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How to Use Local Clays in School Ceramics

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HOW TO USE LOCAL CLAYS
IN SCHOOL CERAMICS

by

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INTRODUCTION

Scope of the Paper

The object of this paper is to assist the ceramics teacher in experimentation with local clays. The use of local clays has a definite esthetic value, especially when the teacher makes use of all of the instructional aids associated with the geology and industrial-ceramic aspects which may be incorporated with field trips and the experimentation and processing necessary to make the clay useful.

The fact that clay is of native origin will carry almost as much significance as the student's own pride in the pottery he has made, especially if he has located the deposit and aided in the digging and processing of the clay.

Sources and Method of Treatment

A thorough investigation was made of the following sources: ceramic engineering text-books, periodicals of the ceramic industry, pottery text-books, theses and papers from the libraries of the University of Washington, University of Oregon, and Central Washington College of

Education; plus technical literature from the Department of Conservation and Development, Division of Geology, State of Washington; and the University of Washington Engineering Experiment Station. The author's experience and training in the fields of pottery, geology, mineralogy, organic and inorganic chemistry, and in the teaching of chemistry and science were correlated with the above information.

The author has collected that information not normally found in ceramic text-books and has written it in such a manner that it may be used by a relatively inexperienced person. An investigation was made of pottery text-books and it showed such information as being very general or wanting. A personal study of the engineer's approach to the problem of preparation and utilization of raw clays was then made in the above-named libraries, plus the author's own library of chemistry, mineralogy, geology, and information on chemistry of the soil. This information was then condensed and written in the light of pottery and its problems of small production, small capital, and a scholastic approach.

During the past years, while on geology excursions with Mr. Beck and on personal exploration of the area, clay deposits have been sampled and their properties tested. Much of the instruction and advice has come from personal experience and the application of this training to the problems confronted in like situations and to the parenthetical problems which will arise when an inexperienced person attempts to make use of this information.

Much of the information contained in this paper cannot be attributed to any person because the information and methods are well known in the engineering and professional branches of ceramics and have been reported from time to time in ceramic periodicals; however, where it is felt that an author has contributed an original statement, notations are made.

Tests which are mentioned in this paper have been carried out by the author in the ceramics laboratory for the purpose of improving qualities of clay. Only those methods which have proven to be satisfactory and within the range of the equipment, time, and economy of school laboratories have been advised.

Chapter II

GENERAL INFORMATION

Definition and Source of Clay

What is Clay

Clay is a soft earthy mixture containing hydrous aluminum silicates and usually silica and organic material along with compounds of some or all of the following: iron, magnesium, sodium, pottasium, titanium, manganese, calcium, and traces of others. Clay is plastic when wet and hard and brittle when dry. Some shales are clays that have been hardened because of pressure and require some processing before they regain the properties of clay.

The Geology of Clay

The eastern part of the United States is geologically very old so the rocks have had millions of years to rot and change to clay. In many places the clay may be had almost any place and the problem is to choose the best one for the purpose. This is not the case with most western localities where the rocks are "young" and the formations of clay-producing materials relatively new. Many of the good deposits have been under pressure during changes in the surface such as lava flows, upheavels, and folding of vast areas. Pressure and minerals carried by water have formed shales which would be good clay except for the cost of mining and grinding, plus the undesirable fluxing action of such minerals as lime. Other deposits of rock flour and silt have not undergone enough disintegration and leaching to make good clay.

How Nature Prepares Clay

Clays originally were part of rocks such as feldspar, gneiss, or sandstone which contained aluminum silicate material. Rocks are broken down by erosion due to streams, glaciation, earth movements, and weathering. Soluble materials are leached out by carbon dioxide and organic acids carried by water, leaving behind the insoluble clay formations. Almost all clay deposits will vary, especially those which show bedding. Some deposits may have only scattered bands of useful clay while others have many. A homogeneous mixture may be more desirable than any one layer due to excessive richness in one and poorness in another.

Residual deposits. Residual clay is formed in its present location from parent rocks. High grade residual clays such as kaolin have been formed by the rotting and leaching of high alumina containing materials such as feldspar, granite, and gneiss. If the parent rocks have high percentages of other insoluble materials only partly decomposed, the clay will be of a poorer grade.

Types of sedimentary clays. Sedimentary deposits are those where the material has been transported from other places by wind and water and may be residual due to decomposition after the deposit was formed.

Alluvial clays are deposited by streams which have picked up clay and other materials and moved them along until they settle out as the water slows down. Alluvial clay beds will usually have marked stratification or layers due to depositing of heavy materials during high water and finer materials during other seasons. These clays may contain much undesirable sand.

Marine and estuarine deposits formed in seas and at the mouths of rivers usually contain lime and shells, and the clay is an end product of their decomposition. The estuary appearance will be somewhat the same as alluvial deposits with usually more uniformity in the clay materials.

Lacustrine deposits result from materials settling out of water after it has reached the still waters of a lake. The appearance will be similar to estuary deposits with probably more fossil leaves and other debris. Many of these deposits contain considerable iron.

Eolian clays are formed from dust and silt which have been deposited by the wind and have undergone decomposition and leaching.

Glacial clay is formed by the disintegration of rock flour and other materials deposited by glaciers. The quality will depend on parent rocks.

Refractory clays contain considerable amounts of materials such as alumina and silica which do not fuse (melt) until fired at extremely high temperatures.

Clays Commonly Used in Pottery

Ball clays are very strong, plastic, slightly refractory, and when used alone have a tendency to crack and have a fairly high shrinkage. Ball clays are used with china clay and other low plastic clays to improve the plasticity, strength, and shrinkage of the mixture. Ball clays are used in some glazes.

Kaolin or china clays are highly refractory, white firing, and relatively free of fluxes and coloring agents. Kaolin is low in plasticity and requires the addition of ball clay, feldspar, bentonite, and fluxes for pottery use. It is used in some glazes.

Fire clays are very refractory and of medium plasticity. They require the addition of ball clay and fluxes for plasticity and low vitrification.

The Chemicals in Clay

The three basic chemicals of the hydrus alumina silicates (basic clay substance) are silica, alumina, and water. These three chemicals make up a great portion of the crust of the earth, but it is only when they have decomposed from rock, sand, and other materials that the basic clay is formed. Pure clay or kaolin is rare considering the quantity of impure clays, primarily because so many other chemicals are associated with the parent rocks of clay.

Alumina

Alumina makes up about forty per cent of kaolin and is found in smaller proportions in the impure clays. The function of alumina in clay is quite important. It is responsible for much of the refractoriness (resistance to melting when fired) of clay, and also for much of the plasticity and workability of clay.

