         | <i>Fire Properties</i> |           |              |                   |
|-----------------------|------------------------|-----------|--------------|-------------------|
|                       | 010                    | 06        | 02           | 1+                |
| Color .....           | Red Brown              | Red Brown | Red Brown    | Deep<br>Brown Red |
| Hardness .....        | Soft                   | Soft      | Soft         | Soft              |
|                       | Per Cent               | Per Cent  | Per Cent     | Per Cent          |
| Absorption .....      | 25.1                   | 24.9      | 22.0         | 18.4              |
| Fire Shrinkage .....  | 1.0                    | 1.0       | 2.0          | 3.0               |
| Total Shrinkage ..... | 8.0                    | 8.0       | 9.0          | 10.0              |
| Condition .....       | Good                   | Good      | Slight crack | Good              |

*Probable Economic Value.* Poor grade of common brick unless mixed with a clay which vitrifies at a lower temperature.

#### Sample No. 75.

*Location.* General location same as No. 74. Sample of shale from the material brought up by burrowing animals.

*Occurrence.* Same as No. 74.

*Field Characteristics.* A fine grained, hard, dark gray shale without visible objectionable materials.

*Dry Properties.* Material lacked molding properties and a brick was not made.

#### Sample No. 76.

*Location.* General location same as No. 74. Sample taken one-fourth mile east of sample No. 74.

*Occurrence.* A flint-like substance taken from the surface immediately adjoining an old lava cone.

*Field Characteristics.* A fine grained, very hard, red and gray, highly indurated shale with iron as the only visible objectionable material.

*General Properties.* Lacked molding properties and a brick was not made. It is reported locally that this material when mixed with material similar to sample No. 72 made a very good grade of sewer pipe and drain tile.

#### Sample No. 77.

*Location.* General location same as sample. No. 75. Sample of shale taken north of and adjoining the previous sample.

*Occurrence.* Same as No. 74. The shale apparently gets softer the farther it is from the lava contact.

*Field Characteristics.* A fine grained, hard, dark gray shale, without visible objectionable materials.

*General Properties.* Lacked molding properties and a brick was not made. This material when mixed with other materials in the vicinity is reported to have made a good grade of drain tile.

#### Sample No. 78.

*Location.* General location same as No. 74. Sample taken from a large barren hill along the railroad track.

*Occurrence.* Same as No. 74.

*Field Characteristics.* A fine grained, sandy, soft, gray clay.

This hillside was reported to have been thoroly tested and found to be good material for sewer pipe, drain tile, etc.

*General Properties.* Water of plasticity 37%, general plasticity good, slakes very readily, dry linear shrinkage 12% without warping but some cracking.

*Fire Properties*

| Cone No. ....        | 010           | 06         | 02         |
|----------------------|---------------|------------|------------|
| Color .....          | Buff Brown    | Buff Brown | Deep Brown |
| Hardness .....       | Steel Hard    | Steel Hard | Steel Hard |
|                      | Per Cent      | Per Cent   | Per Cent   |
| Absorption .....     | 13.7          | 11.4       | 6.3        |
| Fire Shrinkage ..... | 3.0           | 4.0        | 6.0        |
| Total Shrinkage..... | 15.0          | 16.0       | 18.0       |
| Condition .....      | Badly cracked |            |            |

*Analysis.* SiO<sub>2</sub> 50.5%; Al<sub>2</sub>O<sub>3</sub> 18.1%; Fe<sub>2</sub>O<sub>3</sub> 3.7%; CaO 1.6%; MgO 0.14%; Ignition Loss 13.3%.

*Probable Economic Value.* Doubtful value alone on account of cracking. Otherwise it is possible for common grades of structural wares.

**Sample No. 79.**

*Location.* Ten miles west of Weiser and two miles north of the railroad, in a large cut in the creek. Sample from the upper part of the deposit.

*Occurrence.* A six-foot bed of shale striking northeast and southwest and flat, under a 10-foot overburden. It is reported to have been mixed with other materials from this locality and produced a good ware.

*Field Characteristics.* A fine grained, hard, gray shale without visible objectionable materials.

*General Properties.* Water of plasticity 38%, general plasticity good, slakes very slowly, dry linear shrinkage 10% without warping but cracks very badly.

*Fire Properties*

| Cone No. ....        | 010           | 06         | 02         | 3          | 6          |
|----------------------|---------------|------------|------------|------------|------------|
| Color .....          | Light Buff    | Light Buff | Light Buff | Light Buff | Light Buff |
| Hardness .....       | Steel Hard    | Steel Hard | Steel Hard | Steel Hard | Steel Hard |
|                      | Per Cent      | Per Cent   | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....     | 23.6          | 23.7       | 24.1       | 19.2       | 11.7       |
| Fire Shrinkage ..... | 1.0           | 2.0        | 2.5        | 2.0        | 10.0       |
| Total Shrinkage..... | 11.0          | 12.0       | 12.5       | 12.0       | .....      |
| Condition .....      | Some cracking |            |            |            |            |

*Cone Fusion.* Below No. 20, therefore not considered refractory.

*Analysis.* (by the School of Ceramics, Ohio State University, Columbus, Ohio) SiO<sub>2</sub> 70%; Al<sub>2</sub>O<sub>3</sub> 16%; Fe<sub>2</sub>O<sub>3</sub> 0.0%; CaO 1.0%; Ignition Loss 13%.

*Probable Economic Value.* Buff burning structural wares such as face brick and possibly as an ingredient of a crude pottery or terra cotta body.

