

## NATURAL PIGMENT MATERIALS IN THE PACIFIC WEST

Nature of Pigments

Numerous minerals and rocks that occur in the Pacific West can serve as sources for pigments suitable for the craft potter and artist. In this section the more important mineral pigments are identified and classified, and information on how to look for them in the field, make field tests and perform beneficiation is discussed.

Mineral pigments, when used in the arts, give color, opacity and sometimes body to paints, plasters and other art mediums. They must be fine, though not always necessarily uniformly fine, in texture. They must be substantially insoluble, and inert in the vehicle used, and must have a high degree of uniformity of purity.

The pigment requirements for the individual craft potter or artist differ markedly from the industrial user where uniformity of product is of prime importance and tinting strength, oil absorption, hiding power, particle size and chemical composition are also critical factors. Many commercial pigments are made synthetically and are purer, more concentrated and more uniform than any pigment that you are likely to find out in the hills.

The individual artisan seeking his own pigment materials looks first for color and then for the suitability of the pigment in the medium he is working with. In most cases the search for native pigments should be conditioned upon your desire to either: (a) find a new material that uniquely fits your own special needs, or; (b) use only native pigments that are to be combined with other craft materials also obtained in the area. Any economic concerns should be secondary since only rarely is it possible to prospect for, collect, and process raw pigments at less cost than those that are commercially prepared.

Once you have determined that a certain pigment material is suitable for your needs be sure to collect enough to fill all of your foreseeable requirements in the future. It will be difficult, if not impossible, for you to duplicate the original batch at some later date since quality controls are not feasible for small operations, and the source of the pigment may have disappeared beneath some blacktop in the meantime.

### Classification of Pigments

Mineral pigments may be classified or grouped in several ways:

(1) by origin; (2) by chemical composition; (3) by color.

#### By Origin

Pigments are derived from three main sources:

1. Natural mineral pigments that can be mined, easily beneficiated and processed. Included in this group are ocher, umber, sienna, ground slate and shale, and other colored rocks.
2. Pigments made directly from ores. In this group are burnt or calcined siennas, umbers, zinc oxide and sublimed white lead.
3. Chemically manufactured inorganic pigments. White lead, lithopone, Venetian red, chrome yellow, Prussian blue and red and yellow iron oxides made from scrap iron.

#### By Chemical Composition

Pigments may be classified into three groups on the basis of chemical composition.

1. Iron oxides, which form by far the most important group.
2. Non-iron oxides.
3. Various miscellaneous materials, including clay, shale, slate and coal.

#### By Color

Color forms an obvious basis for classifying pigments, and they have been grouped in this manner in Figure 82



### Natural Mineral Pigments.

Only the natural mineral pigments will be discussed here. Although it is possible for the individual artist or craft potter to calcine or roast his own pigments it is felt that few, if any, will choose to do so since special equipment and heat and fume problems make the operation both difficult and expensive.

FIG 82 Since color is the important characteristic of a pigment a logical separation has been made on this basis. Figure 82 lists thirty-three minerals and rocks which can be used as sources for pigments, together with their significant chemical and physical properties and a note on their availability.

Due to the vagaries of the geologic processes there are wide variations in purity, degree of oxidation or chemical alteration of the raw materials which produce various shades and tones that tend to overlap pure color boundaries. For this reason some minerals appear in several color classifications. Although values for both hardness and specific gravity are given, individual specimens of the ochres, siennas and umbers may vary widely from the figures given. Both pyrite and siderite must be calcined before they develop any value as pigments. The data shown for these two minerals is in the raw, or natural state, however.

In sharp contrast, the mineral cinnabar should not be heated at all since toxic mercury vapor would be released. Cinnabar is an unusual mineral in that it has the highest index of refraction of all of the minerals, surpassing even that of diamond (3.02 to 2.42). Historically cinnabar has been used for thousands of years as a pigment. Some of the Old World masters employed various sizes of cinnabar grains in their paintings to take advantage of the light-refracting qualities displayed by the mineral. Chinese artisans used cinnabar in making a red lacquer called tan sha over 500 years ago. The justly famous lacquer was deeply carved after numerous layers had been applied and allowed to harden.

| Mineral                         | Composition                                        | Mineral Properties |       |                          | Color                        | Avail-<br>ability |
|---------------------------------|----------------------------------------------------|--------------------|-------|--------------------------|------------------------------|-------------------|
|                                 |                                                    | H                  | Sp Gr | Streak                   |                              |                   |
| <u>Yellow color</u>             |                                                    |                    |       |                          |                              |                   |
| Goethite                        | $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$   | 5.5                | 4.2   | ochre yellow<br>to brown | yellow, red,<br>black-brown  | awf               |
| Ochre* (4)                      | $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | 5.5                | 4.0   | yellow                   | yellow                       | awf               |
| Sienna                          | $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$   | 5.5                | 4.0   | yellow-brown             | yellow-brown                 | awf               |
| Limonite                        | $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | 5.5                | 4.0   | yellow-brown             | black-brown                  | c                 |
| Orpiment                        | $\text{As}_2\text{S}_3$                            | 2.0                | 3.5   | pale yellow              | lemon-yellow                 | r                 |
| <u>Red-Yellow color</u>         |                                                    |                    |       |                          |                              |                   |
| Realgar                         | AsS                                                | 2.0                | 3.5   | orange-red               | red, orange-<br>yellow       | r                 |
| <u>Red color</u>                |                                                    |                    |       |                          |                              |                   |
| Hematite                        | $\text{Fe}_2\text{O}_3$                            | 6.0                | 5.0   | cherry-red,<br>red-brown | steel-gray,<br>iron-black    | c                 |
| Siderite (1)                    | $\text{FeCO}_3$                                    | 4.0                | 3.8   | white                    | red-brown<br>ash-gray        | ma                |
| Pyrite (1)                      | $\text{FeS}_2$                                     | 6.5                | 5.0   | green-black              | brassy-yellow                | c                 |
| Cinnabar (2)                    | HgS                                                | 2.5                | 8.0   | scarlet                  | cochineal-red                | r                 |
| <u>Brown color</u>              |                                                    |                    |       |                          |                              |                   |
| Umber                           | $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | 5.5                | 4.0   | brown-black              | dark brown                   | awf               |
| Limonite (1)                    | $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | 5.5                | 4.0   | yellow-brown             | black-brown                  | c                 |
| Siderite (1)                    | $\text{FeCO}_3$                                    | 4.0                | 3.8   | white                    | red-brown,<br>ash-gray       | ma                |
| Goethite                        | $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$   | 5.5                | 4.2   | ochre-yellow<br>to brown | yellow, red,<br>black, brown | awf               |
| <u>Black color (3)</u>          |                                                    |                    |       |                          |                              |                   |
| Magnetite                       | $\text{FeOFe}_2\text{O}_3$                         | 6.0                | 5.0   | black                    | black                        | c                 |
| Slate, shale                    | various min-<br>erals                              | ---                | ---   | ---                      | ---                          | c                 |
| Coal                            | C                                                  | 1.0                | 1.0   | ---                      | black                        | awf               |
| Pyrolusite                      | $\text{MnO}_2$                                     | 2.0                | 4.7   | black                    | black                        | awf               |
| Psilomelane                     | $\text{MnO}_2$                                     | 5-7                | 3.5   | brown-black              | iron-black                   | awf               |
| Graphite                        | C                                                  | 1-2                | 2.0   | black                    | black                        | r                 |
| (Continued)                     |                                                    |                    |       |                          |                              |                   |
| * see footnotes at end of table |                                                    |                    |       |                          |                              |                   |



| Mineral                     | Composition                                                | Mineral Properties |       |              | Color                       | Avail-<br>ability |
|-----------------------------|------------------------------------------------------------|--------------------|-------|--------------|-----------------------------|-------------------|
|                             |                                                            | H                  | Sp Gr | Streak       |                             |                   |
| <u>Green color</u>          |                                                            |                    |       |              |                             |                   |
| Green earth                 | mixed minerals                                             | ---                | ---   | -----        | green                       | awf               |
| Terre verte<br>(Glauconite) | hydrous iron-<br>potassium sil-<br>icate                   | soft               | ---   | ----         | green                       | awf               |
| Green ochre(4)              | $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$         | 5.5                | 4.0   | yellow       | yellow                      | awf               |
| Celadon green               | (complex fe-<br>rro-magnes-<br>ian silicates)              | 2.0                | 2.5   | ----         | emerald to ol-<br>ive green | awf               |
| Verona green                |                                                            |                    |       |              |                             | awf               |
| Malachite                   | $\text{CuCO}_3 \cdot \text{CuOH}_2$                        | 3.5                | 4.0   | pale green   | bright green                | ma                |
| <u>Blue color</u>           |                                                            |                    |       |              |                             |                   |
| Vivianite                   | $\text{Fe}_3\text{P}_2\text{O}_8 \cdot \text{H}_2\text{O}$ | 1.5                | 2.6   | blue-white   | blue to green               | r                 |
| Chrysocolla                 | $\text{CuSiO}_3 \cdot \text{H}_2\text{O}$                  | 2.4                | 2.2   | white        | bluish green                | ma                |
| Azurite                     | $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$              | 3.5                | 3.8   | blue         | azure blue                  | ma                |
| <u>White color</u>          |                                                            |                    |       |              |                             |                   |
| White clays                 | -----                                                      | ---                | ---   | -----        | white                       | awf               |
| Talc                        | $\text{H}_2\text{Mg}_3(\text{SiO}_3)_4$                    | 1.5                | 2.8   | <u>white</u> | apple-green                 | awf               |
| Whiting                     | (ground chalk,<br>limestone)                               | ---                | ---   | -----        | white                       | awf               |
| Dolomite                    | $\text{CaMg}(\text{CO}_3)_2$                               | 3.5                | 2.8   | white        | white, reddish              | awf               |
| Gypsum                      | $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$                  | 2.0                | 2.3   | white        | white, gray                 | awf               |
| Barite                      | $\text{BaSO}_4$                                            | 2.5                | 4.4   | white        | white, gray                 | ma                |

Figure 82 Chemical and physical properties and availability of pigment materials.

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FIG 82 Footnotes to Figure 82 (1) must be calcined; (2) Cinnabar crystals may darken with age, also there is a health hazard from fumes if subjected to heat; (3) The various forms of carbon black are not included since they are not naturally occurring materials; (4) Except for differences in color there are close similarities in chemical composition and physical characteristics for siennas, ochres and umbers.

The relative availability of the minerals that have been listed is indicated by various symbols. Minerals that are of common occurrence are indicated by a "c". Those minerals that are known to occur in a limited number of deposits in the Pacific West are indicated by an "r" for rare. Minerals commonly found in mineralized areas are indicated by the symbol "ma". Some minerals have a limited geographic distribution but in localities where they do occur they often are present in large quantities. These are indicated with the symbol "awf", which stands for "abundant where found".



Iron-oxide.Pigments

Iron oxides are unique in that they are the only significant colored minerals found in a natural state that are directly usable as pigments, requiring only pulverization to pigmentary size. It should be noted that the various iron oxides provide a large number of yellow, red, brown and black pigments. Iron oxide pigments are derived from carefully selected ores and should not be confused with most iron ores that are mined for the production of iron or steel.

Here is a simple classification of pigments based upon color for natural iron oxide minerals.

Yellow: goethite, lepidocrocite, ochres, siennas, limonite

Red: hematite, siderite (calcined), pyrite (calcined)

Brown: umbers, limonite (calcined), siderite (calcined), goethite

Black: magnetite

It should be noted that several colors, or shades of colors, can be obtained from one iron oxide mineral by heat treatment, thus the duplication of minerals at several places in the above list. There are two interlopers in the above list of oxides, at least they start out that way but become oxides after calcining. Siderite is an iron carbonate, and pyrite an iron sulfide. By varying the calcining siderite can become either a red or a brown pigment.