Silica

Silica is an essential component of clay. It is present in two forms -- as free silica or quartz in sand, and in combination with other elements in the form of silicates such as feldspar, mica, and kaolin. Sand (silica) lessens the plasticity increasing the porosity, and thus improves drying and lessens shrinkage. "It is not an active flux although when finely ground and mixed with kaolin, it lowers the fusion point." (8:20)

The addition of silica (flint) to the body or glaze will reduce crazing. Gritty substances do not always indicate silica sand because feldspar, rock flour, and iron compounds may appear as sand; however, their presence may give the advantages of silica in working and have another effect in firing.

"Clays containing a high percentage of very finely divided sand (silt) may absorb considerable water in mixing but show a low air shrinkage." (17:)

Water

Chemically combined water (water of chrystalization) which is part of the structure of crystals, such as kaolin, is driven off during firing of the clay. Pore water is that water which adheres to the grains of clay even though the clay is air-dried. Heating above the boiling point removes pore water. Water of plasticity is that water which is needed to make clay plastic.

Iron

Clays which contain iron usually are other than white. Unless iron is bleached with lime or fired without ample air supply, it will give a red tint or color to the ware depending upon the concentration and temperature of firing.

Lime

"The hydrochloric acid test is used to indicate presence of lime in clays, for lime carbonate ($CaCO_3$) is the most common carbonate present." (22:41-2) Ware containing lime may slack or rot due to absorption of water and carbon dioxide by the quicklime formed by firing. "If the quantity does not cause excessive fluxing action and a short vitrification range, clays containing finely-divided lime can be used for common structural wares because the lime unites with the clay to form stable calcium silicates. However, the color of red-burning clays will be bleached, and it is difficult to produce vitrified wares. Pebbles of limestone cause 'poppers' and disintegrated ware." (22:41-2)

"Lime carbonate readily effervesces in cold hydrochloric acid." (22:42) And there is a heavy precipitation of lime in sulphuric acid.

"The rate of vitrification may be undesirably rapid if as much as five to ten per cent of lime is present, particularly if accompanied by other fluxes." (8:22)

Magnesia

"The action of magnesium oxide is similar to that of calcium oxide but it is less effective as a flux and a bleaching agent." (22:42)

Other Minerals

Soda, potash, and lithia are alkalies which act as fluxing agents and promote vitrification. Feldspars are a source of alkalies.

Titanium, rutle, and ilmenite which are present in small quantities in many clays act as fluxes.

Traces of many minerals ("trace minerals") are found in clays, but the quantity is so small that their presence is of little significance.

Organic Matter

Organic matter is quite common in surface clays and sedimentary type clays. Organic acids may be present in any type of clay and assist in the decomposition of clay materials and in producing plasticity. Burning of organic material accounts for some of the loss in weight (ignition loss) during firing.

Characteristics of Clay and How to Alter Them

The characteristics of clays are many and varied. It is the part of the potter to select, discard, try, and improve these characteristics to fit his needs. Through the centuries clay has been and still is an inspiration to those who work it, for to the artist, the potter, the scientist, and the engineer a new clay is a new medium of expression, a new texture, a new color, a new feel, a new challenge unlimited in possibilities.

Original Properties of Clay

Color. The colors of raw clay are of little definite indication of their fired color since some light colored clays will fire red and other clays, especially those with organic matter, may be quite dark yet their fired color will be white. Through experience and experimentation, an acquaintance with local clays will make a raw color analysis fairly certain for a particular locality. Iron, organic matter, and manganese may be present in different proportions and have a definite effect on the fired color of the clay. Other materials, such as lime, may have a bleaching effect.

Hardness

Clays will vary from a powdery material which will make a workable clay almost immediately to hard shales which have to be ground before they are of any use. The hardness of a clay indicates very little as to whether the clay is usable or not. For small production, the inconvenience and expense of grinding may eliminate the use of some shales.

Slacking

Slacking is the ability of clay to disintegrate in water. The slacking test gives some indication as to the characteristics of the clay. If the sample disintegrates immediately when placed in water, it probably contains sand or some other nonplastic material and may be a lean or weak clay.

"The resistance to softening in water of a chunk of the original clay or shale depends not only on the amount and fineness of the pore space, the fineness of the clay grains, and the amount of plastic material present, but also on the compactness and uniformity of the structure resulting from its geologic experience (pressure, leaching, and solidification of lime)." (22:43)

Hard clays or shales may break down into smaller chunks or show no signs of disintegration. Grinding may render them useful, or if they slack only partially, they may be used as grog to lessen dry shrinkage of other clays. Hard clay and shales do not act as grog in firing because they shrink at their own rate on firing.

Texture

The texture of clay is due primarily to the size, shape, and properties of different gritty components of clay. The texture runs from the rough sandy clays and shales to the very fine grained plastic clays and silts. The sandy clays can easily be distinguished by their appearance. Grit can be easily detected between the fingers, by scraping with a knife, or by checking a piece of clay between the teeth. Fine grained silts and clays will have little or no grit when tested by this method. Fine grained clays will be more plastic than those with larger grain; they also dry slowly, crack, and have a high shrinkage.

Wet Properties of Clay

Wet properties or pre-firing characteristics of the clay must also be taken into consideration.

Plasticity

Plasticity is the ability of a clay to respond to forming and to holding the shape given it. The different degrees of plasticity are from the very plastic, the waxy, the sticky, and the medium plastic to the nonplastic sandy clays. There is no practical method of measuring plasticity because of the variety of factors which contribute to varying conditions.

Plasticity is increased by reducing the grain size, removing sand and other nonplastic materials, ageing and weathering, and kneading. "Clays are more plastic in the neutral and flocculated condition than the deflocculated." (23:85)

Grinding the clay to a finer grain size increases the water held by the clay and lubricates the grains. Smaller grains have more of a colloidal action where the grains are forced apart by electric charges carried by the grains. This also prevents friction and allows the clay to flow easier. "Without the non plastic portion, it would be impossible to shape, dry, and fire commercial wares because of excessive stickiness, high content of water, high shrinkage, difficulty of removing water, and a great tendency to crack." (23:101)

Strength

The strength of wet clay is its ability to hold together and retain shape without sagging or cracking. The strong clays usually contain high percentages of plastic clay. Low strength is due primarily to sand content. Strength of a plastic material varies greatly with the content of water and plasticizing agents. Flocculated clays are stronger than deflocculated clays.

Tempering Water

Tempering water is the amount of water necessary to make dry clay plastic. This varies immensely with different types and conditions of clay. Plastic clays usually require more water than nonplastic; and deflocculated clays require less water for the same consistency than do flocculated clays. "A very plastic clay may need forty per cent (by weight), a non-plastic clay may be satisfied with twenty-five per cent." (2:35)

Ageing

Ageing promotes the chemical decomposition of nonplastic materials into plastic colloidal clay by absorption of water, bacterial action, and base exchange. A chemical reaction between colloidal particles and the surrounding electrolite dissolves the particles, hence a more plastic clay.

