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A Development of a Suitable Clay Body From Two Native Clays

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A DEVELOPMENT OF A SUITABLE

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

For the past two years two native clays have been used in the pottery department at Central Washington College of Education. Both of these clays seemed to offer certain advantages as a potter's clay. At the suggestion of Professor Glenn Hogue, an extensive study was made in an attempt to determine the advantages and limitations of the two clays for pottery work.

I. THE PROBLEM

Statement of the problem. The purpose of this study was to conduct a series of tests on two native clay bodies. They were used individually and in various proportions in order to find the most suitable combination for use as a potter's clay.

Importance of the study. The desirability of developing a suitable clay body from these two native clays became apparent in some of the preliminary tests. It was found that the two clays showed good evidence of plasticity, workability, and firing qualities. The convenient location of the two clay bodies was another factor in encouraging the study and development of these clays.

The limitations of this study were set by the amount and kind of equipment available in the pottery department at Central Washington College of Education.

II. DEFINITIONS OF TERMS USED

Refractory. In some clays melting becomes difficult due to materials in the particular clay. When this condition is evident, the clay is known as a refractory clay.

Kiln. A kiln is an oven built of refractory and insulating materials able to withstand high temperatures. Kilns are classified by the type of fuel they burn (oil, gas, electric) or by their construction (muffle, up-draft, and down-draft).

Plasticity. This is the property which makes clay workable. Ageing the clay, that is, keeping it moist in a container for several months, makes it easier to work with. Sometimes, mixing part of an old batch of clay to a fresh batch promotes the growth of bacteria and so helps plasticity. Other ways to aid plasticity are by adding a spoonful of weak hydrochloric acid or a little vinegar, ten per cent of Ball clay, or one to two per cent of bentonite.

Porosity. A clay may be extremely plastic and easy to work yet be unsuitable for making ware because every piece comes out of the kiln warped or cracked. This clay is not sufficiently porous. There is no way for the water to leave. Adding flint in proportions of 5 to 20 per cent may open up the clay. If a coarse texture is not undesirable, 10 to 20 per cent of 40-60 mesh grog can be used.

Non-plastic clay. Some clays are not as plastic as other clays, due primarily to the porosity of the clay. Usually non-porous clays are very plastic, while porous clays tend to lack good plasticity.

Shrinkage. Clay shrinks as it dries, and shrinks more when it is fired. The contraction of clay or bodies in drying or firing is considered the shrinkage of a clay.

Absorption. This refers to the amount of water that a fired clay will absorb. In general, absorption over ten per cent indicates either that the clay will be too absorbent for use or that it will require higher firing.

Vitrification. When clay put in a kiln to be fired melts or becomes glassy, the clay is said to be vitrified. The component parts of clay unite into a dense, strong, glass-like substance.

Cone. Since the temperature at which kilns are fired is sometimes too high to be measured by ordinary thermometers, other devices must be used. Most popular of these are the pyrometric cones. A cone is a little pyramid made of clay with fluxes added so that it will melt at a known temperature. These are inserted in the kiln at a place where they can be observed during firing. When the cone melts, the kiln has reached the known temperature marked on the pyrometric cone.

Throwing. This is the operation performed by the potter on the potter's wheel in making pieces from a plastic body.

ORGANIZATION OF THE REMAINDER OF THE THESIS

In this paper the following development of procedure was carried out: chapter two, review of related research; chapter three, the description of clay; chapter four, characteristics and location of Sultan and Othello clay; chapter five, generally accepted testing procedures and testing procedures used; chapter six, the test results; and chapter seven, the conclusions.

CHAPTER II

REVIEW OF RELATED LITERATURE

An investigation of literature and research directly related to the two clay bodies was made at Central Washington College of Education, the University of Washington, and the Department of Conservation and Natural Resources of Washington State. From these sources nothing was found that directly related to the two clay bodies. The only significant information was gained orally from Professor Glenn Hogue and Mister Stan Healea. Their information was derived from actually working with the clay previous to this study.

INFORMATION CONCERNING SULTAN CLAY

Professor Glenn Hogue characterizes Sultan Clay as follows: (1) the clay was quite plastic and seemed to be somewhat suitable for wheel work; (2) the clay seemed to hold up quite well under firing conditions and showed little trouble with glaze defects; (3) there seemed to be some evidence of warpage with certain types of wares such as bowls with large flares; and (5) there appeared to be about ten per cent shrinkage.[1]

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[1]From a discussion with Professor Glenn Hogue, Central Washington College of Education, March, 1958.

Stan Healea's findings on Sultan Clay were as follows: (1) Sultan Clay seemed to be very good on the pottery wheel, retained a shape given it by the potter, but tended to crack when very thin pieces were attempted; (2) it shrank about ten to twelve per cent when fired; and (3) most glazes held up quite substantially without developing any glaze defects.[2]

INFORMATION CONCERNING OTHELLO CLAY

The only information concerning Othello Clay was obtained from Mister Stan Healea. His observation was that Othello Clay seemed to be more plastic and tended to be more dense.[3]

INFORMATION CONCERNING THE COMBINATION OF SULTAN AND OTHELLO CLAY

Using the two clays in a mixture, but never in specific proportions, Stan Healea found that the mixture seemed to be more suitable on the potter's wheel. The firing qualities of the mixture appeared to be satisfactory and it showed no evident signs of glaze defects.[4]

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[2]From a discussion with Mister Stan Healea at Central Washington College of Education, January, 1958.

[3]<u>Ibid</u>.

[4]<u>Ibid</u>.