The range of chemical compositions for the principal iron oxide pigments produced commercially is shown in Figure 83.

| Chemical Properties       | Hematite | (ochre)<br>Goethite | (sienna)<br>Goethite | (umber)<br>Limonite | Magnetite |
|---------------------------|----------|---------------------|----------------------|---------------------|-----------|
| $\text{Fe}_2\text{O}_3$ % | 63-85    | 20-50               | 62-68                | 45-55               | 98*       |
| $\text{SiO}_2$            | 6-21     | 14-50               | Balance              |                     |           |
| $\text{Al}_2\text{O}_3$   | 1-5      | 6-18                | mainly               |                     |           |
| MgO                       | 1-3      | 0.20                | aluminum             |                     |           |
| CaO                       | 0.8-8.0  | 0.20                | silicates            |                     |           |
| $\text{MnO}_2$            | 0.06     | 0.62                | 10 - 11              |                     |           |

\* Contains 30%  $\text{FeO}$

Figure 83. Typical chemical compositions of principal iron oxide pigments.

Iron oxide colors are extremely permanent since they are the end-products of a long chain of weathering operations on once solid rocks. Egyptian tomb and temple paintings, and Indian pictographs in the Pacific West still retain their original brightness because the artisans used natural iron-oxide pigments.

In addition to the "standard" iron oxides shown in the table above there are some other possibilities that should be considered. The bright red baked contact between a former land surface and an over-lying lava flow may be rich enough in iron to serve as a pigment source. The red soil in the contact zone has been literally baked by the heat of the lava into a brick-like material. Road-cuts in volcanic areas are excellent places to look for these deposits which vary in thickness from a few inches to a foot or more.

High-iron clays and shales are another possibility that should be explored. If the iron content is sufficiently great the material could be finely ground and roasted to produce a selection of red and brown pigments, depending on whether oxidizing or reducing atmospheres were present.

See the section at the end of this chapter on "Beneficiation and Processing" for a method of fine-grinding iron oxides without further dilution from the grinding media.

#### Non-Iron Oxide Pigments

Although iron oxides, both natural and synthetic, provide a large percentage of yellow, brown, red and black pigments there are other natural non-iron minerals that are also used as pigments. Here, listed by color, are some of the more important.

|                   |                                           |
|-------------------|-------------------------------------------|
| <u>Yellow</u>     | orpiment                                  |
| <u>Red-yellow</u> | realgar                                   |
| <u>Red</u>        | cinnabar                                  |
| <u>Black</u>      | pyrolusite, psilomelane, graphite         |
| <u>Green</u>      | glauconite                                |
| <u>White</u>      | dolomite, gypsum, barite                  |
| <u>Blue</u>       | vivianite, azurite, chrysocolla, lazurite |



Miscellaneous Pigment Materials

In addition to the iron-oxide and non-iron oxide pigment sources listed above there are a few other miscellaneous pigments materials that are used in the arts.

Black powdered coal, slate, shale

Green green earth

White white clays, whiting, talc

### How To Look for Pigments

The search for suitable pigment material is largely directed by one's own sight. Any appropriately colored earth material may be of value, although this can only be determined after making tests. Many otherwise suitable pigments fail when tested simply because they are not concentrated sufficiently. Nearly all pigments must be diluted with some vehicle or carrier before they can be used, and pigments possessing little original coloring material will not have enough strength when applied.

Most mineral pigments come from two elements, iron and copper, with iron supplying by far the greater amount. Fortunately iron oxides are widespread, are easy to identify, and can be readily prepared for use. The copper minerals are much less common, are readily identifiable when found, but are more difficult to beneficiate and process.

Natural mineral pigments are found in three main places: (1) areas of deeply weathered soils; (2) mineralized areas; and (3) areas of sedimentary rocks.

### Mineral Pigments in Deeply Weathered Soils

Large areas of the Pacific West have been covered with lava flows. Many of these flows have weathered so completely that they are now soil, or part soil and part rotten rock and mineral fragments. Due to the high iron content of the original lava and the later weathering which removed some of the non-iron minerals, the soil, typically a deep red, may be suitable for use as a pigment.

When looking for this type of soil check out freshly cultivated fields, roadcuts, or excavations. The bright red color is highly visible, but vegetation often obscures it from sight. These soils are often referred to as lateritic (later=brick in Latin), or "red-shot".

Mineral Pigments in Mineralized Areas

Mineralized areas present many opportunities for obtaining mineral pigments. These regions have an assortment of the various metal oxides, and by keeping a sharp lookout for highly colored soils and rocks you can often locate one or more suitable materials right on the surface. Your search should, indeed, be limited to the surface since it rarely is economically feasible to dig very far into the earth, and going into abandoned mines can be detrimental to your health in a variety of ways, none of them pleasant.

The complex chemical activity in mineralized areas also effects the rocks of the surrounding countryside by infiltrating them with mineralized solutions which may produce clays and mineral oxides. See Appendix\_\_\_for a map of the mineralized areas of the Pacific West.

Old mine dumps offer excellent opportunities for picking up lumps of minerals suitable for pigments. The amount of material that you will need is relatively small and most metallic oxide minerals are quite heavy, so the volume will not be great. Look for small chunks of pure mineral that the miner has already found, mined, and discarded because they contained no minerals of value for his purposes. If there are stream courses below the mine workings you might recover considerable quantities of the various metal oxides which are usually much heavier than the gangue, by panning the sands in the shallow pools.

Iron oxides are easy to spot in mineralized areas since all of them are highly colored, with red, brown, and yellow predominating. Outcrops of mineralized veins are commonly capped with a rusty yellow-red or brown covering called an "iron hat" by miners, and used by them to locate the underlying vein. The weathering process disintegrates the exposed portion of the vein and the



iron-bearing minerals magnetite and pyrite, for instance, are broken down into the brightly colored oxides such as limonite, hematite, and goethite. Ochres, siennas, and umbers are eventually derived from these minerals.

Although magnetite is an important mineral in many mineralized veins, and a useful source for black pigment, its recovery from such an environment

by individual effort is not really feasible. The magnetite grains are usually locked solidly in the unweathered portion of the vein and mining and crushing is out of the question. It is far better to let nature do this work for you. Look for black sand patches on sandbars along streams, or on ocean beaches. Recovery is simple due to the magnetic quality of the mineral. An alnico magnet, wrapped in thin plastic wrap, need only be swept through the black sands to pick up the magnetite. The sands should be dry for best results.

Copper minerals such as azurite, chrysocolla, and malachite, are colorful in their own right, and often their blue or green coloring is transferred to other surface rocks nearby. In mineralized areas the copper minerals are easy to locate, but don't be fooled by plain old country rock that has been surface-stained by copper. If in doubt, crack open the rock and take a hard look. Copper ore will show mineralization all the way through, but rock with only a surface coating of copper won't.

Cinnabar, the bright red mercury sulfide mineral, is found only in a few places in the Pacific West. Fortunately all of the important, and many of the lesser deposits have been investigated and reported on and the published records for deposits of this mineral are excellent. Don't bother to pick through the old mercury mine dumps because you will find few if any pieces of high grade ore. Looking underground is also not suggested since most of the mines have been abandoned for many years and are unsafe. Do look for pieces of ore in and around mill buildings and ore bins in particular. You might also try panning the sands along any creeks in the area. Cinnabar is very heavy and is easily recovered in the gold pan. If you find some lumps of disseminated ore and the rock is fairly soft it might pay to crush it to pieces about one-eighth of an inch in diameter and then pan. Some cinnabar

turns black upon prolonged exposure to direct sunlight. If you find pieces of ore that have red crystals on the underside and black ones on the upper parts that have been exposed to sunlight better move on, the mineral is no good as a pigment.

Mercury is a potent health hazard and mercury ore should be handled with this in mind. Do not smoke while working with the ore, do not roast the ore, and wash up thoroly after handling it. Cinnabar itself is not a direct threat, it is the fumes of metallic mercury derived from it in the heat of a cigarette or kiln that causes the malady known as salivation.

#### Mineral Pigments in Sedimentary Rocks

Clays, chalks, shales, dolomite and gypsum are typically found in sedimentary formations where they often occur in large masses. Since sedimentary formations are laid down in horizontal beds and the covered with younger material the best chance of finding a sedimentary deposit is on the face of a bank, roadcut, or steep-sided valley where a nearly vertical face exposes the edge of the bed. Standard prospecting methods should be used here, (see the chapter on "Tracking, Testing and Taming").

A sedimentary deposit may have a wide range of quality of material and close observation, plus some field testing, will usually reveal the highest purity material.

The older sedimentary formations are often tilted and otherwise deformed so don't be too surprized if an outcrop exposed in a roadcut is no longer horizontal and is cut by dikes and veins of either higher grade ore or with some foreign material that must be discarded.

Surface weathering may have altered the exposed portion of the ore body so remove carefully the first six inches or more of the surface material before collecting. Be sure to mix thoroly all of your ore before using it to



eliminate any minor variations in quality that might not be discernible to the eye. An easy way to check for overall purity is to crush a quarter-pound sample and pan it. Any impurities are likely to be either lighter or heavier than the ore you are after and a rough separation and identification can thus be made.

Vivianite is a rare blue mineral usually associated with fossil bones buried in clay or shale. Many mammoth and mastodon bones unearthed in the Pacific West develop a bright bluish coat shortly after they have been dug up. Vivianite is formed by the combination of phosphorus from the bones and iron from the surrounding clay.

Look for masses of bright yellow ooze in swampy areas where iron-forming bacteria are producing limonite. In some swamps a deposit of limonite forms a layer on the bottom of the swamp and when thick enough can be scooped up and used as a pigment.

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8-20-79Beneficiation and Processing of Pigment Materials

Preparation for use of many of the iron pigments requires only crushing and fine grinding. Ochres, umbers and siennas are quite soft and reduction to the very fine particle sizes required is a simple operation. The harder iron minerals will have to be handled along the lines discussed in the "Beneficiation and Processing" chapter. If the pigment is to be ground dry some provision must be made for suppressing the inevitable dust that will be produced. This is not an impossibility, and extensive use of plastic membranes and fans can not only contain the dust but act as a collection system for finished material as well.

If the pigment minerals are ground in the wet way it is somewhat simpler to route the feed-stock through the various stage-grinding units and to re-cycle over-size fractions than when dry grinding is done. One problem will have to be surmounted when the fine grinding is completed. Extremely fine iron oxides have a tendency to cake when dried. This will require a final dry milling to produce a free-flowing product. Care must be taken during drying not to get the material too hot since color changes may take place.

Iron-rich clays, shales, and material from baked contacts may sometimes be ground to -100 mesh, made into a plastic mass by the addition of water, formed into cylinders about an inch in diameter and several inches long, and then fired. The resulting pieces make good grinding media for fine-grinding coarse ore obtained from the same source. Any loss of the grinding media by attrition during the grinding process does not dilute or downgrade the ore since both the ore and grinding media are composed of the same material.

FIG 84  
One method for producing these cylinders is shown in Figure 84. Essentially the device is a stout framework which supports a hydraulic jack on its base and a pipe flange into which is screwed a one inch pipe nipple six inches long and mounted on the underside of the top. A wooden dowel six inches long having a diameter slightly less than the inside diameter of the pipe rests on top of the jack plunger and fits into the lower end of the pipe.

To operate the press the jack plunger is pushed down, the pipe is rammed full with the iron-oxide material and then the jack is pumped to extrude the cylinders through the hole in the center of the top. The cylinders can be cut off with a wire at appropriate intervals as the cylinder emerges from the press.

Size of the hydraulic jack, diameter and length of the pipe, and overall dimensions of the press framework can be selected to fit your individual requirements. The supports for the top can be either iron rods or steel pipe. Two pieces of three-quarter inch thick plywood turned with the long grain at right angles to each other are suggested for the base and top of the framework.



The "common" iron oxide minerals are the result of deep weathering of surface rocks, which have been changed into intensely colored soils. Some of these contain enough iron to permit their direct use, after reduction to the proper grain size. Others may require roasting to heighten the pigmentation.

Roasting may be accomplished by fine-grinding the ore and placing thin layers of it in a kiln. The charge should be stirred at intervals to assure an even roasting. No time-temperature guidelines are available and the roasting will have to be on a trial-and error basis since grain size, depth of charge, kiln temperature, and chemical composition of the pigment will all have an effect on the color of the roasted material. Roasting iron oxides should pose no problems since the presence of sulfur, arsenic or antimony is not normally expected. Test runs should be made to determine colors produced by roasting, both in an oxidizing and a reducing atmosphere. Since iron is a contaminant in most ceramic operations it is suggested that a small, special kiln be made for roasting ores.