"The ageing of clay in the plastic condition has a remarkable effect on its plasticity. This is especially true in the cases of weakly plastic. . . Artificial pottery bodies containing a large per cent of non-plastic material such as feldspar and flint, the fresh body will be difficult to work without tearing and cracking. The aged body will be tougher and smoother, will flow more easily under tool and will give less cracking." (23:87-8)

Tendency to Laminate

Lamination is failure of clay surfaces to blend together. Modeling and throwing clays will have laminations along the wire cuts if the clay is of a type which does not readily blend on contact.

Laminations are more common in less plastic clays and clay that has been wedged a little dry. In thrown pieces laminations will cause complete loss of the piece due to tearing or failure of the clay to form smoothly. Air bubbles in thrown pieces are usually caught between laminations. These, of course, ruin the ware. If laminations are not detected during the forming process, they may show up as cracks on drying or firing.

Dry Properties of Clay

Drying Shrinkage

Moist clays contain considerable water in the pores around and between the clay particles. When clay dries, this water must be conducted to the surface and removed by evaporation. Plastic clays dry slowly because of fine pore space and slow conductivity of water. Drying may be speeded by heat, reduced humidity, air circulation, or a controlled combination. Clays which dry slowly can be improved by the addition of a non-plastic clay, bentonite or flint. Uneven drying and excessive shrinkage tend to cause warping of dry ware. When the process of drying is too rapid, the outer surface dries and shrinks causing cracks. Clays which have a high degree of shrinkage may be blended with clays of a low degree of shrinkage and the product will be highly satisfactory.

Shrinkage Water and Pore Water

Shrinkage water is the water that is driven off during the firing of the clay. Pore water is that water which adheres to the grains of clay even though the clay is air-dried. Heating above the boiling point removes pore water.

Dry Strength

Dry strength is dependent principally upon the alumina content; consequently, most highly plastic clays are strong clays. Some of the strength of the plastic clay can be sacrificed in order to improve drying qualities and workability by the addition of non-plastic materials or the blending with a less plastic clay.

Firing Properties of Clay

Loss of Volatile Material

Absorbed water is driven off after the temperature reaches the boiling point. Chemically combined water of chrystalization is driven off between "400 and 700° C.". (22:27) At the same time, the sulphur and the organic matter are burned out and carbon dioxide is liberated from the carbonates.

Incipient Fusion

Incipient fusion is the phenomenon where a mixture of two or more refractory materials melt at a much lower temperature than they would alone. This, plus the natural low melting fluxes, promotes vitrification at a much lower temperature than would be possible otherwise.

Vitrification and Fusion

"As the temperature is raised, more of the clay material is fused until, without loss of shape, nearly all of the pore space between the fused grains is filled with the viscous, semimolten matter." (22:28) Fusion occurs when firing is continued until the entire body becomes viscous. Complete vitrification is not necessary on all pottery ware if glazes are to be used.

Vitrification Range

The vitrification range is the temperatures between which satisfactory wares can be fired and still hold glazes and not lose shape due to fusion. The addition of silica increases the range; an excess of lime reduces it to a point where vitrification and fusion take place at almost the same temperature.

Fired Shrinkage

Shrinkage from firing is caused by the loss of chemical water and by the filling of pore space with viscous material.

Porosity

Vitrification and shrinkage fill most of the pore space and make the ware water-tight. If the ware is to be glazed, there should be some porosity in order to absorb the glaze. If the vitrification has failed to mature, and porosity is more than ten per cent, glazes may craze.

Color

The color of fired ware depends primarily upon the presence or absence of iron compounds. Different firing temperatures will give different colors because of the formation of different iron compounds. Red colors are characteristic of iron oxide. Blackened colors indicate over-firing.

Strength and Hardness

"The tensile strength and hardness of ware varies with the clay used and with the amount of vitrification produced. . . The composition of the clay, which governs the kind of complex silicas forming the glassy cement, determines the toughness of the ware. Some clay products are used soft and porous, but, in general, the harder the ware without becoming brittle, the more desirable it is for most purposes." (8:30)

Chapter III

HOW TO LOCATE, EXPLORE, AND FIELD TEST CLAY DEPOSITS

Location and Exploration of Clay Deposits

Prospecting for clay is like prospecting for other minerals; it is much easier and more efficient when one knows what to look for.

Sedimentary Deposits

Deposits laid down in water will have bedding or layers; this may show as layers of bolders, gravel, sand, and clay. Layers will vary in thickness from a fraction of an inch to yards. Each layer warrents investigation unless it is obvious that it is sandstone or bolders. Some clay may be found associated with fairly large rocks if the decomposition process has altered the surrounding material.

There may be a definite cycle of bolders, gravel, sand, and clay layers if the deposit was laid down by a stream, along its banks or where it emptied into a lake. High water carries heavy materials and as the flow subsided, lighter and lighter materials were deposited until only the lightest materials reached the still water. Silt and clay settle out in the still water.

Where there has been such a cycle, look up and down the face of the deposit for the next clay layer in the next characteristic cycle.

Clay thickness will vary from one cycle to another because of variations in the flow of water. Layers may "pinch out" to hairlines or disappear completely. It will be worthwhile to follow the next layer above or below and check for a reoccurance of the clay.

Some deposits are faulted (cracked); one or more areas have risen or fallen, sometimes only a few inches and at other times yards. Some deposits will have faults every foot or so; this may make tracing difficult if there is much difference in the levels. Stains or special textures of some layers are a help in locating the new position of the one being followed.

Some deposits will vary from sand to silt or clay several times in an inch. This type of deposit should be tested in several places due to possible variations in quality. Do not overlook even small layers of this type that show clay properties, because the excess sand can be removed by making a thin slip and allowing the sand to settle. Some of these clays may make excellent bodies by using run-of-the-pit material. If the clay is very plastic, sand will be needed to correct shrinkage and improve working properties.

Subsoil and Soft Earth Deposits

Some subsoils have a good clay composition because the action of organic acids and rain water is considerably faster here than further down. Post holes, basements, irrigation ditches, washes, and leveling operations may reveal subsoil clay. Check the soil in and directly below the grass roots in all deposits because even though most of the other material is not decomposed enough to be used, the subsoil may be a good clay.

Dirt banks should be checked by digging out moist dirt; make a ball of it, then see how it feels. If the dry portions of the exposure are hard dried mud, this may indicate that plastic clay is somewhere in the bank; see if it will polish.

