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USE OF LOCAL NATURAL MATERIALS IN CERAMIC PROCESSES

By

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A Critique presented to the General Faculty
of The Claremont Graduate School in partial
fulfillment of the requirements for
the degree of Master of Arts

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Visiting Examiner

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Faculty Adviser

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Faculty Examiner

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I. Introduction

Enduring qualities of texture and color in pottery objects have come about when naturally-occurring minerals were used. Modern chemical processes filter out the so-called "impurities" in order to give the commercial ceramic producers a standard, dependable supply of materials, but the result is a product lacking in the aesthetic individuality which can be found in the natural combination of several chemical elements whose variations are used to advantage by the sensitive artist-potter. Through using these naturally occurring materials, it is possible for the artist-potter of today to duplicate or approximate pottery of the greatest periods of ancient pottery history. The range of colors, textures, and other ceramic qualities of ware made from these unrefined substances is as limitless as the earth and the imagination of the artist-potter.

There is a fair amount of information available on most other phases of this aesthetic-scientific craft, but the available literature on the phase of ceramics which deals with the discovery and preparation of local materials is extremely limited. The intent here is to show how to find suitable natural materials, and how to process and test them for use in making pots. Ceramic literature has kept pace with the technical developments of the field, but has been confined to the uses of constantly refined raw materials.

The present study is an original investigation into the possibilities of using native ceramic materials -- rocks, rock clays, and minerals -- found within a few miles of Claremont, California. It is intended to be of service to artist-potters and school ceramics classes where there is a need for correlation between cultural and scientific studies.

Among the desirable qualities one can achieve by using unrefined clays is that which stimulates the sense of touch. The subtle, irregular surface formed by a comparatively coarse clay on a sturdy shape creates a pleasant response, while a pasty clay body made from over-refined materials elicits little or no pleasant tactile reaction. Unforced textures, a varying play of color, and the sympathetic relation of glaze to body are desirable areas of harmonious sensations. The abstract beauty found in broken color results from the hand grinding of colorants. Variations in particle size is the physical basis for the interesting qualities of depth and richness obtained from such materials.

Nature offers much variety in textures and colors that are harmoniously related. By observing these native harmonies and contrasts, the artist-potter can more easily combine his local materials into a genuine expression of his environment. The type of material dictates the method of making and the design of the ceramic form. A sensitivity to this approach may be developed by a close study of rocks, shells, seeds, and other components of the natural world. The beauties inherent in such forms have an inspirational force which borders on the psychic--the area in which is found the impetus for creative energy.

II. Body Ingredients

(1) Finding Suitable Clays.

Clay deposits can be located with the help of local geologists, road workers, farmers, or well diggers. Some clays can be used as they are dug from the ground. A general rule for getting a more dependable clay body is to mix several clays together -- this method dilutes sticky clays with more sandy bodies and makes for a more workable mix.

(a) In a road cut, the best clay is often found from the grass roots to a depth of 12" to 24". This clay is usually high in iron content and will often fire red. Clay from an open field should be taken from below the topsoil to avoid excessive organic material.

(b) Good workable clay is often found in or around the edges of ponds or reservoirs that are drying up. Organic material sometimes makes it appear black, but it will almost always fire red.

(c) Some good clays are found in sedimentary beds exposed by washouts or road cuts. Such clays are often only a few inches thick but are of good, white-firing quality. The lime content is apt to be high, so the clay must be tested for excess calcium carbonate.

(d) Another source of white-firing clay of fine quality is decomposed feldspathic country rock. It occurs as great masses or as dikes in decomposed granite. This is the famous Chinese "petuntse". The inclusion of micas and iron minerals make for interesting colors and textures. Kaolins and china clays are formed by decomposition when these rocks have disintegrated. This material, washed and sieved to 80 mesh, will help a body to vitrify at a surprisingly low temperature.

(e) In volcanic regions, highly plastic clays are formed by the decomposition of volcanic ash, tuff breccia, scoria, and other fine grained volcanic rocks. These clays are useful as both body and glaze ingredients because of their plastic character.

(2) Making Clays Usable.