Pyrite, an iron sulfide, must be roasted to remove the sulfur before it can be used. The roasted iron oxide resulting from the removal of the sulfur should be treated with a basic solution to remove any traces of acid remaining. The material is then wet-ground to remove any salts formed by the addition of the base.

If you do decide to roast pyrite some provision will have to be made for the sulfur fumes that will be given off. The roasting should be done outside if at all possible, and as far away from other buildings as you can get.

Siderite, an iron carbonate, must also be roasted to drive off the carbon dioxide before it can be used as a pigment. Although both realgar, orpiment,

and cinnabar are sulfides, they do not need calcining because the minerals are naturally colored and need only to be ground. In fact it is strongly advised that these three minerals should not be heated at all since the first two could produce arsenic oxide and the latter mercury vapor. Both arsenic and mercury pose distinct health hazards.

Lateritic or "red-shot" soils often contain incompletely weathered rock or mineral fragments. These impurities should be removed by screening before grinding. If any mineral pellets that are black and the size of fish eggs are found in the soil they are probably magnetite and may be removed with a magnet and used as a source of black pigment.

Testing Pigments

Commercial tests applied to pigment materials include the following: color, tinting strength, oil absorption, hiding power, particle size, specific gravity, and analyses for iron, ferrous iron, silica, alumina, calcium, magnesium and manganese. Several references to the American Society for Testing Materials testing procedures are included in the Bibliography.

The craft potter and artist will not normally have need for all of the various tests listed above. The essential properties for his purposes are: color, tinting strength, oil absorption, hiding power and particle size. The other tests are primarily designed to assure uniformity of product in the market place and have little impact on the individual who is seeking a special pigment for his own limited use.

High-iron clays and shales can be tested in the field by forming small pellets or coils and firing them with a propane torch. The pellets are then finely ground in a mortar and pestle. A half gram sample is then mixed with ten times as much zinc oxide or white lead. Unless the pigment being tested is quite concentrated the zinc oxide will be only slightly changed in appearance. Before going into the field it might be advisable to make up several standard chips of commercial pigments mixed with ten and twenty times their weight of zinc oxide. If this is done you have a simple means of comparing tinting strength in the field where light conditions might be confusing.



## PRELIMINARY REPORT ON VOLCANIC ASHES AS GLAZE FLUXES

A series of experiments are being made to determine the practicality of Oregon volcanic glasses or ashes as a glaze constituent. This is a progress report on the experiments to date and should not be taken as complete or conclusive in any way. The bare surface of the testing has been scratched and it is hoped that more time will be available for work in the future.

Nelson ash (grey Nelson)

Location: Near St. Helens

Analysis:

(Mineralogical formula)

SiO<sub>2</sub> . . . . . 55.51  
Fe<sub>2</sub>O<sub>3</sub> . . . . . 7.23  
Al<sub>2</sub>O<sub>3</sub> . . . . . 22.17  
MgO . . . . . 1.50  
K<sub>2</sub>O . . . . . .15  
Na<sub>2</sub>O . . . . . .20

MgO .885      Al<sub>2</sub>O<sub>3</sub>      SiO<sub>2</sub>  
                    5.34      22.4  
K<sub>2</sub>O .039  
Na<sub>2</sub>O .078      Fe<sub>2</sub>O<sub>3</sub>  
                    1.11

Weight 2313

Moisture and loss  
on ignition . . . . . 13.10

P.C.E.: Circa C/16 (much higher than feldspars)

Color: Dark brown

Note: This material is more of a clay substance than an ash.

Tests were run as fusion buttons to C's - /03-6

Ash 100% - infusible.

- a. Ash 80% + colemanite 20% C/1 medium button.  
Ash 60% + colemanite 40% C/03 low button.

- Ash 80% + cryolite 20% C/2 low button.  
b. Ash 70% + cryolite 30% C/2 flat.  
Ash 60% + cryolite 40% C/01 flat.

- Ash 90% + dolomite 10% C/2 high unfused mass.  
c. Ash 80% + dolomite 20% C/6  
Ash 70% + dolomite 30% C/2

- Ash 90% + whiting 10% hard cinter.  
d. Ash 80% + whiting 20% hard cinter.  
Ash 70% + whiting 30% hard cinter.

Ash P-8373

Location:

Analysis:

P.C.E.: Circa C/02 Good fusion, light brown color.

Ash P-8442

Location: Sec. 4, T. 7 S., R. 41 E.

Analysis: Volcanic glass est. 75-85%

Mineral grains est. 15-25% (feldspar dominant)

P.C.E.: C/2 Badly bloated.

Ash P-8444

Location: NE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 9, T. 27 S., R. 9 E.

Analysis: Volcanic glass est. 85-90%

Mineral grains est. 10-15% (feldspar dominant)

P.C.E.: C/3 Good fusion, dark brown.

Ash P-8443

Location: NE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 9, T. 27 S., R. 9 E.

Analysis: Volcanic glass est. 80-85%

Mineral grains est. 15-20% (feldspar dominant)

P.C.E.: C/3 Same as P-8444.

Ash P-8441

Location: Sec. 32, T. 2 S., R. 2 E.

Analysis: Volcanic glass 60-70%

Mineral grains 30-35%

Diatoms 2- 5%

P.C.E.: C/4 Bloating



Ash P-8481

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass est. 70-80%

Mineral grains est. 10-15% (feldspar dominant)

Rock grit 5%

Pumice grit 5-10%

P.C.E.: C/4 Good fusion, dark brown.

Ash P-8480

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass 60-65%

Mineral grains 35-40% (feldspar dominant)

P.C.E.: C/2 Dark color, fusion good.

Ash P-8479

Location: Sec. 23, T. 33 S., R. 1 E.

Analysis: Volcanic glass 60-65%

Mineral grains 25-30% (feldspar dominant)

Pumice fragments 5-10%

P.C.E.: C/3 Dark color, fusion good-fair.

Ash P-8484

Location: From Merle Sleeper pit 1 mile west of Bend, Oregon.

Analysis: Volcanic glass 95%

Mineral grains 5% (feldspar dominant)

P.C.E.: C/3 Light brown fusion.

Ash P-8483

Location: From Sleeper pit approximately 1 mile west of Bend, Oregon.

Analysis: Volcanic glass 85%

Mineral grains 10%

Rock fragments 5%

P.C.E.: C/4 Fusion dark brown.

Note: Ashes P-8483 All started to tip at minus C/2 but did not bend  
P-8484 completely until given temperatures.  
P-8481

Sample P-8519

Location: Adair, Oregon, E $\frac{1}{2}$  of SW $\frac{1}{4}$  sec. 33, T. 31 S., R. 46 E.

Analysis: Volcanic glass 95% (Highest percent of volcanic glass submitted to date)

Mineral grains (negligible)

P.C.E.: C/8 Gray translucent fusion. Highest temperature to date, also lightest in color of all ashes reported in this paper.

Ash P-8519

Was made as mixture with whiting and colemanite and fired to C/2.

Ash 90% + whiting 10% Some glassy fusion, did not wet surface, crawling to marked degree.

Ash 80% + whiting 20% Same as above but less crawling present.

Ash 95% + Colemanite 5% Some glassy fusion, did not wet surface, crawling to marked degree.

Ash 90% + Colemanite 10% Same as above but less crawling.

Ash 85% + Colemanite 15% Good fusion, crawling evident but less than any mixes in this group.

Ashes tentatively selected for further work:

P-8373 All others were eliminated due to: 1. darkness  
P-8443 2. bloating  
P-8484 3. uneven fusion and/or unpleasant  
P-8519 effects of fusion.

New ashes received up to January 1, 1950:

P-9231  
P-8596 (Removed from testing because of high plastic content. Probably bentonite)  
P-9321  
P-9229

Ash P-9231

Location: Secs. 1, 2, 7, 8, 11, and 12, T. 18 S., R. 12 E.

Analysis: Volcanic glass est. 95%

Mineral grains est. 5% (mainly feldspar)

P.C.E.: C/2 Good glass, dark gray color at C/6 as a glaze, no crazing present.

Ash P-9330

Location: Secs. 1, 2, 7, 8, 11, and 12, T. 18 S., R. 12 E.

Analysis: Volcanic glass 95%

Mineral grains 5% (mainly feldspar)

P.C.E. C/2 Dark glass, good fusion at C/6, crazing present.

Ash P-9229

Location: Sec. 24, T. 6 S., R. 13 E.

Analysis: Volcanic glass 99% (exploded perlite)

P.C.E.: C/4 Light colored glass, clean fusion at C/6 as glaze, bubbles present (probably caused by insufficient grinding of bubbles in the bloated perlite).



The ashes tested so far produced in all cases, except one (P-8519), dark-firing glasses at temperatures in the neighborhood of C/1-5, most of them about C/4 or 2150° F. P-9519 produced a light gray to white fusion at C/8 or 2300° F.

All the ashes with the exception of P-8519 have no use as a feldspar substitute. They could be used as fluxes for building products production or as low-grade fluxes for dark-colored, low temperature glazes for use on architectural facing tile, roofing tile, etc.

The commercial glasses (Frits) used as fluxes at this time run in the neighborhood of \$80.00 to \$120.00 per ton f.o.b. plant. These glasses have a standard known composition and are usually compounded for a specific plant's use by the manufacturer.

Whether or not the low cost of the ashes would or could offset the standard materials and practice is a moot question. There is one plant, however, using volcanic ash of a light-firing color and a fusion of circa C/3. This plant is in Kansas and manufactures a low price art-ware for the florist trade. They have had success in the use of their ash as a glaze base to which other oxides are added. Not much has been reported on their production or the quality of the ware produced.

The ashes selected for the testing will be used as constituents of a group of glazes at C/04 as well as C/2-4. The higher range seems more practical from the sale of the ash, since more could be used. There is a chance that eutectics may be reached which will produce glasses for use at the lower temperatures which will contain an appreciable ash content.



# State Department of Geology and Mineral Industries

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## PROGRESS REPORT II Addition to Preliminary Report on Volcanic Ashes as Glaze Fluxes

A series of mixtures of volcanic ashes and the materials colemanite, cryolite and white lead were tested in the temperature range C/02 - 4.

|       | <u>Ash P-8373</u> | <u>Colemanite</u> | <u>Results C/02 - 01</u>              |
|-------|-------------------|-------------------|---------------------------------------|
| A I   | 80                | 20                | Texture glassy, color brown to yellow |
| A II  | 75                | 25                | " " " " " "                           |
| A III | 70                | 20                | " " " " " "                           |

Clear dark glass, some fine bubbles present. Good fit.

|       | <u>P-8373</u> | <u>White lead</u> | <u>Results C/02 - 01</u>               |
|-------|---------------|-------------------|----------------------------------------|
| B I   | 90            | 10                | Texture glassy, medium brown, fit good |
| B II  | 80            | 20                | " " olive brown " "                    |
| B III | 70            | 30                | " " " " " "                            |

Glass clear. Bubbles increase as lead increased. Solid material present in glass.

|       | <u>P-8373</u> | <u>Cryolite</u> | <u>Results C/02 - 01</u>                |
|-------|---------------|-----------------|-----------------------------------------|
| C I   | 90            | 10              | Glassy texture, brown speckle, poor fit |
| C II  | 80            | 20              | " " " " " "                             |
| C III | 70            | 30              | " " " " " "                             |

Crazing present, clear glass and bubbles



|       | <u>Ash P-8484</u> | <u>Colemanite</u> | <u>Results C/3 - 4</u>        |
|-------|-------------------|-------------------|-------------------------------|
| A I   | 80                | 20                | Glassy, olive brown, fit good |
| A II  | 75                | 25                | " " " fit fair                |
| A III | 70                | 30                | " " " " "                     |

Less crazing than in P-8373 and cryolite medium dark glass bubbles evident.

|       | <u>P-8484</u> | <u>White lead</u> | <u>Results C/3 - 4</u>     |
|-------|---------------|-------------------|----------------------------|
| B I   | 90            | 10                | Glassy, dark brown, crazed |
| B II  | 80            | 20                | " medium brown, crazed     |
| B III | 70            | 30                | " yellow brown "           |

Bubble capacity. Crazing increase with lead. Glassy.