Some clays do not wash as easily as other material, so check the sides and bottom of new cuts in creeks, ditches, and where water runs down the side of a road cut or bank for places where there has been resistance to the smooth cutting action of water; some clay will show little resistance to high-water erosion but will account for small water falls in a normal flow. If this clay is moist, make a ball of it to check the plasticity; if dry, there may be the characteristic cracks of a plastic clay. Try to polish a dry piece; then dig out some moist clay and check it.

Shale Deposits

Some exposures will have shale which is a compressed form of silt, sand, clay, fossil leaves, and small gravel. Shales vary in hardness from material that can be easily cut with a knife to ones that can hardly be scratched. Shales usually are fine grained, and are in layers with sandstone or alone. Some are smooth and fractured vertically; others are fractured both vertically and horizontally along the bedding markings. Many shales will crack open when dry and can be easily split with a knife.

Some soft shales will show clay properties and can be used; however, if the shale does not disintegrate after several days in water, the added work of grinding or working into suitable fineness may rule out the use of even a good quality shale. Therefore, check shales for the usual clay properties and then put a dry piece in some water to see how readily it disintegrates.

Check the disintegrated material from the shales in the deposit as a clue to their possibilities. Check all the layers of a shale outcrop and especially those layers that have weathered more than the others; some of these may be covered by debris from the layers above. Shales often contain fossil leaves which may be of interest to a geologist or, at least, as specimens for science classes.

Color

Color is a distinguishing factor in some localities where there is a characteristic iron-yellow or orange-red or dark color due to carbon content.

Spot Check

At the base of high banks there is usually an assortment of material which has broken loose from different portions of the bank. If the fine material has clay characteristics, further investigation is imperative. Clay materials can usually be traced to their source by characteristic colors or textures. The investigations of this type are especially valuable when there is only time for a short stop, or a thorough investigation of the face of the cut is not practical at the time. Enough evidence may be gained by this method to warrent an excursion for an exploration party.

After a field trip, samples of clay should flood in from all parts of the community. Now the problem will be which place to check next, for there is little that can escape the eye of a boy who knows what he is looking for.

Field Tests: How to Determine the Presence of Clay

1. Take a ball of the moist material in the hand and check it for plastic qualities. Plastic clay will stick together and can be worked into different shapes without cracks developing. Sprinkle a little water on the ball; plastic clay will make a muddy slick surface when rubbed and the body of the ball should remain fairly solid.

2. Take a small piece of the moist material and rub it between the fingers; clays will polish and feel slick.

3. Dry clay is fairly hard and retains its wet shape.

4. When dry clay or clay shale is rubbed with the fingers it will polish.

5. To distinguish clay from rock flour and sandy silt, place a drop of water on the hardened surface and

rub. Clay will be shined; the others will be dull or part of the material will be rubbed off.

6. The texture of the clay material can be checked by cutting a piece of the plastic or dry clay and then scraping with a knife. A gritty sound will indicate some sandy material which may be seen as well. If there is no indication of grit, place a very small piece of the clay between the front teeth and check for grit. Lack of grit will indicate very fine grain size.

7. A fine grained clay will produce polished chips when whittled with a knife, either moist or dry.

8. To check the clay for slacking or the ability to disintegrate in the water, place several small pieces in some water and see if they will disintegrate. Dry clay absorbs water much faster than moist clay. Some may take hours to disintegrate but will make good clay.

9. Sandy clays can be easily tested for the amount of plastic clay. Work up a teaspoonfull of the material in the palm of the hand to a smooth muddy consistency, then place the clay in a test tube. Fill the test tube almost full of water and shake until the sample has disintegrated; then add several drops of vinegar or dilute hydrochloric acid, and set the tube aside for

five or ten minutes to settle. A visual examination will show relative proportions of clay to sand. Definite patterns of comparison should be worked out with clays of known working qualities previous to field tests.

These tests are not infallible. They are only indications one way or the other and if there is any question, laboratory tests should be made. Tests will need to be varied and revised to fit changes in topography.

Chapter IV

SAMPLING AND PROCESSING OF SAMPLE MATERIALS

Selection of Samples

The samples should be as uniform a representation of the specific portion of the deposit as possible. Therefore, do not pick out the best looking material for samples if the clay which will later be used will have to include other qualities of material.

Accurate records should be kept on each sample as to location, tests made, and conclusions. The sight should be marked with stakes or some other easy-to-find mark.

The quantity of the sample will depend partially upon the location of the deposit. If the deposit is located in an inaccessible or distant place, a quantity large enough for production should be taken if possible. If it is convenient to return to the site, only enough to warrent ample quantity and uniformity should be taken. The quantity will then depend upon what purpose the clay was intended and how extensive the testing was to be.

When taking the test material from the deposit, make sure to include only material originating at the specific area of interest.

If slacking tests have shown that the clay easily disintegrates in water, there will be little difference as to whether moist or dry samples are taken as the problem of making a slip will not be great. If the slacking test shows that disintegration is difficult or that further processing is needed, take dry samples if possible because dry materials disintegrate faster than moist ones; also, crushing and grinding will be easier.

Division of Samples

1. An ample quantity of the sampled material should be processed to provide sufficient material for all testing.

2. If the entire sample is not being used, the material should be divided in such a way as to have a representative quality which will reflect the properties of the sampled area. This may be done by quartering.

3. Put all the sampled material on a table or floor where it will not be contaminated with other materials or lose any of its own. Remove the roots, sticks, rocks, and other obvious impurities.

4. Break up any chunks, then stir the material thoroughly.

5. Divide the quantity in half and place one half in a container for future use. If the quantity remaining is still more than needed, stir the material and divide it again. Place half in storage container and process the other. This will assure that if future tests need to be made, the sample will be uniform.

Procedure for Slury or Slip Method of Preparation

Materials Needed

Two galvanized pails or five-gallon buckets, depending on quantity of sample; one sieve, one-quarter inch hardware cloth; one sieve, small mesh -- mosquito screen, or, better, forty to sixty mesh brass screen; for grinding, a canvas sack or old grist mill or sausage grinder; for mixing, a power drill mixer, or small cement mixer for large quantities.

Procedure

Mixing wet clay. If the clay is wet, it may be dried and ground or put directly in water and mixed or allowed to soak for some time before mixing.

Grinding. If the clay is dry, crush it so that it will go through the quarter-inch mesh (that is, if slacking tests show that material of quarter-inch size will disintegrate easily). If a method of grinding is available, the hard lumps may be ground; if not, the clay may be placed in a cloth or canvas sack (the oil from the lint of a gunny sack might contaminate the clay), tied, and stomped to break up the lumps. Then sift the material through the quarter-inch mesh screen. Pick out any rocks or other debris and place the uncrushed clay back in the sack and stomp it again.