Naturally occurring clays are often contaminated with rocks, leaves, or roots. Methods of preparing clays for use depend largely upon the sort of foreign matter in them. One general rule to follow is to take the clays from near the surface when possible -- this will take advantage of natural weathering. However, the addition of ordinary vinegar in the amount of one tablespoon to a gallon of warm water in making a mix will hasten the plasticizing of the clay mass and make it suitable for use quickly. It has been found that by adding vinegar to clays from deep workings, and to clays from commercial suppliers, the aging time can be reduced to almost zero. It is better to add the vinegar after the mix has been sieved, because of the flocculating or thickening action of the acid.

(a) Soak the lumps of clay in a bucket of water. Stir occasionally with a stick until all lumps have gone, pick out the larger rocks, sticks, and leaves.

(b) Sieve this sloppy mix through hardware cloth screens and window screen to get out the smaller rocks and coarse sand. Finer sieves can be used if desired. Stir in the vinegar after the sieving is done.

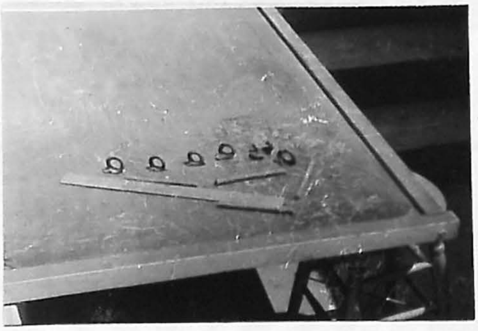
(c) Pour this mixture, which can now be called "slip", onto boards, a brick or cement floor, or into plaster batts, so that much of the water will evaporate. When it has dried to a consistency where it can be picked up as a mass without stickiness, it is ready for smearing or kneading.

(d) Smearing on a solid surface such as a table top or marble slab is a good way to work the body to an even texture. Store the body in a covered container to promote aging and reduce drying.

(e) If larger quantities are desired, one can make a blunger from salvaged machine parts. A mixer of this sort will handle two to three hundred pounds of wet mix. A mixer can also be made from bakery dough mixers or restaurant kitchen mixers.

(3) Testing Clays for Use.

Defects of a clay may be determined easily by means of simple tests. Some clays may be too "fat", others too "lean". Some will crack too easily, some will shrink too much. As has been noted before, a mixture of several clays with different qualities usually results in a very suitable body.



(a) Roll a small amount of the clay into a stick about the size of a crayon. Bend it into a ring with about a one inch hole. If the clay cracks, it needs an addition of a more plastic clay.

(b) Some clays are too plastic -- they will often crack on drying or they will shrink too much. If this happens, add a more sandy, or a lean or open clay. Mark the samples for shrinkage measurement. Over 6% drying shrinkage can be considered excess.

(c) If the clays are taken from a formation known to be of sedimentary marine origin, they may be tested for excess calcium carbonate by pouring a few drops of hydrochloric acid on a fragment. If a large amount of bubbling takes place, the clay should not be used.

III. Glazes

Since most school ceramic classes and non-commercial potters do their work at relatively low kiln temperatures -- cones 07 to 04 -- glazes have been developed to mature satisfactorily within these heat ranges. It has been found that if the same clay which forms the body of the ware is used as a main ingredient in the glaze, better adjustment between glaze and body will result. Borax or boron minerals can be mixed with clay in certain proportions to produce a wide range of vitreous coatings.

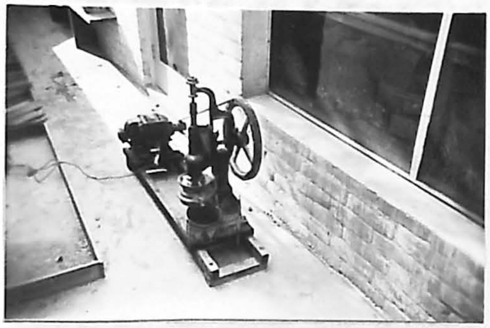
Another low-fire glaze used for centuries is the galena (lead sulphide) and clay combination. This must be tested rather carefully, in order to get a balance between the silica content of glaze and body. The sulphur in galena sometimes affects adversely the underglaze colors; larger particles may cause cratering in the glaze surface.