Due to excessive crazing noted in the use of cryolite as a fluxing addition to the glaze, the use of it was abandoned in this testing program.

|       | <u>Ash P-8519</u> | <u>Colemanite</u> | <u>Results C/2</u>                   |
|-------|-------------------|-------------------|--------------------------------------|
| A I   | 90                | 10                | Color gray, bubble opacity, fit good |
| A II  | 80                | 20                | " " " " " "                          |
| A III | 70                | 30                | " " " " " "                          |

Great deal of bubbling present in glass. Smell of sulphur.

|       | <u>P-8519</u> | <u>White lead</u> | <u>Results C/2</u>                                        |
|-------|---------------|-------------------|-----------------------------------------------------------|
| B I   | 90            | 10                | Yellow color, great bubbling, fit could not be determined |
| B II  | 80            | 20                | " " " " " "                                               |
| B III | 70            | 30                | " " " " " "                                               |

Great deal of boiling.



|                                   | <u>Glass P-9229</u> | <u>Colemanite</u> | <u>Results C/2 - 4</u>                    |
|-----------------------------------|---------------------|-------------------|-------------------------------------------|
| A I                               | 90                  | 10                | Clear gray, orange peel texture, good fit |
| A II                              | 80                  | 20                | " " slight orange peel, good fit          |
| A III                             | 70                  | 30                | " " smooth texture, good fit              |
| Smooth glassy surface and bubbles |                     |                   |                                           |

|               | <u>P-9229</u> | <u>White lead</u> | <u>Results C/2 - 4</u>                         |
|---------------|---------------|-------------------|------------------------------------------------|
| B I           | 90            | 10                | Clear gray, bubbly texture, fit not determined |
| B II          | 80            | 20                | " " " " " " "                                  |
| B III         | 70            | 30                | " " " " " " "                                  |
| Bubbling high |               |                   |                                                |

|                           | <u>P-8443</u> | <u>Colemanite</u> | <u>Results C/2 - 4</u>  |
|---------------------------|---------------|-------------------|-------------------------|
| A I                       | 90            | 10                | Glassy opaque, no craze |
| A II                      | 80            | 20                | " " " "                 |
| A III                     | 70            | 30                | " " " "                 |
| Crazing less than in 8373 |               |                   |                         |

|                                                             | <u>P-8443</u> | <u>White lead</u> | <u>Results C/2 - 4</u>                |
|-------------------------------------------------------------|---------------|-------------------|---------------------------------------|
| B I                                                         | 90            | 10                | Dark brown, bright glaze, not crazed  |
| B II                                                        | 80            | 20                | Speckled yellow, bright glaze, crazed |
| B III                                                       | 70            | 30                | " " " " "                             |
| Crazing at higher Pb value. Brilliance increased with lead. |               |                   |                                       |



Chemical analysis - L. L. Hoagland

P-8373

|                                          |       |
|------------------------------------------|-------|
| SiO <sub>2</sub> . . . . .               | 64.36 |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 16.43 |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 2.23  |
| CaO . . . . .                            | 2.60  |
| MgO . . . . .                            | 1.27  |
| K <sub>2</sub> O . . . . .               | 2.26  |
| Na <sub>2</sub> O . . . . .              | 7.10  |
| Loss on ign. . .                         | 3.72  |

Molecular formula

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .528 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .111 | .745                           | 7.89             |
| MgO               | .148 | Fe <sub>2</sub> O <sub>3</sub> |                  |
| CaO               | .213 | .065                           |                  |

M.W. 621.8

P-8519

|                                          |       |
|------------------------------------------|-------|
| SiO <sub>2</sub> . . . . .               | 68.70 |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 13.50 |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 1.00  |
| CaO . . . . .                            | .80   |
| MgO . . . . .                            | .41   |
| K <sub>2</sub> O . . . . .               | 4.55  |
| Na <sub>2</sub> O . . . . .              | 5.65  |
| Loss on ign. . .                         | 5.49  |

Molecular formula

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .554 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .290 | .784                           | 6.87             |
| MgO               | .072 | Fe <sub>2</sub> O <sub>3</sub> |                  |
| CaO               | .084 | .036                           |                  |

M.W. 567

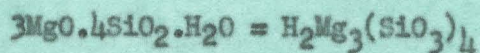


P-9229

|                                          |       |                        |                                |                  |
|------------------------------------------|-------|------------------------|--------------------------------|------------------|
| SiO <sub>2</sub> . . . . .               | 70.40 | Molecular formula      |                                |                  |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 15.10 | Na <sub>2</sub> O .508 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 0.76  | K <sub>2</sub> O .282  | .850                           | 6.77             |
| CaO . . . . .                            | 1.20  | CaO .127               | Fe <sub>2</sub> O <sub>3</sub> |                  |
| MgO . . . . .                            | 0.57  | MgO .081               | .027                           |                  |
| K <sub>2</sub> O . . . . .               | 4.63  |                        |                                |                  |
| Na <sub>2</sub> O . . . . .              | 5.48  |                        |                                | M.W. 619         |
| Loss on ign. . .                         | 1.86  |                        |                                |                  |

Discussion of method of calculating ash analysis  
into a form used in calculating glazes

In writing the formula of many ceramic materials it is customary to use the oxide form instead of the chemical form thus



This gives the ceramist a means of estimating the properties of the compound or mineral based on the amount of molecules or molecule of oxides within the formula. A modification of this practice is used in calculating a glaze formula.

In calculating a glaze formula the oxide constituents are divided into three groups:

- (1) RO or R<sub>2</sub>O group
- (2) R<sub>2</sub>O<sub>3</sub> group
- (3) RO<sub>2</sub> group



The symbol of R indicates a metallic atom and the O is, of course, oxygen. Therefore from the following chemical analysis of a volcanic substance perlite (this material has been fused) we divide the percentage of each oxide compound by its molecular weight in order to calculate the molecular formula from this analysis.

| P-9229                                   | Mol.<br>Wt.        |
|------------------------------------------|--------------------|
| SiO <sub>2</sub> . . . . .               | 70.40 ÷ 60 = 1.173 |
| Al <sub>2</sub> O <sub>3</sub> . . . . . | 15.10 ÷ 102 = .148 |
| Fe <sub>2</sub> O <sub>3</sub> . . . . . | 0.76 ÷ 160 = .004  |
| CaO . . . . .                            | 1.20 ÷ 56 = .021   |
| MgO . . . . .                            | 0.57 ÷ 40 = .014   |
| K <sub>2</sub> O . . . . .               | 4.63 ÷ 94 = .048   |
| Na <sub>2</sub> O . . . . .              | 5.48 ÷ 62 = .088   |
| Ign. loss . .                            | 1.86               |

In calculating this material to the proper form for ceramic calculation the next step is to put the oxides into their proper columns.

RO or R<sub>2</sub>O    R<sub>2</sub>O<sub>3</sub>    RO<sub>2</sub>

It is always considered that the RO (R<sub>2</sub>O) group is unity. 1.00 and all the others are based in ratio accordingly. Therefore the formula is written

|                   |             |                                |                  |
|-------------------|-------------|--------------------------------|------------------|
| CaO               | .021        | Al <sub>2</sub> O <sub>3</sub> |                  |
| MgO               | .014        | .148                           | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .048        | Fe <sub>2</sub> O <sub>3</sub> | 1.173            |
| Na <sub>2</sub> O | <u>.088</u> | .004                           |                  |
|                   | .171        |                                |                  |



Now all the molecular equivalents are divided by the total of the RO(R<sub>2</sub>O) column.

|                                |                |      |
|--------------------------------|----------------|------|
| CaO                            | .021 ÷ .171 =  | .127 |
| MgO                            | .014 ÷ .171 =  | .081 |
| K <sub>2</sub> O               | .048 ÷ .171 =  | .282 |
| Na <sub>2</sub> O              | .088 ÷ .171 =  | .508 |
| Al <sub>2</sub> O <sub>3</sub> | .148 ÷ .171 =  | .850 |
| Fe <sub>2</sub> O <sub>3</sub> | .004 ÷ .171 =  | .027 |
| SiO <sub>2</sub>               | 1.173 ÷ .171 = | 6.77 |

We now have

| RO                | R <sub>2</sub> O | R <sub>2</sub> O <sub>3</sub>  | RO <sub>2</sub>  |
|-------------------|------------------|--------------------------------|------------------|
| CaO               | .127             | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| MgO               | .081             | .850                           | 6.77             |
| K <sub>2</sub> O  | .282             | Fe <sub>2</sub> O <sub>3</sub> |                  |
| Na <sub>2</sub> O | .508             | .027                           |                  |

The molecular weight is now derived by multiplying each of the amounts of given oxide by its molecular weight and adding the sum.

|                                |              |               |
|--------------------------------|--------------|---------------|
| CaO                            | .127 x 56 =  | 7.11          |
| MgO                            | .081 x 40 =  | 3.24          |
| K <sub>2</sub> O               | .282 x 94 =  | 26.51         |
| Na <sub>2</sub> O              | .508 x 62 =  | 31.50         |
| Al <sub>2</sub> O <sub>3</sub> | .850 x 102 = | 86.70         |
| Fe <sub>2</sub> O <sub>3</sub> | .027 x 160 = | 4.32          |
| SiO <sub>2</sub>               | 6.77 x 60 =  | <u>404.20</u> |
|                                |              | 563.08        |



To incorporate this material into a glaze the following method of calculation is used:

| <u>Glaze formula</u> |      |                                |                  |
|----------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O    | .288 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O     | .160 | .487                           | 3.88             |
| MgO                  | .046 | B <sub>2</sub> O <sub>3</sub>  |                  |
| CaO                  | .503 | .648                           |                  |

As much of the sample P-9229 is to be used as possible. Therefore the following graph method is used. The molecules to be satisfied in the formula are written across the top of the paper with the amounts in formula underneath. The next step is to decide from what materials you are going to obtain the oxides. Since there is no B<sub>2</sub>O<sub>3</sub> in the ash we are using, we eliminate that oxide fully by using colemanite. 2CaO3B<sub>2</sub>O<sub>3</sub>2H<sub>2</sub>O molecular weight 412 using .648 molecule of B<sub>2</sub>O<sub>3</sub> carries .432 molecule of CaO with it in the mineral colemanite. The amount of CaO .432 is then multiplied by the molecular weight of the mineral. 412 weight is divided by 2 since there are 2 molecules of CaO in colemanite and only part of 1 in the formula to be satisfied.

$$.432 \times \frac{412}{2} = 89 \text{ parts colemanite}$$

The rest of the formula is now satisfied by the ash P-9229 as if 288 parts of Na<sub>2</sub>O<sub>2</sub> is taken in ratio to the amount of Na<sub>2</sub>O in the ash P-9229 amount of K<sub>2</sub>O is .160 the CaO .072, MgO .0459 or .046 Al<sub>2</sub>O<sub>3</sub> .482, SiO<sub>2</sub> .384 - the total of the RO of the molecules of P-9229 = .565 x molecular weight 563 = 328 parts. Therefore the batch to be weighed out equals 89 parts colemanite and 349 parts P-9229 on percentage basis roughly

21 parts colemanite  
79 parts P-9229



| <u>Na<sub>2</sub>O</u> | <u>K<sub>2</sub>O</u> | <u>MgO</u> | <u>CaO</u>          | <u>Al<sub>2</sub>O<sub>3</sub></u> | <u>B<sub>2</sub>O<sub>3</sub></u> | <u>SiO<sub>2</sub></u> | <u>Raw material</u>               |
|------------------------|-----------------------|------------|---------------------|------------------------------------|-----------------------------------|------------------------|-----------------------------------|
| .288                   | .159                  | .046       | .504                | .482                               | .648                              | 3.84                   |                                   |
| .288                   | .159                  | .046       | <u>.072</u><br>.432 | .482                               | .648                              | 3.84                   | Sample P-9229<br>.565 x 563 = 328 |
|                        |                       |            | .432                |                                    | .648                              |                        | Colemanite<br>.432 x 412/2 = 89   |

A glaze was compounded to use 9229 and colemanite in the same ratio as test A II

|                   | <u>Emperical formula</u> | A2 - GMI                                        |
|-------------------|--------------------------|-------------------------------------------------|
| Na <sub>2</sub> O | .288                     | Al <sub>2</sub> O <sub>3</sub> SiO <sub>2</sub> |
| K <sub>2</sub> O  | .163                     | .482 3.84                                       |
| MgO               | .046                     | B <sub>2</sub> O <sub>3</sub>                   |
| CaO               | .503                     | .648                                            |

| <u>Batch</u>    | A2 - GMI |
|-----------------|----------|
| P-9229 - 328    |          |
| Colemanite - 89 |          |

This glaze is a typical white ware glaze using a commercial frit.