Slacking. Pour a cup of water for every pound of clay into one of the buckets, then pour the clay in slowly and let it mound up above the water. Set it aside to soak overnight.

Mixing. Then check to see if the lumps are disintegrated. If most of them are, the slip can be worked by hand or with a mixer; water may need to be added to bring the slip to a whipping cream consistency.

Screening. Pour the slip through the fine screen into a container. Do not rub the slip through; this would fill up the mesh. If the slip is a little thick to go through the screen, mix a little more water with it.

<u>Ageing</u>. Clays usually improve with age, so if the slip is not needed immediately, cover it and set it aside. The water which has accumulated on top can be drained off before it is used. Siphon it off or pour it off carefully.

<u>Dewatering</u>. When clay is needed immediately, a quantity for test strips can easily be obtained by pouring clay in plaster bats or molds and then pour it back into the container. The thin layer of clay left on the plaster will be dewatered within a short time. For dewatering of a quantity, pour the slip into dewatering bats or casts and leave it until it is of a working consistency.

Chapter V

TESTS, CONCLUSIONS, AND METHODS OF IMPROVING QUALITIES

Now that the clay is in a workable condition, there is great temptation to make something out of it. There are several different approaches depending upon the desired use of the clay.

There seems to be little difference as to whether fired characteristics or workability is checked first, for if the first test shows satisfactory and the second does not, the first will have to be run again after additions have been made, in order to satisfy the second deficiency.

However, it may be more convenient to check the clay for usability first because of the difference in time involved. It is inadvisable, however, to make several nice pieces and then run the chance of having no glazes that will fit them.

Check Working Qualities

A small bowl or vase could be made on the wheel to check the throwing qualities such as plasticity, resistance to centering, absorption of water, and strength. The test piece should be made quite thick at the bottom and thin at the top. Its drying characteristics will indicate what is to be expected if the clay is used straight from the pit. (See page 19.)

Or if the clay is to be used for modeling or slip, make a preliminary test to see if the characteristics are satisfactory. (See page 49 for characteristics of good slip clay.)

Shrinkage, Warpage, and Glaze Test

One of the most important characteristics to be tested is the shrinkage due to drying and firing. If shrinkage is considerable (over ten per cent) dangers of warping and cracking increase rapidly. Also, high shrinkage makes an undesirable difference between wet size and fired size of the ware. Shrinkage is also a very good indication as to what ingredients need to be added to improve the clay. Very high shrinkage will indicate plasticity and fineness of grain, and usually relatively low vitrification. Addition of flint, grog, talc, or a refractory type clay will improve shrinkage qualities. Those of low shrinkage usually contain considerable quantities of sands. These may not be of a desired plasticity and will require addition of ball clay or bentonite. Low shrinkage usually indicates a clay which will be easy to fit with glazes when vitrified.

Equipment Needed

Two sticks one-quarter inch thick and six to twelve inches long; paper; rolling pin or large dowel; knife or spatula; and a ruler with centimeter scale.

Procedure for Making
Shrinkage, Warpage, and Glaze Test Strips

1. Wedge and knead the sample until it is of a good modeling clay consistency. Roll it into a long column about an inch thick. Cut off about six inches.

2. Place the paper on a smooth surface and lay the sticks on either side of it, placing the six inches of rolled clay between the sticks. Then roll it down to an even quarter-inch thickness, the usual thickness of the ware.

3. Cut out a strip about an inch and a half in width and the length of the clay. Square up one end with a knife and measure twelve centimeters from the end, and cut it square. Measure in one centimeter from one end

and make a mark with the knife edge. Measure accurately ten centimeters and mark it again.

4. With a pencil, scratch in the number or other record information in one end of the clay strip. Always make a complete record of numbers and symbols which are used to designate different clays and mixes.

5. For accuracy, at least two test strips of each clay should be made for each firing temperature.

6. With the surplus cut from the ends, mark off lengths of two inches and square them up. Then make a hole with a pencil about a quarter of an inch from one end and centered. These pieces are to be used for glaze testing bars if the shrinkage shows a good quality clay. They will be dried and fired with the shrinkage tests.

7. Lay the test strips aside on the paper and in a few hours turn the test strips over and place across two sticks. Check them later and if they have warped some, tturn them over again. After several days of drying, check their dryness by placing against the cheek or the back of the hand. If they still feel cool, it indicates that they are not thoroughly dry.

Procedure for Making Warpage (Sag) Test Strips

Make a strip similar to the test strip, but six to eight inches long. Dry in the same manner and record any warpage before firing so that the deflection, if any, can be measured.

Fire the strips at the same time the other tests are being fired. Place the supports at each end so that if there is a tendency to warp or sag there will be a maximum stress on the strip. This test will also be helpful in determining strength of the clay at different degrees of vitrification. If the strip should sag noticably, it is overfired.

Procedure for Making
Combination Shrinkage, Warpage, and Glaze Test Strips

When firing at several temperatures, a considerable amount of clay and time can be saved by making two sag bars for each firing temperature; then measure and mark ten centimeters, as in procedure for test strips. After firing, glaze one-inch bands across each bar with different glazes and fire to the maturing point of the glazes.

Accurate records should be kept of all shrinkage and fired characteristics such as color, vitrification, and strength.

Firing of the Test Strips

Test strips and scraps should be fired in the usual method along with other bisque fire.

Altering the clay to fit the firing range. One method is to fire at a temperature convenient to the firing range of the kiln, the common glaze preparation, and other clays which are already in use. In this case, if the clay does not vitrify (does not have a ring when struck with a pencil) or show signs of overfiring or melting, additions will have to be made to the clay. Additions of fluxes such as lead oxide, borax, frits, ground glass, feldspars, or nepheline syenite will lower the vitrification point. Additions of flint, grog, kaolin, or a sandy refractory clay will raise the fusion point and prevent sagging and overfiring.

Add to samples of two hundred grams each of clay one, two, five, ten, and twenty-five per cent of one of the fluxes or refractories. Then make test strips. Fire and check the difference in shrinkage. Working qualities and glaze fit probably will be changed.

The glaze test strips and scraps should be fired along with the shrinkage tests so that the shrinkage will be the same and the glaze characteristics will correspond with the shrinkage.

It may be more convenient and less expensive to fire the clay at a higher temperature than to add other ingredients.

Altering the firing range to fit the clay. The other method of testing is to fire the test strips at various temperatures, such as 06, 04, and 02. This may find a firing temperature wherein the clay will need no further alteration.