**Sample No. 80.**

*Location.* Same as No. 19. Sample taken from beneath No. 79.



*Field Characteristics.* A fine grained, very hard clay, light cream in color and without visible objectionable materials.

*General Properties.* Water of plasticity 33.5%, general plasticity good, slakes very slowly, dry linear shrinkage 8% without cracking or warping.

#### Fire Properties

| Cone No. ....         | 01         | 3          | 6          | 6          | 15              |
|-----------------------|------------|------------|------------|------------|-----------------|
| Color .....           | Light Buff | Light Buff | Gray Buff  | Gray       | Gray            |
| Hardness .....        | Light Hard | Steel Hard | Steel Hard | Steel Hard | Steel Hard      |
|                       | Per Cent   | Per Cent   | Per Cent   | Per Cent   | Per Cent        |
| Absorption .....      | 10.7       | 8.5        | 8.3        | 4.1        | 0.6             |
| Fire Shrinkage .....  | 5.0        | 7.0        | 11.0       | 11.0       | 6.0             |
| Total Shrinkage ..... | 13.0       | 15.0       | 19.0       | 19.0       | 14.0            |
| Condition .....       | Good       | Good       | Good       | Good       | Slight bloating |

*Analysis.* (by School of Ceramics, Ohio State University, Columbus, Ohio) SiO<sub>2</sub> 77.5%; Al<sub>2</sub>O<sub>3</sub> 14.2%; Fe<sub>2</sub>O<sub>3</sub> 0.0%; CaO 0.0%; MgO 0.0%.

*Probable Economic Value.* Buff burning structural wares such as face brick or tile and possibly as an ingredient of a crude pottery, stoneware or terra cotta body.

#### Samples No. 81 and 82.

81 and 82. *Location.* General location same as No. 79. Sample taken from beneath No. 80.

*Occurrence.* Same as No. 79.

*Field Characteristics.* A fine grained, medium hard, very soapy feeling, gray material without visible objectionable materials.

*General Properties.* Water of plasticity 50%, general plasticity fine, slakes readily, dry linear shrinkage 18% with warping, and cracking so badly that brick could not be tested.

#### Samples No. 83 and 84.

*Location.* Ten miles west of Weiser and one mile north of the railroad in a large irrigation ditch along the wagon road.

*Occurrence.* A six-foot exposure, in an irrigation ditch, of a soft blue shale striking north and south and flat. The extent is unknown altho it is exposed for possibly 200 feet in length.

*Field Characteristics.* A very fine grained, medium soft, blue gray shale, without visible objectionable materials.

*General Properties.* Water of plasticity 43.2%, general plasticity fine, slakes readily, dry linear shrinkage 7% with some warping and cracking.

#### Fire Properties

| Cone No. ....         | 010            | 06        | 02         | 1          | 3          |
|-----------------------|----------------|-----------|------------|------------|------------|
| Color .....           | Brown Buff     | Lt. Brown | Buff Red   | Dark       | Dark       |
| Hardness .....        | Soft           | Hard      | Steel Hard | Red Brown  | Red Brown  |
|                       | Per Cent       | Per Cent  | Per Cent   | Steel Hard | Steel Hard |
|                       | Per Cent       | Per Cent  | Per Cent   | Per Cent   | Per Cent   |
| Absorption .....      | 26.8           | 23.7      | 7.4        | 2.1        | 2.0        |
| Fire Shrinkage .....  | 3.4            | 41.0      | 11.0       | 13.0       | 15.0       |
| Total Shrinkage ..... | 10.5           | 11.0      | 18.0       | 20.0       | 22.0       |
| Condition .....       | Glazed surface |           |            |            |            |

*Analysis.* (by School of Ceramics, Ohio State University, Columbus, Ohio) SiO<sub>2</sub> 62.1%; Al<sub>2</sub>O<sub>3</sub> 24.1%; Fe<sub>2</sub>O<sub>3</sub> 0.4%; CaO 1.8%; MgO 0.0%; Ignition Loss 11.2%.

*Probable Economic Value.* Structural wares such as common brick, drain tile and sewer pipe.

**Samples No. 85 and 86.**

*Location.* Eleven miles east of Weiser, along Cole Creek and one mile above junction of Cole Creek with Weiser River; and one and one-half miles from the railroad. Sample taken near center of the exposure and over a 12-foot face.

*Occurrence.* An exposure one mile in length along the hillside, from 1 to 12 feet in thickness, striking east and west and lying flat. Reported to have been used for facing buildings in Weiser and to mix with the materials from west of Weiser for paving filler.

*Field Characteristics.* A fine grained, hard, gray shale without visible objectionable materials.

*General Properties.* Water of plasticity 34.1%, general plasticity poor, slakes slowly, dry linear shrinkage 2% without warping or cracking but easily broken into a fine powder.

*Fire Properties*

| Cone No. ....         | 010        |      | 06         |            | 02       |            |
|-----------------------|------------|------|------------|------------|----------|------------|
|                       | Buff Brown | Soft | Buff Brown | Steel Hard | Brown    | Steel Hard |
| Hardness .....        | Per Cent   |      | Per Cent   |            | Per Cent |            |
| Absorption .....      | 32.2       |      | 16.6       |            | .....    |            |
| Fire Shrinkage .....  | 3.0        |      | 10.0       |            | 14.0     |            |
| Total Shrinkage ..... | 5.0        |      | 12.0       |            | 16.0     |            |
| Condition .....       | Good       |      | Good       |            | Fused    |            |

*Probable Economic Value.* Doubtful value for clay products owing to short vitrification range.

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