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .291 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .045 | .301                           | 2.925            |
| CaO               | .510 | B <sub>2</sub> O <sub>3</sub>  |                  |
| ZnO               | .100 | .349                           |                  |
| MgO               | .050 |                                |                  |



This glaze uses .7 equivalents of a commercial frit, therefore a direct substitution of .7 equivalents was made of P-9229 for frit. This substitution produced a glaze with the following formula:

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .254 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .141 | .425                           | 3.38             |
| CaO               | .468 | B <sub>2</sub> O <sub>3</sub>  |                  |
| MgO               | .050 | .35                            |                  |
| ZnO               | .100 |                                |                  |

Called A 21 GMI

Batch composition

|            |   |       |
|------------|---|-------|
| P-9229     | - | 394.1 |
| Colemanite | - | 47.6  |
| Dolomite   | - | 1.8   |
| Zinc oxide | - | 8.1   |
| Whiting    | - | 15.9  |



#### RESULTS ON GLAZE A2 GMI

All tests were fired to Cone 3

- (1) This test is the base glaze alone with no colors added. On the buff stone-ware body it produced a clear glaze with some opacity due to a slight bubble structure plus the opacifying effect sometimes produced by  $B_2O_3$  glasses. On the red tile the opacity and bubbling is more noticeable, yet no more intense within the glass than on the buff clay tile, the contrast in tones being greater.
- (2) A typical cobalt blue was produced rather opaque probably due to the thickness of the glaze.
- (3) The chrome produced in this test a green, very opaque, as is expected from the opacifying effect chrome has in most glazes.
- (4) The iron oxide addition produced the typical brown of iron silicate.
- (5) In this test the manganese dioxide produced an alkaline manganese color of brownish plum, if lead was used instead of colemanite in this glaze the color produced would be more brown.
- (6) The rutile produced an opaque warm buff color, again very typical of alkaline borosilicate glazes.
- (7) Copper seemed to cause a slight fluxing action to the glaze and produced a typical bluish green which was almost transparent.
- (8) Nickel oxide gave a warm gray and seemed to make the glaze more opaque.

#### RESULTS ON A21 GMI

- (1) This base is much less opaque than tests A2 GMI I. It should be more stable in reaction than the first glaze due to the greater number of fluxes interacting to give a glass with a slightly higher  $SiO_2$  ratio.



- (2) The cobalt carbonate produced a more intense blue than in A2 GMI II.
- (3) Chrome oxide gave a greenish brown due to the presence of ZnO in the glaze.
- (4) The iron oxide produced a darker brown than in glaze A2 GMI IV and had a higher glass.
- (5) The manganese dioxide gave a deeper plum color and was more opaque than in A2 GMI V.
- (6) The rutile did not produce as opaque a glass as in A2 GMI VI but had a better surface.
- (7) The copper color was more typical than in A2 GMI VII and was more opaque.
- (8) Nickel again produced a warm brown and was more refractory in reaction producing a rough feeling glaze surface.

#### GENERAL

In general, Sample P-9229 compares favorably with both feldspars and a commercial frit.

In glaze, A2 GMI a feldspar would not have matured within the glaze at the temperature fired.

In glaze A21 GMI there was little or no difference between the frit and P-9229 in their reaction toward the finished fired result in the glaze.

The glazes produced by this material P-9229 show very favorable use for the material as a medium temperature glaze ingredient and produce fusion at a lower temperature than the average feldspar, probably due to the lower  $Al_2O_3$  content of the material. Also it is thought that a eutectic mixture of P-9229 and colemanite aids in the acceptance of a greater amount of  $SiO_2$  into the glaze. These tests show Sample P-9229 is a favorable material to test further as a substitute for feldspar in colored glazes.



### Fusion buttons

Fusion buttons were made in a 00 "Coors" porcelain crucible. One of a commercial feldspar (BS1) (Buckingham feldspar, mined and marketed by Consolidated Feldspar Corporation) and the others of ground bloated perlite (P-9229) (P2); hydro separator overflow of perlite (P3); sizer cell #4 (P4); volcanic ash from Adrian, Oregon, P-3519 (VA1); ground pumice from one of Merle Sleeper's pits, P-3434 (GP1). All samples were fired at the same time to C/8 (1225° C) in a small gas test kiln in about 4 hours.

### Results on fusion buttons

- (BS1) The feldspar button formed to a consolidated glassy mass that had not yet started to slump but was reduced to 19 mm. or a loss in size of 6 mm. The color was white to blue white and the surface was pebbly.
- (P2) The ground bloated perlite (P-9229) consolidated to a greater degree than (BS1) Buckingham feldspar. The height measured a loss from 25 mm. (the formed size) of 10 mm. or a final height of 15 mm. after firing. It was a warm medium gray color and very smooth and glassy.
- (P3) The hydro separator overflow perlite did not consolidate as much as sample (P2) (ground perlite). The height of the fused sample stood at 17 mm. or a loss in height of consolidation of 8 mm. The color was a little darker than the bloated perlite (P2) and the button showed a smooth glassy surface.
- (P4) The #4 sizer cell material did not give a satisfactory test. The material was too coarse to give a good physical bond to the button before the thermal bonding action took place. The button slumped and an accurate measurement is not available. However, the fusion was good, though not as smooth as the other tests, probably due to large grain size.



- (VA1) The ash from Adrian, Oregon (P-8519) consolidated to a height of 18 mm., a loss of 7 mm. from the formed size. The color was a dark gray and the surface was glassy but not as smooth as (P3).
- (GP1) The ground pumice (P-8484) produced a better glass than all buttons tested in this series, showing a slump to 13 mm. or a loss of 12 mm. from forming size. The fusion was very glassy and smooth, color was medium to dark gray.

Comparison of perlite (hydro separator overflow)  
volcanic ash (P-8519) and ground pumice (P-8484)  
with standard commercial feldspathic material

Three glazes were tested to compare hydro separator overflow perlite, sample P-8519 and sample P-8484, with standard commercial materials. All tests were fired to C/3 - 4 in an electric kiln.

Glaze 100 X Batch composition

Cornwall stone - 50 parts  
White lead - 19 parts  
Whiting - 10 parts

100 C Batch composition

Hydro separator overflow perlite - 50 parts  
White lead - 19 parts  
Whiting - 10 parts

100 D Batch composition

P-8484 - 50 parts  
White lead - 19 parts  
Whiting - 10 parts



100 E Batch composition

P-8519 - 50 parts

White lead - 19 parts

Whiting - 10 parts

Results on Series 100

Glaze 100 X (standard ceramic material batch) was much whiter than

C, D, or E, due to the lower iron content of the Cornwall stone.

Glaze 100 C did not craze as did X, D, and E. The color was yellower than 100 X.

Glaze 100 D looked the same as 100 X except for very yellow color due to higher iron content of material.

Glaze 100 E was the least opaque of group though it showed the same yellowing action from iron in material.

In general, all glazes crazed on the test body except 100 C. Volcanic glasses seem to successfully replace Cornwall stone in this glaze except for yellow color they impart to the glaze. This would be negligible in nearly all colored glazes.

Glaze 200

Glaze 200 X is a typical artware glaze. In this glaze Buckingham feldspar is used to provide  $K_2O$  1.13  $Al_2O_3$  6.45  $SiO_2$ .



Glaze 200 X Batch composition

|                     |       |
|---------------------|-------|
| Whiting             | 30.0  |
| Colemanite          | 102.8 |
| Buckingham feldspar | 238.4 |
| Flint               | 88.8  |
| China clay          | 5.1   |
| $\text{CuCO}_3$     | 4%    |

Glaze 200 C Batch composition

|                                  |       |
|----------------------------------|-------|
| Whiting                          | 30.0  |
| Colemanite                       | 102.8 |
| Hydro separator overflow perlite | 238.4 |
| Flint                            | 88.8  |
| China clay                       | 5.1   |
| $\text{CuCO}_3$                  | 4%    |

Glaze 200 D Batch composition

|                 |       |
|-----------------|-------|
| Whiting         | 30.0  |
| Colemanite      | 102.8 |
| P-3484          | 238.4 |
| Flint           | 88.8  |
| China clay      | 5.1   |
| $\text{CuCO}_3$ | 4%    |

Glaze 200 E Batch composition

|                 |       |
|-----------------|-------|
| Whiting         | 30.0  |
| Colemanite      | 102.8 |
| P-8519          | 238.4 |
| Flint           | 88.8  |
| China clay      | 5.1   |
| $\text{CuCO}_3$ | 4%    |



### Results on Series 200

Glaze 200 X produced a very good glass with a smooth fusion and a slight boron opacity. The color produced by copper carbonate was a watery blue green semi-transparent glaze and showed a tendency to craze in heavy areas.

Glaze 200 C produced a very good glass with smooth fusion and quite a boron opacity. Color produced by copper carbonate was more green than glaze 200 X and showed excellent texture and color interest. There was less tendency to craze in heavy areas of application than in glaze 200 X.

Glaze 200 D produced nearly the same optical and physical reaction and effect as glaze 200 C.

Glaze 200 E produced nearly the same optical and physical reaction and effect as glaze 200 C except the material P-8519 increased the fluidity of the glaze.

### Series 300

Glaze 300 X is a typical artware semi-matt glaze. In this glaze nepheline syenite is used to provide  $\text{KNaO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ .

#### Glaze 300 X Batch composition

|                   |   |    |
|-------------------|---|----|
| Nepheline syenite | - | 34 |
| Dolomite          | - | 6  |
| Colemanite        | - | 4  |
| Flint             | - | 6  |



Glaze 300 C Batch composition

|                                  |    |
|----------------------------------|----|
| Hydro separator overflow perlite | 34 |
| Dolomite                         | 6  |
| Colemanite                       | 4  |
| Flint                            | 6  |

Glaze 300 D Batch composition

|            |    |
|------------|----|
| P-8484     | 34 |
| Dolomite   | 6  |
| Colemanite | 4  |
| Flint      | 6  |

Glaze 300 E Batch composition

|            |    |
|------------|----|
| P-8519     | 34 |
| Dolomite   | 6  |
| Colemanite | 4  |
| Flint      | 6  |

Results on Series 300

Glaze 300 X produced a fair semi-matt glaze with a bubble opacity and a definite whitish cast on the red clay tile. Good fusion is apparent but tile shows a great deal of bubble opacity and some pinholing. Crazeing is quite evident on this body.

Glaze 300 C produced a fair to good semi-matt glaze with less apparent bubbling and a much greater opacity. The color is definitely yellow (caused by iron content of perlite). Pinholing is still in evidence as in test 300 X. Crazeing, while not so great as in test 300 X is still evident.



Glaze 300 D produced a glaze much like test 300 C. A textural color effect is produced in this glaze which looks like a  $B_2O_3$  reticulation pattern.

Glaze 300 E produced a glaze much like test 300 C. A textural color effect is produced in this glaze which looks like a  $B_2O_3$  reticulation pattern but is not as strong as in test 300 D.

#### GENERAL RESULTS OF SERIES 100, 200, 300

In general, hydroseparator overflow perlite, volcanic ash, and crushed pumice produce results which compare favorably with feldspar, Cornwall stone, and nepheline syenite.

In glazes containing the volcanic glasses as substitutes for Buckingham feldspar, Cornwall stone and nepheline syenite, the maturing point of the glaze is somewhat reduced. When color is added to the glaze to hide the effect of iron discoloration caused by the iron content of the volcanic glasses, an improvement of color tone is rather apparent and not unpleasing.

The volcanic glasses tested do not seem to cause any undesirable effects so far as fusion, material behavior or glaze defects are concerned. In fact, in glaze 100 C there was no crazing as in the standard 100 X, and in glaze 200 there was less apparent crazing in C, D and E than in the standard 200 X.

The color produced by the reaction of the iron contained in the volcanic glasses tested makes the material impractical for use as a flux in the production of white ware. However, if color is added either in the glaze or in the body, there should be no difficulty in finding volcanic glasses good and usable substitutes for the feldspathic content of a glaze or body.