Tests for Vitrification

1. Scratch the fired piece with a knife. A poorly vitrified piece will scratch easily. A well-vitrified piece will not scratch and is said to be "steel hard".

2. A well-fired piece has a ring when struck with a pencil. Different shapes, however, will give different tones.

3. An accurate method of measuring the degree of vitrification is to weigh accurately a fired test bar and then soak it in water overnight and weigh it again.

If the percentage of water is over ten per cent, it is underfired. The vitrification is not reached and glazes would undoubtedly craze.

4. Place a drop of water on the surface of a piece of fired clay. If the water is absorbed slowly, it indicates adequate firing. If the water is absorbed immediately, it indicates underfiring. Overfired pieces have difficulty holding glazes because of the lack of porosity needed to hold the glaze in place.

5. Scraps or test strips of poorly vitrified clay will break easily. Well vitrified pieces require a hammer to break them. This is also an indication of strength of the ware.

Chapter VI

ADAPTATION OF GLAZES TO NEW CLAY BODIES

Testing Glazes on the New Body

The fitting of glazes is not a matter of hit-or-miss. There is a possibility that a new clay may be fit with an old glaze. If the clay shows good vitrification when fired, select several glazes commonly used which mature at the same cone and apply to the test strips with a brush. Pat on the glaze on the top surface of the strip, except for a band across the strip which includes the hole; or, in the case of the combination test strip, pat on one-inch bands across the strip. Mark the test strip with a ceramic pencil and record the data. Fire the strips in the usual manner and inspect them to see if any glazes appear to fit the clay (that is, a smooth, glossy, or mat finish with good thickness and absence of bubbles, crazing or crawling, etc.). Some glazes will appear satisfactory on flat tests, but may flow or crawl on perpendicular ware.

The problem of improving the fit may be met in one of two ways, altering the clay or altering the glaze to fit.

Altering the Clay to Fit the Glaze

One way of improving the fit is to change the clay to fit the glaze. However, if one good glaze fits the clay, it would not be advisable to risk the sacrifice of it for the chance that another might be fit by the addition of other materials. It would then be advisable to adjust the glazes.

If none of the glazes fit, the clay body can be varied by adding refractories or fluxes if this method is more economical than adding to the glazes.

Addition of silica (flint) helps to correct crazing by reducing the expansion. Body fluxes and ground glass lower the vitrification point. Their cost may be prohibitive if a large percentage is required.

The addition of refractory clays or grog will reduce crazing. They also add properties which may be undesirable.

Nepheline syenite is added to further compression and reduce crazing.

Altering the Glaze to Fit the Clay

Improvement of glaze fit can be guided by solving the problems indicated by defects noted in the glazes.

Glaze Defects

Overfiring

Overfired crazing will show immediately and usually does not increase with age. A small amount of glaze can be rubbed into the crazes and the piece fired at the proper temperature. The coefficient of expansion (per cent of expansion per degree of temperature change) can be increased by addition of silica, boric oxide, zinc oxide, magnesium oxide, nepheline syenite, barium oxide, lead oxide, tin oxide, and zirconium oxide. Silica is the major anti-crazing agent and the most economical. It also lowers the porosity to ten per cent or less.

Underfiring

"The body may be underfired or overfired. In the former case, the crazing does not always appear at once and it grows worse on standing." (2:165) Cracks may change direction without meeting other cracks.

Crazing and Shiver

Crazing. Crazing is the "crackle" texture made up of small cracks in the glaze because the glaze is too little for the ware, or "unequal coefficients of expansion of the glaze and body". (6:55)

<u>Shiver</u>. Shivering, the opposite of crazing, is caused by the glaze being too big for the ware. It may peel off. The cracks are similar, but show immediately after the ware has been removed from the kiln. Shivering is remedied by removal of some of the silica or other anti-crazing agent, or by adding alumina.

"Shivering may be due to too rapid firing and cooling." (11:213)

Crawling

Crawling or pulling away from the ware may be caused by "too porous a body, too much plastic clay in the glazes, underfiring, too heavy application," (11:212) dirty or oily spots, or cracked dry glaze before firing.

Running

Running may be reduced by adding ball clay. Reducing the amount of fluxes or firing at a lower temperature will also help.

Pinholes, Bubbles, and Rough Texture

Pinholes, bubbles, and rough texture may be caused by underfiring, cooling too fast, or the presence of air or some volatile material in the body.

Adaptation of glazes to new bodies is a science in itself. Each new clay makes problems peculiar to itself as does each variation of a glaze to fit a body.

Chapter VII

CHARACTERISTICS AND PREPARATION OF CASTING SLIP

Testing of Raw Slip

It usually would be unsatisfactory to use the slury as casting slip because the chance of having an ideal deflocculation is small. A sample might be run, however, just for comparison with later treatment.

Dilute the slip to a creamy consistency and test it in a small slip cast. Follow the usual procedure for slip casting. Note whether the slip solidifies at a normal rate or whether it builds up and then stops.

If the slip builds to a satisfactory thickness in a reasonable time, pour the excess slip out and note the time required for the clay to separate from the plaster. Remove the plaster and check the properties with the list of properties of good slip clay. (See page 53.) If it proves to be satisfactory, fire the piece and note its fired properties.

Addition of Deflocculants

If the slip does not prove to be satisfactory in its original form, pour a gallon or so into drying bats and then completely dry the clay. Then weigh out a pound of the dry clay, add a cup of water, and stir until it is smooth. Now dissolve two-tenths of a gram of soda ash in a teaspoonful of water; add this to the mixture and stir thoroughly. Then add ten drops of sodium silicate solution. Always add soda ash first and mix thoroughly before adding the sodium silicate solution. Now stir thoroughly and let set for a day. If it has curdled or thickened, try adding a drop or two of sodium silicate to a cup of slip; and if it thins to a good consistency, add a proportional amount to the rest of the slip. If this has no effect, add water to get a good consistency, then follow the aforementioned procedure for checking the properties of the slip. Some slip will scum and leave lumps on the inside of the mold. To remedy, add a teaspoon of barium carbonate to a gallon of slip.

Different clays will require different amounts of deflocculating agents and water because of the differences in acidity and colloidal material already present.

"The leaner clays work better with higher (sodium silicate) content, since this produces some colloidal silica." (14:92)

"The slip should weigh about twenty-six ounces per pint. If it weighs more, it needs more water; if less, it contains too much water." (20:16)

Flocculation and Deflocculation

Flocculation can be thought of as flocking together. A colloid is a finely ground material, ranging from microscopic to molecular particles in a basic or alkaline solution. These particles contain a negative electrical charge. They repell each other as do like poles of a magnet. Consequently, the particles are suspended in solution because of the repelling forces and the impact of molecules referred to as the "Browning Movement". These two forces, the repelling force of the negative charged particles, and the constant bombardment on all sides by fast moving molecules counteract the attraction of gravity.