For higher temperature glazing the use of vegetable ash is recommended. This simple material in the hands of an imaginative artist-potter can result in the most satisfying sort of creative achievement.

(1) Preparation of Natural Glaze Material -- Rock.

(a) Pick clean, unstained material from the workings, using a wrecking bar or pick. If samples are taken for testing, mark the spot with a tagged stake and record data in a notebook. Many rocks found will fuse at a rather low temperature. Fluxes, such as borax, galena, or wood ash, can be added to lower or widen the melting point.

(b) Break into small pieces for reduction to $\frac{1}{2}$" or less in a hand crusher. Many rocks can be hammered to dust with an ordinary hammer and then fine-ground in a mortar.



(c) Hard rock can be powdered to 100 mesh easily in an inexpensive power fine grinder.

(d) Rock and colored glass can be finely ground in an old coffee mill of this sort if the hardness is 6 or less (Moh's scale). For rougher or longer service, the face plates can be hard-faced by welding.

(e) The jar or ball mill is an inexpensive form of crusher-grinder. Make certain the pebbles are varied in size and that the speed is such that there is both a cascading and a rolling action.

(f) Sieve all glaze materials through 80-100 mesh sieves. Re-run unclassified material through mortar or grinder until it passes sieve; dry in sun or on plaster batts for dry measurement.

(2) Preparation of Natural Glaze Material -- Wood Ash.

(a) Bark and twigs give the best ash for use in glazes. The more mature wood is usually higher in silica than the young growth. Burn the vegetation on firebrick, sand or gravel, if possible. Take only the upper part of the ash from a pile burned on soil. This will avoid impurities such as unwanted iron oxides and other minerals found in soils.

(b) Soak the ash in a pail of water and scrape off the scum of charcoal and other residue. Stir the whole mass and decant quickly into another pail, leaving rocks and heavy waste in the first pail. Remove the soluble alkalies by changing the water until tasteless. The purified ash will settle out easily. Dry on plaster batts and store for use.

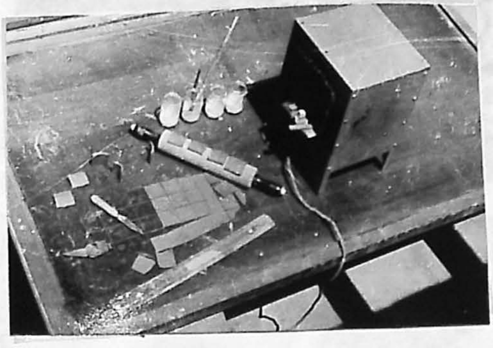
(3) Testing Glaze Ingredients.

Probably the most important thing to achieve in the testing of ceramic glaze materials is the correct proportion of fluxes or melting agents to the non-fluxing or stable materials. When a fluxing material is found, such as ash, galena, or a borax mineral, it should be tested in a wide range of proportions, because too much or too little will cause a high melting point. The right amount, determined only by testing in a kiln, will cause the materials to flux at the lowest possible temperature. This correct combination is called a "eutectic".

(a) The best form in which to measure materials is the dry state. A simple balance such as a child's toy or postal scales will do for small amounts. Some sort of gram scale is available from a chemical laboratory or druggist. Use the same measuring system for working batches as for testing.

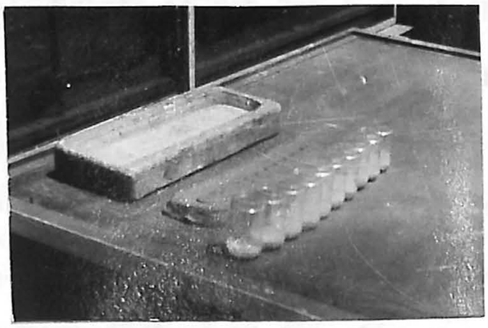
(b) Another way to measure is the bulk dry method. Such kitchen tools as measuring spoons, cups, and pans are satisfactory. Again, if this method is used for testing, use it also for working batches.