Marketing is the most important part of the sale of the volcanic glasses as feldspar substitutes. The testing data may show very good results and good handling qualities but it is necessary for a good sales program to promote the use of these materials in the ceramic industry at the present time. For many years the criteria of feldspathic materials for the bulk of the industry has been whiteness. This is tradition and not at all necessary in the production of colored wares such as terracotta, artware, stoneware, etc. Therefore the persons who would like to use the ceramic industry as an outlet for these raw products must break down this attitude first.

*Charles W. F. Jacobs*

Charles W. F. Jacobs  
June 1, 1950



# State Department of Geology and Mineral Industries

702 Woodlark Building  
Portland 5, Oregon

## USE OF VOLCANIC GLASSES IN CERAMIC GLAZES

In the course of a research project conducted by C.W.F. Jacobs for the Oregon Department of Geology and Mineral Industries on the use of volcanic glasses in the ceramic field, it was found that perlite, both raw and popped, provided a good source of  $\text{KNaO}$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{SiO}_2$  for use as fluxes for both glaze and body. The experiments made on the perlite are as follows:

Sample P-9229

Location: Sec. 26, T. 6 S., R. 13 E.

Petrographic analysis: volcanic glass (exploded perlite)

P.C.E. approximately C/4 - light colored glass

Clear fusion at C/6 as a glaze, bubbles present. Probably caused by insufficient grinding of bubbles in the floated perlite.

### Tests of glaze fusion and firing reaction

Sample P-9229 (bloated perlite) was combined with colemanite and white lead and fired to C/2 - 4.

|       | <u>P-9229</u> | <u>Colemanite</u> | <u>Results</u>                            |
|-------|---------------|-------------------|-------------------------------------------|
| A I   | 90            | 10                | Clear grey, orange peel texture, good fit |
| A II  | 80            | 20                | " " slight orange peel texture, good fit  |
| A III | 70            | 30                | Smooth glassy surface, some bubbles       |



|       | <u>P-9229</u> | <u>White lead</u> | <u>Results</u>                                |
|-------|---------------|-------------------|-----------------------------------------------|
| B I   | 90            | 10                | Clear gray bubbly texture, fit not determined |
| B II  | 80            | 20                | " " " " " "                                   |
| B III | 70            | 30                | " " " " " "                                   |

### Fusion buttons

Fusion buttons of perlite (popped and raw) were prepared in porcelain crucibles.

- (1) Test button was made of Buckingham feldspar ( $K_2O$  1.13  $Al_2O_3$  6.45  $SiO_2$ ) mined and marketed by Consolidated Feldspar Corporation. This was used as the standard because of white color and approximate fusion range of typical commercial feldspars.
- (2) Fusion button was made of popped perlite which had been crushed and bonded slightly with water and 10 percent gum tragacanth solution.
- (3) Fusion button was made of hydro separator overflow bonded slightly with water and gum tragacanth solution.
- (4) Fusion button was made from raw perlite from sizer cell #4 and bonded slightly with water and gum tragacanth solution.

### Results on Fusion Buttons

Fired at C/8

#### (1) Buckingham feldspar

Consolidated to a white vitreous ware holding remnant of original shape well. Button has a slightly rough surface.

#### (2) Popped perlite

Consolidated to a greater degree than feldspar and is nearly completely glassy. Color is a medium tan and surface is smooth.



(3) Hydro separator overflow

Consolidated to about the same extent as feldspar, yet fusion is more glassy. Color is about the same as Sample 2 (medium tan) and surface is smooth.

(4) Perlite from sizer cell #14

Did not readily consolidate. Physical bond weakened before thermal action took place and button fell losing original shape. Particles do show a glassy fusion. Bond is more particle to particle rather than a vitreous mass. Color is darker than any other perlites and surface is more rough. (This reaction is thought to be caused more by particle size than difference in composition or thermal action.)

The chemical analysis of P-9229 as made by L. L. Hoagland is as follows:

| P-9229                         |       | Molecular formula derived from chemical analysis |      |                                |                  |
|--------------------------------|-------|--------------------------------------------------|------|--------------------------------|------------------|
| SiO <sub>2</sub>               | 70.40 | Na <sub>2</sub> O                                | .508 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| Al <sub>2</sub> O <sub>3</sub> | 15.10 | K <sub>2</sub> O                                 | .282 | .850                           | 6.77             |
| Fe <sub>2</sub> O <sub>3</sub> | 0.76  | CaO                                              | .127 | Fe <sub>2</sub> O <sub>3</sub> |                  |
| CaO                            | 1.20  | MgO                                              | .018 | .027                           |                  |
| MgO                            | 0.57  |                                                  |      |                                |                  |
| K <sub>2</sub> O               | 4.63  |                                                  |      |                                |                  |
| Na <sub>2</sub> O              | 5.48  |                                                  |      |                                |                  |
| Loss on ign.                   | 1.86  |                                                  |      |                                |                  |
|                                |       |                                                  |      | Mol. Wt.                       |                  |
|                                |       |                                                  |      | 563                            |                  |



From this molecular formula the following glazes were tested and/or developed:

A2 - GMI

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .288 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .163 | .482                           | 3.84             |
| MgO               | .046 | B <sub>2</sub> O <sub>3</sub>  |                  |
| CaO               | .503 | .648                           |                  |

Batch

P-9229 - 328 parts

Colemanite - 89 parts

Results on glaze A2 GMI - fired at C/3

- (1) This test is the base glaze alone with no color added on the buff clay. It produced a clear glaze with some opacity due to a slight bubble structure plus the opacifying effect sometimes produced by B<sub>2</sub>O<sub>3</sub> glasses. On a red clay the opacity and bubbling is more noticeable, yet no more intense within the glass than on the buff clay, the contrast in tones being greater.
- (2) A typical cobalt blue was produced, rather opaque, probably due to the thickness of the glaze.
- (3) The chrome produced in this test a green, very opaque, as is expected from the opacifying effect chrome oxide has in most glazes.
- (4) The iron oxide addition produced the typical brown.
- (5) In this test the manganese dioxide produced an alkaline manganese color of brownish plum.
- (6) The rutile produced an opaque warm buff color, again very typical of alkaline borosilicate glazes.



- (7) Copper caused a slight fluxing action to the glaze and produced a typical bluish green which was almost transparent.
- (8) Nickel oxide gave a warm grey and seemed to make the glaze more opaque.

Industrial type glaze using perlite

Another glaze, A21 - GMI, was used in which .7 equivalents of sample P-9229 (perlite) was substituted for a commercial frit. This substitution produced the following formula:

|                   |      |                                |                  |
|-------------------|------|--------------------------------|------------------|
| Na <sub>2</sub> O | .254 | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> |
| K <sub>2</sub> O  | .141 | .425                           | 3.38             |
| CaO               | .468 | B <sub>2</sub> O <sub>3</sub>  | .                |
| MgO               | .050 | .35                            |                  |
| ZnO               | .100 |                                |                  |

Batch composition

|              |       |
|--------------|-------|
| P-9229 -     | 394.1 |
| Colemanite - | 47.6  |
| Dolomite -   | 1.8   |
| Zinc oxide - | 8.1   |
| Whiting -    | 15.9  |

Results on A21 - GMI

- (1) This base is much less opaque than test A2 - GMI. It should be more stable in reaction than the first glaze due to the greater number of fluxes interacting to give a glaze with a slightly higher SiO<sub>2</sub> ratio.



- (2) Cobalt carbonate produced a more intense blue than in A2 - GMI 2.
- (3) Chrome oxide gave a greenish brown due to the presence of ZnO in glaze.
- (4) The iron oxide produced a darker brown than in glaze A2 - GMI 4.
- (5) The manganese dioxide gave a deeper plum color and was more opaque than A2 GMI 5.
- (6) Rutile did not produce as opaque a glaze as in A2 GMI 6.
- (7) The copper color was more typical than in A2 GMI 7 and was more opaque.
- (8) Nickel produced a warm brown and was refractory in fusion making the glaze surface feel rough.

Comparison of perlite with feldspar, Cornwall stone,  
nepheline syenite in glazes containing an appreciable  
amount of these materials

The hydro separator overflow was used for these tests because of properties shown in fusion tests.

Glaze 100

100 X Batch composition

50 parts Cornwall stone

19 parts white lead

10 parts whiting

100 C (Substitution of hydro separator overflow perlite for

Cornwall stone by direct substitution in batch.

50 parts hydro separator overflow perlite

19 parts white lead

10 parts whiting



Glaze series 200

200 X Batch composition

Whiting - 30.0 parts

Colemanite - 102.8 parts

Buckingham feldspar - 238.4 parts

Flint - 88.8 parts

China clay - 5.1 parts

Copper carbonate - 4.0 parts

200 C Batch composition

Substituting hydro separator overflow perlite for

Buckingham feldspar directly in batch.

Whiting - 30.0 parts

Colemanite - 102.8 parts

Hydro separator overflow perlite - 238.4 parts

Flint - 88.8 parts

China clay - 5.1 parts

Copper carbonate - 4.0 parts

Glaze series 300

300 X Batch composition

Nepheline syenite - 34 parts

Dolomite - 6 parts

Colemanite - 4 parts

Flint - 6 parts



300 C Batch composition

Substituting hydro separator overflow of perlite  
for nepheline syenite directly in batch.

34 parts - hydro separator overflow perlite

6 parts - dolomite

4 parts - colemanite

6 parts - flint

Discussion of results of substitution of hydro separator overflow  
perlite for feldspar, Cornwall stone and nepheline syenite in glazes

100 series. Typical lead, stone whiteware glaze

Glaze 100 X produced a glaze with a bubble opacity which produced  
a whitish overcast to the glaze on the red clay test tile.

Fusion is good. Glaze had tendency to craze on this individual  
body.

Glaze 100 C produced a glaze with a bubble opacity which produced  
a yellowish overcast to the glaze on the red clay test tile.

(Probably due to iron content in material). Fusion is good.

Glaze had no tendency to craze as in test 100 X.

200 series. Typical borosilicate, feldspathic artware glaze.

Glaze 200 X produced a very good glass with a smooth fusion and  
slight boron opacity. Color produced by copper carbonate  
was a watery blue green semi-transparent, glaze showed  
tendency to craze in heavy areas.

Glaze 200 C produced a very good glass with smooth fusion and  
quite a boron opacity. Color produced by copper carbonate  
was more green than in 200 X and showed excellent texture and



color interest. There was less tendency to craze in heavy areas of application than in 200 X.

300 series. Typical artware semi-matt glaze.

Glaze 300 X produced a fair semi-matt glaze with a bubble opacity and a definite whitish cast on red clay tile. Good fusion is apparent but tile shows great deal of bubble opacity and some pinholeing. Crazing is quite evident on this body.

Glaze 300 C produced a fair to good semi-matt glaze with less apparent bubbling and a much greater opacity. The color is definitely yellow (caused by iron content of perlite). Pinholing is still in evidence as in test 300 X. Crazing, while not so great as in test 300 X, is still present.

#### GENERAL RESULTS OF TESTS

In general, sample P-9229, popped perlite and raw perlite, especially the hydro separator overflow material, compares favorably with feldspar, Cornwall stone, nepheline syenite, and a commercial frit.

In glazes containing Buckingham feldspar the maturing point of the glaze was somewhat reduced by the substitution of perlite for this material.

In glaze A21-GMI there was very little difference between the frit and P-9229 in their reaction toward the finished final results of the colored glazes.

This material (perlite) has produced glazes which show very favorable use for this material as a medium to high temperature glaze ingredient and produces fusion at a lower temperature than the average commercial feldspar, probably due to the lower ratio of alumina to fluxes and silica.



It is thought that a eutectic mixture occurs between perlite and colemanite which aids in the acceptance of a greater amount of  $\text{SiO}_2$  into the glaze.

The material when used in a glaze does produce a discoloration due to the iron content which is higher than the average and standard commercial feldspathic fluxes. This, however, can be nullified if colors are added to the glaze to hide or enhance the appearance and effect.

The fusion characteristics of the perlite leads one to believe that it could be successfully used as a body flux in stoneware or other colored clay mixtures or bodies to produce a low cost flux. This would be an advantage in utility wares where color is not too critical, but economy is critical.

This work was done for and under the supervision of the Oregon State Department of Geology and Mineral Industries during the time of July 1949 to this writing, May 12, 1950.