A deflocculated clay slip is as nearly as possible a completely colloidal solution. To produce a better suspension of the naturally colloidal materials such as alumina, soda ash (Na_2CO_3, Sodium Carbonate) is added to insure the maximum negative charge and to prevent flocculation, which cannot occur when there is a slight excess of alkali or base; (excess alkali causes floccula- tion). In addition, a natural colloid, water glass (Sodium Silicate), is added to the solution to bolster the condition.

Flocculation is the exact opposite of deflocculation and is produced by adding an acid to the solution (vinegar, acetic acid, or hydrochloric acid). The addition of the acid neutralizes the excess alkali and the negative charge on the particles and produces an acid solution. Consequently the particles exercise their natural attractive forces and collect in small bundles or flocks. The weight of the flocks causes them to settle or precipitate because there are not enough molecular collisions to counteract gravity.

The flocculated or deflocculated condition of clay can very easily be tested by placing a small quantity of the slip in a test tube of water and shaking it; then watch to see if the clay will settle. A well flocculated clay will almost immediately show a demarkation between the water and the clay. A colloidal suspension will not have a definite line between water and the clay suspension. If there is any question as to whether the clay was deflocculated or not, shake the tube quite well, then put half of it into another tube. To the one tube add several drops of dilute acid. If the original was deflocculated, the difference will be noted almost immediately by the settling line, and a visual examination will show small flocks rather than a translucent solution.

Properties of a Deflocculated Casting Slip

"The water flowing into the plaster must pass through the stiffened wall of clay adjacent to the plaster, which acts as a filter. Therefore the rate of casting depends largely on the permeability of the clay layer. For example, bodies high in ball clay cast slowly while those containing coarse clays cast rapidly." (14:90)

Deflocculation makes possible a definite break between the slip and the solid clay surface next to the plaster. It also reduces the amount of water in the cast layer and prevents settling while casting is in process, therefore prevents a difference in thickness of walls and bottom. Deflocculated clays make a firm interlocking pattern of colloidal and nonplastic materials.

Desired Properties of Casting Slip (14:91)

1. A low enough viscosity to flow into the mold readily.
2. A low rate of settling out on standing.
3. Ability to drain cleanly (in drain casting).
4. Giving sound casts in solid castings.
5. Stability of properties when stored.
6. Quick release from mold.

7. Proper casting rate for each operation.

8. Low drying shrinkage after casting.

9. High dry strength after casting.

10. High extensibility when partly dried.

11. Freedom from trapped air.

12. Freedom from scumming.

"Ball clays slow the casting rate and if used in too large an amount (over twenty-two per cent) are likely to cause soft spots. They also increase the green strength of the ware. The kaolins give faster casting but lower green strength." (14:92)

Chapter VIII

CHARACTERISTICS AND METHODS OF IMPROVING WHEEL CLAYS

Introduction

Pottery texts usually start their throwing section, "Take a piece of wheel clay and wedge it," or just, "Take some clay." A survey of twenty years of a leading professional and amateur potters' magazine failed to give even one article of any consequence concerning the characteristics of wheel clays. The almost complete lack of information is not without reason. There is a wide range of variation within each limiting characteristic of clay, and compensation for inadequate clays are made by change of method or type of production to fit the clay. When the potter has learned the "feel" of a clay, he then knows what to expect of it and consequently does not exceed those limits.

Characteristics of Wheel Clay

Wheel clay characteristics follow generally those of subsoil clay: those plastic clays with a pleasing feel, those that possess enough body or strength to hold the form which is given them, yet soft enough to yield freely to the pressure of the hand; those characteristics which make a child want to roll, to pinch, and to make into marbles to be dried in the sun -- the same characteristics that urge the potter to get some on the wheel and see how it feels, how it yields to his every touch, how it rises, how it flares, and how much it will take before it warns him he has reached its limits.

Clays seem to have personalities which clash with one potter and fit as a glove with the next, so to place a definition within absolute limits is folly when those who work the clay are considered. However, potters will agree that a wheel clay should have enough plasticity to yield to a moderate pressure without cracking and enough strength to prevent falling of reasonably thin walls. There should be a resistance to absorption of water, but enough absorption to make a lubricating slip; and enough dry strength to permit handeling: fast but even drying with a shrinkage of less than ten per cent.

Methods of Improving Wheel Clays

Remedying of Weaknesses

Water is one of the chief variables. A wet body is weak even with the strong clay. Soft clays that absorb water too fast can be wedged on a plaster until they are fairly stiff; thus more water has to be absorbed before the piece falls. Weak clays can be thrown thick and trimmed when leather-hard. Soft weak clays will "quake" or "give" when a ball is twisted between the palms. This is due to fineness of the grain and deflocculation. Such a clay may be sprinkled with a dilute acid (vinegar) while wedging or after the cylinder has been thrown. Flocculation with acid will make the clay stronger, drier, less slip will be formed when throwing, clay will not gouge as easily, and water absorption is cut down.

Soft, weak clays may be improved by the addition of ball clay (plastic clay). This will add strength, cut down the water absorption, and lubricating slip will last longer. Try additions of five, ten, and twenty-five per cent. Of course shrinkage and drying problems will be increased.

Wittemore has found that bentonite can be used in place of ball clay. It adds plasticity, increases dry and fired strength, and lowers the vitrification point. Bentonite reduces cracking by lengthening the drying time. The author found it undesirable for plastic clays for throwing because it was almost impossible to dry the clay by wedging.

Bentonite gives a characteristic called "thixotropism" (1:236) where the clay will be rigid until pressure is applied. The portion under pressure "liquifies", as the pressure of a skate on ice produces a film of water which lubricates the skate.

Ladoo has found that nepheline syenite in semi-vitreous ware produces increased vitrification and gives less warpage.

Blending of Clays

Ball clays and refractories can be blended in a line blend to find the best mixture. A line blend, for instance, would consist of mixing of ten, twenty, thirty, and forty per cent of ball clay with ninty, eighty, seventy, and sixty per cent of fire clay in that order. Each sample would be then tried on the wheel.

Wedging characteristics such as sticking to the table, slowness of removal of water on the plaster table, failure of wire cuts to close, quaking, texture, and plasticity would be checked.

On the wheel, note the ease of centering, gouging and pulling, slip forming, frequency of additions of water, water absorption of thin edges, strength of flares, tendency to fall, effect of sprinkling with dilute acid, drying time, cracking, etc. Keep a record of each and any other peculiarities. These are not definite scientific analyses but indications of what may be expected of the mixture.