(c) Muffin tins, bottles, or cups can be arranged in the order needed for the particular test being made. Here three mixes of clay are being tested with four mixes of glaze material.

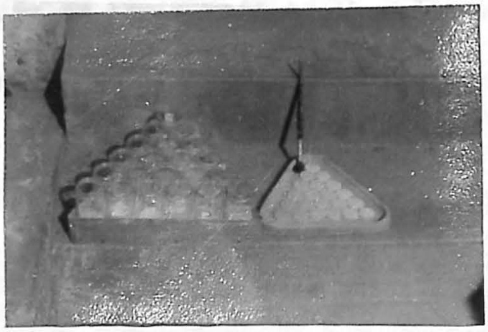


(d) Little chips of clay can be used for testing glazes if they are rolled out, cut, and curved so that flow characteristics of the melted glaze may be observed. Number the damp chips on the back with a nail, or mark the bisque with an underglaze pencil or a liquid oxide.

(e) Butter molds make good testing forms, as they are easily handled, glaze flow characteristics are easily seen in the embossed designs, and a hole can be punched in one edge so that the piece can be hung up for reference.



(f) A more permanent form of test is the monaxial mold. In this, a plaster mold is cast from a sample test piece made in clay with the number of steps wanted. Any number of monaxials can be made by the pressing process.



(g) For testing mixtures of three materials a triaxial mold is prepared. The mixture containers are arranged in the same order as the embossings on the triaxial. The number of bosses on the triaxial depends on the number of steps wanted in the testing. Six bosses will give a 20% interval of amount.

(h) A triaxial can be used for a wider range of tests by cutting off two of the sides to form a 60 degree angle. This makes a hexaxial plaque.

(i) Test rings are used for discovering the expansion or contraction characteristics of a glaze. After bisque firing make a cut $\frac{1}{4}$" wide in the ring, paint the glaze on the inside of the ring. If the ring contracts after firing, the glaze is crazing. If it expands, shivering is taking place.

(4) Treatment for Crazing and Shivering.

Consult a good reference[1] on ceramic glazes for study on the correction of these defects. If the chemical nature of the material is not certain, the following information may be of use. If crazing takes place, one may add sand or a more sandy clay to the body. The body may be bisque fired higher than the glaze firing, or one may add up to 10% borax or boric acid to the glaze. If shivering occurs, one may add a more plastic clay to the body.

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[1] C. W. Parmelee, Ceramic Glazes, Urbana, Illinois, 1947.

IV. Finding and Processing Ceramic Colorants

Virtually the entire spectral range of colors in ceramics may be obtained from two the most widely distributed minerals in the earth -- iron and copper. For the complete story on the historical use of these versatile colorants, refer to "Chinese Ceramic Glazes" by A. L. Hetherington.[2]

(a) Iron oxide, the most common colorant, is the cause of most reds and yellows in rocks and soils. Highly colored orange-yellow masses in a road cut or gravel bank indicate a high concentration of iron oxide. These can be dug out, hammered to a fine powder, and wet-sieved to remove coarse particles. Further preparation is not essential, but if the resultant powder is calcined to red heat in a kiln, it will give more uniform results.

(b) Another source of iron minerals is almost any stream bed. Recovery of the concentrate is made by the method used for recovering placer gold. Small amounts can be obtained by washing the fine sands in an old iron pan or by settling and decanting the lighter sands from one container to another with water. Not only iron minerals, but many other interesting heavy minerals can be recovered in this way.

(c) Beach sands are a source of zirconium, titanium, and iron minerals. These concentrates are recovered in the same way as the stream sand minerals. They may be calcined to remove any sulphides present as pyrite (fool's gold).

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[2] A. L. Hetherington, Chinese Ceramic Glazes, Commonwealth Press, LosAngeles, California, 1948.

Copper is found widely distributed in the United States. Almost every amateur geologist has samples and can tell where to find more. The native copper carbonates, malachite and azurite, green and blue in color, are suitable substitutes for the synthetically produced colorant. The copper silicate, chrysocolla, contains both copper and silica -- this mineral should prove a useful source of color for the experimenter. For reduced copper red glaze formulae, see any good reference on ceramic glazes.