Respectfully submitted,

Charles W. F. Jacobs  
Ceramist

May 12, 1950



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES  
WASHINGTON

March 14, 1942

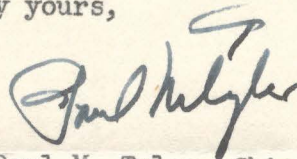
Mr. John Eliot Allen, Geologist,  
State Department of Geology and Mineral Industries,  
702 Woodlark Building,  
Portland, Oregon.

Dear Mr. Allen:

Thank you for your letter of March 9 submitting information with regard to the survey of mineral pigments available for camouflage purposes now being conducted by the Bureau of Mines for the Board of Engineers, War Department.

The names submitted are being tabulated and I will also be glad to receive the additional lists of producers of rocks and aggregates which you are compiling. Your cooperation is deeply appreciated.

Cordially yours,



Paul M. Tyler, Chief,  
Nonmetal Economics Division.

RECEIVED  
MAR 18 1942  
STATE DEPT OF GEOLOGY  
& MINERAL INDS.



General Paint Corp. (Factory) 1119 NE Irving St, Portland

W. P. Fuller (Factory) 2181 NW Nicolai Rd "

~~Pittsburg~~ Pittsburg Plate Glass (Factory) 1235 NW 15th Ave "

Miller Paint Co. 732 SW Tst St "

Rodda Paint Co. 1103 SE Grand Ave "

Duncan Paint Co. 4246 SE Belmont St "

S + S. Paint Mfg Co. 1944 NW Roosevelt St. "

### Clay plants

Columbia Brick Works 1320 SE Water St. Portland

Willamina Clay Products Co 0132 SW Mill St "

Washington Brick, Luml and 220 SE Anthony St "

Sewer Pipe Co

A. P. Green Firebrick Co. 677 N. Tillamook Ave "

many others throughout state.





## Mason mud notes on pigments from mason kerns

Definition: A pigment is a finely divided colored substance which imparts its color effect to another material when mixed with it or applied over its surface in a thin layer.

pigments are either organic, inorganic or synthetic (which may be combinations of either)  
inorganic include native earths, calcined native earths and minerals

definition: Levigation - to rub, grind or reduce to a fine powder

Mineral pigments: azurite, malachite, chrysocolla, orpiment, realgar,

cinnabar, lapis lazuli, ultramarine, verdigris, vivianite, glauconite

The covering or hiding power of pigments depends upon its refractive quality, fineness of the particle size, and depth of color. The size and shape of pigment grains is important for even and smooth film surface. With certain minerals such as Azurite, Malachite and Cinnabar, the broken crystals are not fine; the edges are sharp, angular, and irregular.

inorganic pigments include oxides, sulphides, carbonates, chromates, sulphates, phosphates and silicates of the heavy metals.

the oxide pigments such as the ochres, siennas and umbers are regarded as the most stable with respect to the action of air, light and moisture. In general sulphates, phosphates, and carbonates are stable.

Terre verte is essentially the mineral glauconite

Boston Paint Stone - stone ball resting on a ~~stone~~ stock block, a Colonial device used for grinding minerals/pigments in oil.

whiting - ground chalk or limestone

Iron pigments - natural

Yellow iron oxide pigments: Ocher is a form of limonite mixed with clay.

Ochers should have 17 to 60%  $\text{Fe}_2\text{O}_3$  (NO SHARP DIVISION BETWEEN SIENNA & OCHER)  
Siennas (raw) contain hydrated iron silicate in addition to the limonite  
and should analyze 40 to 75%  $\text{Fe}_2\text{O}_3$ .

XXXXXXXXXXXX



Mason mud note on pigments from maud kerns--2

Umbers - greenish brown when raw.  $\text{Fe}_2\text{O}_3$  content is 45 to 50%,  $\text{MnO}_2$  8 to 15%

Red oxides - largely hematite with  $\text{Fe}_2\text{O}_3$  content of at least 60%

Black iron oxide - magnetites, 90 to 95%  $\text{Fe}_3\text{O}_4$

Ocher has been mined in Calif in Calaveras, Napa and Riverside counties

Ref: Hodge, E.T., 1938, Marketing For Columbia River Hydroelectric Power,

N.W minerals, Calys of the NW, Vol IV.

*Lapis lazuli no longer used*

*IRON OXIDE COLORS. YEL. RED, BROWN ARE END- PRODUCT  
COLORS OBTAINED BY WEATHERING - VERY STABLE  
USED BY EGYPTIANS.*

*PROSPECTORS SHOULD USE SIMILAR PROCEDURE  
TO GRIND W/ 10X ZINC OXIDE - COMPARE W/ STD  
COMMAL DIG DIL IN SAME PROPORTION (WET & DRY)*

*SOFT. CLAY LIKE PIGS ARE BLUNGED, DRIED  
& GROUND*



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES  
WASHINGTON

February 26, 1942.

1352-7A  
Mr. Earl K. Nixon,  
Director,  
State Dept. of Geol. & Min. Ind.,  
702 Woodlark Bldg.,  
Portland, Oregon.

RECEIVED  
MAR 4 - 1942

STATE DEPT OF GEOLOGY  
& MINERAL IND.

Re: Pigments for camouflage

Dear Mr. Nixon:

Do not copy  
The Bureau of Mines has been requested by the U. S. Army to furnish a list of producers and possible producers of mineral pigments in the coastal areas. In the event of air raids, large quantities of certain classes of natural mineral pigments may be required for camouflage to hide cantonments and other areas which might be subjected to attack.

Your assistance in compiling this register would be deeply appreciated. The Bureau would like to receive the names and addresses of present producers, in your State of mineral pigments more or less similar in shade to the standard camouflage colors as shown on the enclosed color chart, and would also like to have the names of potential producers. "The pigments need not have the covering power and other properties demanded of pigments which are mixed in an oil vehicle as they would probably be applied on an asphalt surface. However, they should be granular and not have a fine body or texture, and in fact materials that would be valueless in commerce may be used so long as the color is uniform. Bright hues should actually be avoided. Some of the browns and reds, particularly the clay colors, might require firing and grinding to develop the desired color. On the other hand, coarse sand and fine gravel could probably be employed with no treatment whatever. Sand, clay, ocher, sienna, umber, hematite, magnetite, siderite, greenstone, slate, and almost any other minerals with dull earth colors have possibilities as camouflaging materials.

"It may take some time to search your records, but the Army requires this information promptly. I shall appreciate it, therefore, if you would furnish available information as to producers and potential sources of these materials as soon as possible. Then, as subsequent names or ideas come to your attention you might write again."

Cordially yours,

Paul M. Tyler

Paul M. Tyler, Chief.  
Nonmetal Economics Division.

Enclosure 2758807



Sylvania District, Gold Mountain Ridge and Slate Ridge. Nye County has deposits of feldspar at Bullfrog Hills near the original Bullfrog Mine; at Bare Mountain near Gold Center and in the Belted Range southeast of Oak Spring. Potash and plagioclase feldspars outcrop in Humboldt Canyon at Lakeview in Pershing County, and along the Trinity<sup>ir</sup> River west of Lovelock. Feldspar is also reported on the east base of the Bluewing Mountains. An outcrop of the soda feldspar albite occurs near the Red Rock Road eighteen miles north of Reno in Washoe County. In White Pine County feldspar is found in the Kern Mountains and in Walter Canyon on the<sup>ir</sup> southwest side, also in the southern Snake River district.

In the State of Washington most of the potential for obtaining feldspar lies in Chelan County. The Chelan hiway tunnel, Sec. 20, Twp. 27 N., Rge. 21 E.; the Trinity Tunnel, SE/4SE/4 Sec. 21, Twp. 30 N., Rge. 16 E.; Wenatchee Lake, Sec. 20, Twp. 27 N., Rge. 17 E. (on the north shore of the lake); and the Winesap property, Secs. 1, 2, 11, Twp. 26 N., Rge. 21 E., are typical. In Ferry County feldspar occurs at the Belcher Mine, Sec. 6, Twp. 37 N., Rge. 34 E. In Pend Oreille County feldspar is reported in rocks associated with the Kaniksu batholith in the Metaline quadrangle. In Spokane County feldspar is found in the granitic rocks in the MT. Spokane district.

In Oregon the potash feldspar orthoclase outcrops on Evans Creek in Jackson County near the common corner of Secs. 20, 21, 28, 29, Twp. 34 S., Rge. 2 W. Feldspar dikes up to eighteen inches thick cut a pegmatitic quartz body at the Hugo Silica Mine, three miles southwest of Hugo, Josephine County in the NE/4 Sec. 5, Twp. 35 S., Rge. 6 W. In Jackson County the Freeman Prospect in Sec. 27, Twp. 39 S., Rge. 1 E. has a dike composed of red-brown orthoclase and white plagioclase feldspar together with quartz. At the Sparks Mine, SE/4 Sec. 2, Twp. 35 S., Rge. 4 W., Jackson County a pegmatite dike contains both white



Orthoclase and some plagioclase feldspar that is probably albite. Pink orthoclase feldspar crops out in a quartz-rich vein at the Seven L. molybdenum prospect in SE/4 Sec. 27, Twp. 40 S., Rge. 1 E., Jackson County. Albite has also been reported at several localities in southern Coos County. A mass of pure white mineral crops out along a Forest Service road running along the divide separating Coos County from Curry County in Twp. 33 S., Rge. 12 W. Several similar occurrences are found north of this point along Johnson Creek.



March 2, 1942

Dr. G. F. Loughlin, Chief Geologist  
U. S. Geological Survey  
Washington, D. C.

Dear Dr. Loughlin:

I have just returned from the East and find your request of February 24th. Our geologist, Mr. Allen, has prepared a spot map, and he has dictated the following for your information:

"Re: Green rocks for camouflage in Oregon. Oregon is fairly well supplied with green rocks adjacent to accessible highways. There are at least three shades which might be of value: the light green for deciduous trees, the dark green for deciduous and some coniferous tree areas, and the very dark green to black for the dense conifer woods along the coast.

"I am enclosing a spot map of the State on which the various green rocks have been indicated together with their type. Light green rocks occur in the Clarno and John Day tuffs of the Cascades and central Oregon. Dark green rocks occur in the serpentines and peridotites of central and southwestern Oregon and the very dark green rocks occur in tuff breccias and shales of the coast range.

"If further information is required, we are prepared to give more or less exact localities where these rocks could be quarried."

Yours very truly,

Director

EKN:ac



UNITED STATES  
DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY  
WASHINGTON

February 24, 1942.

RECEIVED  
FEB 28 1942

Mr. Earl K. Nixon, Director,  
State Department of Geology  
and Mineral Industries,  
702 Woodlark Building,  
Portland, Oreg.

STATE DEPT OF GEOLOGY  
& MINERAL INDs.

Re:

Dear Mr. Nixon:

Interest is growing in the availability of rock material that may be useful in camouflage work. Green rocks are of special interest because their colors blend most readily with colors of vegetation. The Federal Geological Survey has been asked to provide this kind of information and it can do so insofar as the members are familiar with rocks of the different States, but members of your State Survey are doubtless familiar with areas in which none of the Federal geologists have worked, and your cooperation is therefore requested in providing information at your disposal.

As work in camouflaging progresses it may be that district engineers of the U. S. Engineers Corps will have their attention directed to your Survey as the most ready source of information and as the logical organization to make any local field examinations.

I shall be glad to hear from you at your early convenience and shall get in further touch with you whenever the situation warrants.

Sincerely yours,

G. F. Loughlin

Chief Geologist.

green tuff - "beryllium" district  
serpentine -



STATE DEPARTMENT OF  
GEOLOGY & MINERAL INDUSTRIES  
702 WOODLARK BLDG. - PORTLAND, ORE.  
PIGMENTS FOR CAMOUFLAGE

I have listed the colors of the Standard Camouflage color card, and have given brief discussion of each with reference to possible rock types from which pigment might be derived; to general areas in which these rocks occur; and in a few cases to specific quarry sites which might be opened up.

#1 Light Green

- A. Serpentine: Green serpentine which, when crushed, would make an aggregate or sand approaching #1 or #2 in color is found in unlimited amounts in southwestern and in central northeastern Oregon. It is fairly soft and crushes easily, and number of quarry sites on main highways or railroads are available. It slacks down somewhat upon weathering, but only over a period of years. Possible quarry sites near:

Canyon City and Prairie City, Grant County.  
Myrtle Creek, Douglas County.  
Hugo, Selma and O'Brien, Josephine County.  
Gold Beach and Pistol River, Curry County.