If the clay passes these tests, make test strips and test for shrinkage and sag, firing temperature, and glazes.

For beginning students, it is desirable to have a clay that is relatively soft and does not absorb water easily because of the length of time usually consumed in learning the fundamentals.

Appendix I

RESULTS OF CORRESPONDING TESTS MADE BY THE AUTHOR

The tests found in this paper have been carried out by the author in the C.W.C.E. Ceramics Laboratory and have been found to be satisfactory inasmuch as they can be carried out by others with a minimum amount of expense and equipment.

The results of the investigations of local clays in this area have been that the silty clays found between lava flows are either very lean or very fat, and that blending of lean and fat with the addition of other ingredients is necessary.

The author found but one exception: a subsoil clay in a new cut of a mountain stream. This clay has a plasticity that makes it very workable on the wheel. Experimental ware was made intentionally quite thick at the bottom and thin at the top. Water was left in the vase on a wet plaster bat and no cracks developed. The dry hardness was found to be better than most commercial clays. It also has a dry strength that is stronger than most clays, has a drying and firing shrinkage of nine per cent, fires a bright red, and has a bell-like tone when fired at cone 04. The only noticable defect was crazing of the glazes which is easily alleviated by the addition of silica. Inaccessibility of the deposit, however, makes it of no commercial value.

Several clays were flocculated (dilute acid was added). Fire clay showed a marked improvement in strength, workability, and resistance to the absorption of water. Others showed no marked effects.

Mixing of ball clay with fire clay gave added strength and decreased the tendency to sag when flared. The addition of bentonite to plastic clays was found to be unfavorable for plastic wheel clays because of its resistance to dewatering.

It was found to be desirable to add soda ash to the wet slury. Thoroughly mix and then add sodium silicate Mixing of the deflocculents before adding was found to be unsatisfactory. Different clays were found to need different proportions of deflocculents.

Appendix II

ALPHABETICAL INDEX

Appendix III

GLOSSARY OF TERMS

Alumina - (AL_2O_3) Basic clay forming material.

Ball clay - Very plastic clay; used to give plasticity to clay.

Bat, plaster - A flat slab of plaster on which clay is formed. The plaster absorbs the moisture from the wet clay. Dewatering bowls made of plaster are also used.

Bentonite - A highly plastic clay, used in place of ball clay in some blends of clay. A maximum of 2% is used to keep glazes from settling. Too much bentonite makes glaze shrink and peel.

Bisque or biscuit-ware - Unglazed clay which has been fired once.

Borax, boric acid, and boric oxide - Strong fluxes used in glazes, frits, and occasionally in clay bodies.

Chemical water - Water of crystalization; a part of the crystals of some compounds (kaolin).

China clay - Same as alumina or kaolin. Up to 25% will give opacity and a matt quality to a glaze. It withstands a very high temperature (refractory).

Colloids - Suspensions of small particals in other substance as casting slip.

Cones - Cone-shaped pieces of clay used to measure the time and temperature at which a clay or glaze matures.

Crawling - Defect in glazing resulting in blobs and lumps.

Crazing - The appearance of cracks on the finished pot.

Deflocculent - A substance put into casting slip in order to keep it in suspension and of a smooth consistency.

Example of deflocculents: Sodium carbonate (soda ash) and sodium silicate.

Fault - A vertical crack where one section of rock has slipped down or up.

Feldspar - A widely found mineral of which there are several varieties. Orthoclase feldspar which contains potash is the one most frequently used in bodies and glazes. It produces density. When decomposed it becomes kaolin.

Field tests - Tests that can easily be made without laboratory equipment at the deposit.

Flint - Silica, the addition of which gives porosity to clay or glaze and reduces crazing in glazes.

Flocculent - Acid which neutralizes a deflocculated clay and causes the particles to flock and settle. (Acetic acid, hydrochloric acid, or vinegar)

Flux - A material which melts under heat, thus providing the medium for the fusion of all the other materials which are contained in a glaze or clay.

Fossil - Impression or remains of plants and animals found in shales, sandstone, etc.

Frit - A mixture of soluble and insoluble glaze materials which have been calcined. The purpose of fritting is to change the soluble materials into insoluble form.

Fusion - Melting together of ingredients.

Geologist - A person who studies geology (a study of the earth).

Glaze - Glass fused to clay. (Bopia)

Grog - Clay which has been biscuit-fired and finely ground; used to give clay porosity and texture and to decrease shrinkage and warping.

Ilmenite - Titanium oxide.

Kaolin - China clay. Pure refractory clay. (Hydrous aluminum silicates)

Kiln - An oven-like furnace for firing pottery.

Leather-hard - Clay which is still wet, yet too firm to bend easily.

Line blend - A method of mixing samples of clay so as to get even intervals of variation; such as, 100% A; 90% A plus 10% B; 80% A plus 20% B, etc.

Modeling clay - Any clay with strength and moderate plasticity suitable for hand molding or forming.

Refractory - Hard, infusible, as kaolin.

Residual clay - Clay formed in its present location from parent rocks.

Rich - Sticky and fusible clays; plastic, as ball clays.

Rock flour - Dust from glaciation or water action in streams; may decompose into clay if alumina is present.

Sand - Gritty substances, usually quartz, feldspar, mica, etc.

Shivering - Defective glaze coming away from the body; has the same appearance as crazing except that cracks can be felt.

Short - A lack of plasticity in clay; as sandy clays which crumble and crack when they are being shaped.

Silica - Flint (quartz sand).

Silt - Fine material which has settled out of muddy water.

Slacking of clay - Disintegration of dry clay in water.

Slip - Sieved clay or glaze in a moist, soft or creamy state.

Slurry - Unsieved clay in a liquid state.

Soda ash - (Sodium carbonate) NA_2Co_3.

Sodium carbonate - Used as a deflocculent in casting slip.

Sodium silicate - Water glass, a deflocculent in casting slip; also used in mending biscuit ware.

Suspension - The state in which particles mixed with water are kept in equal distribution, preventing them from settling to the bottom of the container. Minute particles in a liquid which do not settle out.

Test strips - Samples of clay used to test firing and glazing properties.

Throwing - Forming ware on the pottery wheel.

Turning - Trimming ware in the leather-hard state while it is being turned on the pottery wheel.

Vinegar - dilute acetic acid.

Viscous - Thick, slow-running liquid, as syrup or molten glaze.

Vitrification - The stage at which glazes melt; the component particles of clay unite into a dense, strong and glass-like substance.

Volatile material - Will turn to gas when heated.

Wedging - Throwing and pounding or kneading clay before it is used in order to drive out the air and make an even consistency.

Wheel clays - Clays satisfactory for throwing.

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