For other, more reliable colorants, it is often necessary to resort to commercially prepared colors. One can get inexpensive oxides at hardware and paint stores, or one can use some of the colors found in poster paints. However, through experimentation with both oxidizing and reducing kiln atmospheres, an extremely wide range of color can be obtained with iron and copper minerals.

V. Some Materials Tested by these Methods.

It was discovered, in the course of this study, that all of the ingredients used in many commercial pottery bodies are mined within a forty mile radius of Claremont, California. The purpose of this study, however, was not to use commercially prepared minerals but to locate, extract, and prepare pottery materials for studio use.

Owing to the overwhelming number of ceramic raw materials discovered in the course of field trips and discussions with local rock collectors and amateur geologists, it was necessary to limit the experiments to a few readily recognized and easily prepared materials.

(1) Clays and Body Ingredients.

Many local clays were tested singly and in several mixtures. The different mixtures were made to vitrify at temperatures from cones 04 to cone 5. The following body ingredients were found to be outstanding in their ceramic qualities and potentialities:

(a) PEGMATITE: A local rock quarry furnished a semi-decomposed rock altering to kaolin which closely corresponded to the famous Chinese "petuntse". Mixed with more plastic clays for the throwing wheel, it formed a highly vitreous body at cone 05. It contained inclusions of biotite micas which gave "hare's fur" streaking to the low fire matt glazes. The material was washed and sieved to 80 mesh before mixing with other clays.

(b) TUFF BRECCIA: This volcanic rock occurred in great masses, forming greenish-white outcroppings in local road cuts. It was first sieved as a dry dust, but when ball-milled, broke down completely to a very plastic clay of high shrinkage. As a body ingredient, it added to the plasticity and fired density of the ware. Used 50-50 with orange wood ash, it formed a soft olive-green glaze of high viscosity and great durability at cone 10. An analysis of this material showed it to be almost identical to a similar analysis of Albany slip clays.

(c) DOLOMITE: Local dolomite was substituted for the lime fluxes, calcium and magnesium, in some test bodies and glazes. Used in balanced proportions it was satisfactory. A body made up of 50% dolomite ruptured in an 05 kiln. This material would have commercial possibilities if the chemical constituents were constant. Considerable tonnage was observed in Cucamonga Canyon, Upland.

(d) MONTMORILLONITE: This bentonite clay, found in the Hannawalt quarry, Claremont, is an alteration product of the decomposing feldspars. Several pounds of the comparatively rare clay were taken in a few minutes from the formation. Washed and sieved, it was a very satisfactory substitute for commercial bentonite.

(e) CORNISH STONE: The acid pegmatites of San Diego County were ground and tested as a local variety of Cornish stone. The high content of tourmaline and iron oxides caused staining of white bodies, but the pyrometric reactions were the same as the imported variety. Test glazes made from this material matured at a lower temperature than those with a similar quantity of feldspar, but the high iron content ruled out the local Cornish stone from further competition with the imported pegmatite.

(f) FELDSPAR: Much feldspar occurs locally as dikes in decomposed granite. It tested favorably with commercial spar with the exception of a high iron content which stained the body. In glazes it caused a yellowish cast on white bodies, but was not noticeable on red or other dark bodies.

(g) Other materials tested: Local ACTINOLITE was substituted for talc, and except for the irregular iron staining, caused good vitrification at cone 05. ALBITE, a soda-feldspar, worked well as a test body ingredient. FLUORSPAR, from Azusa, was tried as a material to increase translucency in white bodies, but caused bloating to an unsatisfactory extent. Samples of PYROPHYLLITE, from Mesa Grande, were substituted for talc in body specimens and seemed to cause good vitrification at cone 05. None of the foregoing materials were found in sufficient quantity to warrant further testing as commercial deposits.

(2) Glaze Materials Tested.

An effort was made to find local borax materials suitable for lead-free, low temperature glaze materials. An old borax works nearby supplied material of sufficient commercial possibilities to warrant extensive testing. Other glaze ingredients were found in profusion. Some of these were tested at length, but most were found to contain so much iron as to look quite similar in the test pieces.