- B. Volcanic Tuff: Light green massive volcanic tuff which very closely approximates #1 in color can be found on and near the highway in southern Oregon. The green shades within each piece of tuff are somewhat variegated and mottled, but the general effect is light to dark green. Possibly quarry site near Trail, Jackson County.

Light fine-grained tuff in eastern Oregon is generally paler than #1. It is usually very fine grained with an even texture, and would require little grinding. Possible quarry sites near:

Post and Prineville, Crook County.  
Dayville, Grant County.

- C. Altered lavas: In several regions in the western Cascade Range alteration of andesitic lavas has produced pale to dark green rocks which might be of use. Possible quarry sites near:

Detroit, Marion County.  
Disston, Lane County.

#2 Dark Green and #9 Olive Drab

- A. Dark green flow breccia: Massive outcrops of a dense dark green to black flow breccia, with a texture of fragments about 1/16 to 1/8 inch; forms cliffs along the Wilson River highway and elsewhere. Possible quarry site near Tillamook, Tillamook County.

- B. Serpentine and peridotites: Many serpentines and peridotites when crushed will form a dark green aggregate. Possible quarry sites near:

Canyon City, Grant County.  
Selma, O'Brien, Josephine County.  
Gold Beach, Curry County.



### #3 Sand

A. Pumice: Much of the area east of the southern Cascade Range, between Bend and Klamath Falls is blanketed many feet in thickness with granular pumice which is light buff in color, varying between #3 and #8 in color. Pumice adjoins and forms the road cuts in Highways #58 and 97 for many miles, and could be taken from any of a hundred localities within the national forest. It is light in weight, easy to size (simple screening) and maintains its color under most conditions. Possible quarry sites could be located anywhere along federal highway #58 south of Crescent Lake, or along highway #97 between Bend and Klamath Falls.

B. Beach sand: Buff to darker colored beach sand adjoins the coast highway #101 in Oregon for much of its length. Darker shades are obtainable along the southern shores, while paler colors predominate north of Coos Bay. Sizing of the sand is rather uniform, ranging from 50 to 100 mesh, but averaging 80 mesh. Possible quarry sites near:

(dark colored) Marshfield, Bandon, Coos County  
Langlois, Port Orford, Curry County.  
Hammond, Clatsop County

(light colored) Numerous localities along coast between  
Marshfield and Astoria.

C. Tuff: Pale yellow tuffs are found along the valley of Rock Creek and the John Day River west of Dayville in central Oregon and along the western edge of the Cascade Range in the western part of the State. Possible quarry sites near:

Brownsville, Linn County.  
Dayville, Grant County.  
Prineville, Redmond, Deschutes County.

D. Sandstone: Much of the slightly weathered sandstone of the coast range are close to #3 in color. They occur from Coos County on the south to Clatsop County on the north. When iron oxide content is large, they approach #8 in color.

### #4 Field Drab, #5 Earth Brown and #7 Loam

Rocks of these colors could be either produced by grinding of some of the darker colored shales of the coast range, or from some of the valley soils. (See later)

### #6 Earth Yellow and #8 Earth Red

Weathering of Oregon Coast Range shales and sandstone also furnish soils of colors varying between these two. Since the weathered zone in this part of the country is excessively deep (sometimes up to 100 feet in thickness) amounts of the materials would be available at a great many places. These two colors would, on this account, probably be the most easily obtainable of all. They could also be obtained by the firing of prepared pigments. Most road cuts in western Oregon show rocks and soil approaching these two colors.

Soils of the Willamette valley are classified below according to their color and the rock type from which they have originated. These soils have been mapped



throughout most of western Oregon by the Soil Survey of the United States Department of Agriculture who have published maps in Washington, Josephine, Linn, Marion, Yamhill, Polk, Clackamas, Multnomah, Coos, Jackson, and Baker Counties, and of the Eugene, Grand Ronde Valley, and Hood River areas.

These soils have been mapped and named as follows:

Derived from basaltic rock:

Red soil on red sub-soil; Aiken.

Rusty brown soil on red-brown sub-soil; Olympic.

Derived from sandstone and shale:

Light brown soil on yellow brown sub-soil; Melbourne.

Gray brown soil on light brown sub-soil; Carlton.

Derived from old sediments:

Gray soil on yellow blue mottled sub-soil; Dayton.

Gray brown soil on mottled yellow brown sub-soil; Amity.

Brown soil on yellow brown gravel sub-soil; Salem.

Brown soil on yellow brown sub-soil; Willamette.

Derived from recent sediments:

Black clay on blue black gritty clay; Cove.

Dark brown soil on brown mottled sub-soil; Wapato.

Brown soil on heavier yellow brown sub-soil; Chehalis.

Brown soil on sandier yellow brown sub-soil; Newberg.

By referring to the type name, the color of the soil may be approximately determined.

John Eliot Allen, Geologist  
April 9, 1942



STATE DEPARTMENT OF  
GEOLOGY & MINERAL INDUSTRIES  
702 WOODLARK BLDG. - PORTLAND, ORE.  
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- C. Tuff: Pale yellow tuffs are found along the valley of Rock Creek and the John Day River west of Dayville in central Oregon and along the western edge of the Cascade Range in the western part of the State. Possible quarry sites near:
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  - Dayville, Grant County.
  - Prineville, Redmond, Deschutes County.
- D. Sandstone: Much of the slightly weathered sandstone of the coast range are close to #3 in color. They occur from Coos County on the south to Clatsop County on the north. When iron oxide content is large, they approach #8 in color.

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Rocks of these colors could be either produced by grinding of some of the darker colored shales of the coast range, or from some of the valley soils. (See later)

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John Eliot Allen, Geologist  
April 9, 1942



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Mr. Paul M. Tyler

Page 4.

April 9, 1942

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Brown soil on heavier yellow brown sub-soil; Chehalis.

Brown soil on sandier yellow brown sub-soil; Newberg.

By referring to the type name, the color of the soil may be approximately determined.

I hope that the foregoing will prove to be of some slight value to you.

Very sincerely yours,

John Eliot Allen  
Geologist

JEA:jr



March 9, 1942

Mr. Paul M. Tyler, Chief  
Nonmetal Economics Division  
United States Bureau of Mines  
Washington, D. C.

Re: Pigments for camouflage

Dear Mr. Tyler:

Mr. Nixon has asked me to reply to your letter of February 26,

There are three large factories in Portland producing paint pigments which would probably be available for camouflage paint production. These are:

General Paint Corp. (factory) 1119 N.E. Irving St., Portland, Oregon.  
W.P. Fuller (factory) 2181 N.W. Nicolai Road, Portland, Oregon.  
Pittsburg Plate Glass (factory) 1235 N.W. 15th Ave., Portland, Oregon.

There are several smaller concerns which have facilities for producing pigments and paints on a smaller scale. These are as follows:

Miller Paint Co., 732 S.W. First St., Portland, Oregon.  
Rodda Paint Co., 1103 S.E. Grand Ave., Portland, Oregon.  
Duncan Paint Co., 4246 S.E. Belmont St., Portland, Oregon.  
S. & S. Paint Mfg. Co., 1944 N.W. Roosevelt St., Portland, Oregon.

In the Portland district there are several brick and tile concerns which undoubtedly could make pigments with red colors produced by firing and grinding. These are:

Columbia Brick Works, 1320 S.E. Water St., Portland, Oregon.  
Willamina Clay Products Co., 0132 S.W. Mill St., Portland, Oregon.  
Washington Brick, Lime & Sewer Pipe Co., 220 S.E. Ankeny St., Portland  
A.P. Green Firebrick Co., 677 N. Tillamook Ave., Portland, Oregon.

There are a large number of other brick and tile concerns scattered throughout the State and we would be glad to furnish you their names if you think it worth while.

I am at present compiling a list of possible quarry localities in the State which might produce rocks or aggregates of suitable color characteristics. I have also asked the two district offices of this Department to forward data to



March 9, 1942

me concerning prospective areas and this will be sent to you as soon as it arrives.

Very sincerely yours,

John Elliot Allen  
Geologist

JEA:jr

P.S. Following are further manufacturers which have come in since writing the above letter:

Boysen, Walter N. Co., 903 N. Williams Ave., Portland, Oregon.  
Fisher-Thorsen Co., 2100 N.W. 22nd Ave., Portland, Oregon.  
Flexoid Paint Co., 4850 N.E. 97th Ave., Portland, Oregon.  
Gorton Co., 2455 N.W. 29th Ave., Portland, Oregon.  
Hollingsworth Co., 1383 N. Larrabee, Portland, Oregon.  
Laucks, I. F., Inc., 911 N.W. Hoyt St., Portland, Oregon.  
Nason, R. N. & Co., 2181 N.W. Nicolai St., Portland, Oregon.  
National Lead Co., 1211 N.W. Glisan St., Portland, Oregon.  
Pacific Laboratories, Inc., 10330 N.E. Marx St., Portland, Oregon.  
Portland Paint & Lacquer Products Co., 6629 S.W. 39th Ave., Portland  
Rasmussen & Co., 838 S.W. Second Ave., Portland, Oregon.  
Republic Paint & Varnish Co., 109 S.E. Salmon St., Portland, Oregon.  
Solastic Products Co., 129 S.E. Alder St., Portland, Oregon.



STANDARD CAMOFLAGE COLOR CARD

No.1 Light green



No.2 Dark green



No.3 Sand



No.4 Field Drab



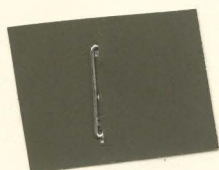
No.5 Earth brown



No.6 Earth Yellow



No.7 Loam



No.8 Earth red



No.9 Olive drab



*mollala chays*



STATE GOVERNING BOARD  
W. H. STRAYER, CHAIRMAN, BAKER  
ALBERT BURCH . . . . MEDFORD  
E. B. MACNAUGHTON . . PORTLAND

STATE ASSAY LABORATORIES  
400 E. 1 ST., GRANTS PASS  
RAY C. TREASHER  
FIELD GEOLOGIST



2102 COURT ST., BAKER  
HUGH K. LANCASTER  
FIELD ENGINEER

EARL K. NIXON  
DIRECTOR  
F. W. LIBBEY  
MINING ENGINEER  
JOHN ELIOT ALLEN  
GEOLOGIST

STATE DEPARTMENT OF GEOLOGY AND  
MINERAL INDUSTRIES

702 WOODLARK BUILDING  
PORTLAND, OREGON

March 6, 1942

Mr. Fay W. Libbey  
Chandler Hotel  
Marshfield, Oregon

Dear Fay:

I received your letter and Claire Holdredge says he will handle A.I.M.E. business.

We have a communication with the Bureau of Mines, requesting us to give data for large quantities of certain classes of natural mineral pigments which may be required for camouflage to hide cantonments in other areas which might be subjected to attack.

"The pigments need not have the covering power and other properties demanded of pigments which are mixed in an oil vehicle as they would probably be applied on an asphalt surface. However, they should be granular and not have a fine body or texture, and in fact materials that would be valueless in commerce may be used so long as the color is uniform. Bright hues should actually be avoided. Some of the browns and reds, particularly the clay colors, might require firing and grinding to develop the desired color. On the other hand, coarse sand and fine gravel could probably be employed with no treatment whatever. Sand, clay, ocher, sienna, umber, hematite, magnetite, siderite, greenstone, slate, and almost any other minerals with dull earth colors have possibilities as camouflaging materials.

"It may take some time to search your records, but the Army requires this information promptly. I shall appreciate it, therefore, if you would furnish available information as to producers and potential sources of these materials as soon as possible. Then, as subsequent name or ideas come to your attention you might write again."

I would appreciate it very much if you would spot, as near as possible, quarry sites on your return trip up the coast which might produce rock or aggregate of ~~coniferous~~ texture which might be of value in this way. The enclosed colors are requested as shown on clippings from color card which we have received.

*granular*  
I am also sending this to the local offices, and would appreciate their listing of quarry sites and sending them to this office as soon as possible.

Kindest regards,

John Eliot Allen  
Geologist

JEA: jr  
cc Treasher & Lancaster