(a) COLEMANITE, ULEXITE, and HOWLITE were the borax minerals tested. The first is commercially available for leadless glazes, hence was tested in a limited way. The second is an interesting mineral but is not available in much quantity. The third, HOWLITE, was found to be a natural frit containing calcium, boron, and silica. In all tests, under conditions of rapid cooling, mixtures with almost any colorant, and almost any clay base, it proved to be a tough, stable, and altogether satisfactory glaze material. The intention is to explore it further for its commercial possibilities. It is this sort of discovery that makes a project such as this a most interesting and valuable experience.

(b) VOLCANIC ASH, PUMICE, and PERLITE were tested as glaze materials to replace feldspar and part of the silica. Most batches were made of 50% ASH with HOWLITE as the flux. Colorless glazes could not be obtained at any temperature because of the iron in the volcanic materials. Excellent coverage and flow were to be had from these materials.

(c) TOURMALINE was tried as a self-contained glaze because of its boron content of 10%. It refused to mature at cone 10, but with the addition of tuff breccia and borax minerals it fused to a deep brownish glass at much lower temperatures.

(d) LEPIDOLITE was tested because of its lithium content. It caused higher brilliance in small quantities, seemed to reduce crazing on porous bodies, and in amounts up to 20% gave fine crystalline matt glazes with HOWLITE as the flux. Manganese present gave a slight purple cast to the glass. This material is available in rather large quantities and is used in the glass industry.

(e) GALENA is a rather common mineral which should be experimented with to a large degree, as it matures at a rather low temperature and is non-poisonous. It can be dusted onto green clay ware and seems to work well on terra cotta bodies. The sulphur is driven off in the kiln, and if the material is sieved to 80-100 mesh, will not cause craters or excessive pinholes in the surface. This glaze was one of the most commonly used in ancient times and much literature is available on its use.

(f) WOOD ASH was used as described in several good references but requires temperatures of cone 7 and above for maturity. It is a most pleasing and durable glaze ingredient. Potters are urged to experiment with this common material. With local TUFF BRECCIA a fine olive-green celadon-like glaze was obtained at cone 10 -- the mixture was 50% BRECCIA and 50% ORANGE WOOD ASH.

(3) Colorant Tested and Used.

The iron-oxide minerals HEMATITE and LIMONITE were tested separately and gave colors of the iron-reds and yellows. Under reducing conditions, in combination with WOOD ASH and BRECCIA, the iron gave a green with a distinct bluish tinge. Under oxidizing fire the same glaze was olive green. At cone 05 the HEMATITE retains its red color but changes to yellowish brown at higher oxidizing temperatures. Experiments should be conducted with the local iron minerals under both conditions for wider color ranges.

Copper minerals are often combined with iron and silica in their natural state, hence it is best to break up the ores and pick out the purer pieces. AZURITE and MALACHITE (the natural carbonates of copper) were tested and gave good greens under oxidizing conditions. Interesting reddish-brown colors resulted from tests under reducing conditions. The brown color was due to iron inclusions.

CHRYSOCOLLA, a copper silicate mineral, worked better than the copper carbonates as a colorant for copper reds under reduction because of its lower copper content. It cannot be depended on for deep greens for the same reason.

PYRRHOTITE (nickeliferous) was tested because of its nickel content. The sulphides were driven off in the kiln, and the resultant color was a brown glaze with a greenish tint.

Black beach sands yielded ILMENITE, an iron-titanium oxide mineral. This was used as a texture-colorant over light bodies to give an interesting black sand background for designs applied over it with white clay. It was put on the freshly thrown piece and adhered well during drying and firing. EPIDOTE and GARNET were tried as colored glazes in themselves but were subject to crazing without the addition of clay or a borax flux.

VI. Conclusions

The attempt has been made to show ways in which anyone can find and use common materials for making pottery of distinction. Those interested are further encouraged to experiment with homemade kilns and to try kitchen materials for their glazes and paint materials for their colors. The references given are of general interest and should be available throughout the United States. Reference is also made to certain periodicals which contain formulae and processes for more advanced experimentation.

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