CHAPTER III

DESCRIPTION OF CLAY

Origin of Clay

Most clay originates from the decomposition of felspathic (granite-like) rocks by the natural processes of erosion in geological times. These rocks all changed into clay when chemically and physically altered by weather, as in prolonged action of water, wind, frost, and gasses. Pure clay thus formed is called primary clay and includes kaolin or china clay, from which porcelain is made. It is white and maintains its light color when fired. Secondary clays are much more widespread. Consisting of clays which have been carried far from their original source and deposited in sedimentary beds, they contain various impurities of mineral and vegetable origin.[5]

A closer study of the two groups of clays by Carleton Ball led him to the following definitions:[6]

> 1. Residual Clays - or primary clays are those that are found in the place where original parent rock decomposed or clays that have remained in the place where they are made.

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[5]Winfield Digby, *The Work of the Modern Potter* (London: John Murray, Ltd., 1952), p. 43.

[6]Carleton Ball, "University of Southern California Instructor," Los Angeles, California, 1957-58. (Mimeographed.)

2. Sedimentary Clays - or secondary clays are clays that have been moved or transported by nature from the place in which the original parent rock was located. The transportation of these secondary clays was effected by water, wind, glaciers, etc. In the transportation of the clay, foreign materials or impurities were added to the clay. The secondary clays are consequently much more plastic than the primary clays.

Nature of Clay

Clay consists of three basic compounds, alumina, silica, and water. These three chemicals make up a great portion of the crust of the earth, but it is only when rock, sand, and other materials decompose that the basic clay is formed.

Alumina makes up to forty per cent of kaolin and is found in smaller portions of the impure clays. Alumina's function in clay is quite important. It is responsible not only for much of the refractoriness of clay but also for much of its plasticity and workability.[7]

Silica is present in two forms: (1) as free silica or quartz in sand, and (2) in combinations with other elements in the form of silicates such as feldspar, mica, and kaolin. Sand (silica) lessens the plasticity, increasing the porosity, and thus improved drying and lessens

[7]Warren R. Scott, "How to Use Local Clays in School Ceramics," (unpublished Master's thesis, Central Washington College of Education, Ellensburg, Washington, 1952), p. 9.

shrinkage.[8]

Water chemically combined, part of the structure of crystals such as kaolin, is driven off during the firing of clay. Pore water is that water which adheres to the grains of clay even though the clay is air-dried. Water of plasticity is that water needed to make clay plastic.[9]

Organic matter is quite common in surface 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 materials accounts for some of the loss in weight during firing.[10]

General Characteristics of Clay

Clay possesses certain ingredients not found in ordinary soil. In general, clay is white, greenish-black, or bluish-black and of uniform structure and substance. The texture of clay is generally smooth, but sometimes foreign particles give the feeling of roughness. Clay with foreign matter is quite common and can be found quite easily.[11]

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[8] *Ibid.*, p. 10.

[9] *Ibid.*, pp. 10-11.

[10] *Ibid.*, p. 12.

[11] Charles S. Binns, *The Potter's Craft* (New York: D. Van Nostrand Co., Inc., 1947), p. 17.

These clays with foreign matter in them, used quite often in manufacturing, fire red due to the oxide of iron present. A pure clay, one without iron-oxide or other foreign matter, becomes white or nearly white in the kiln.[12]

The color of raw clay is not always an indication of its fired color. Some clays which are dark in their natural state will fire light whereas some light clays will fire dark. Testing of clays will determine these qualities. Iron, manganese, or other minerals present in different proportions have a definite effect on the fired color of clay. Materials such as lime may have a bleaching effect.[13]

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 its usability.[14]

The texture of clay is due primarily to the size, shape, and properties of different gritty components. The texture runs from rough sandy clays and shales to the very

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[12] Ibid., p. 19.

[13] Geza de Vegh and Alber Mandi, The Craft of Ceramics (New York, Toronto, London: D. Van Nostrand and Company, Inc., 1949), p. 3.

[14] Ibid., p. 4.

fine grained plastic clays and silts. Grit or sand can be detected in a clay by rubbing it between your fingers or by scraping it with a knife. Fine grain clays will have little or no grit when tested by this method. Fine grained clays are more plastic than those with larger grain; they also dry slowly, crack, and have a high shrinkage.[15]

Wet Properties or Pre-Firing Characteristics of Clay

Plasticity is the ability of a clay to respond to forming and to hold the shape given it. Grinding the clay to a finer grain size increases the water held by the clay and lubricates the grains. This also prevents friction, allows the clay to flow more easily, and increases plasticity.[16]

It is also important to have a non-plastic ingredient in a clay body. "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

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[15] Scott, *op. cit.*, p. 14.

[16] Fredrich H. Norton, *Elements of Ceramics* (Cambridge, Massachusetts: Addison Wesley Press, Inc., 1952), p. 60.

a great tendency to crack."[17]

Dry Characteristics of Clay

Clays that are moist 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. Uneven drying and excessive shrinkage tend to cause warping of dry ware. 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.[18]

Fired Characteristics of Clay

On firing, clay changes its characteristics. At the temperature of 148° Fahrenheit to 238°F. the mechanical water is drive off. At 572°F. the clay has changed forever its ability to be plastic, and between 752°F. and 1472°F. oxidation takes place, burning off all carbonaceous matter. Depending on the materials present, vitrification takes

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[17]Hewitt Wilson, Ceramic Clay Technology (New York: McGraw-Hill Book Company, Inc., 1927), pp. 87-88.

[18]Ibid., p. 42.

place at about 1700°F. and above.[19]

"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 viscous molten matter."[20] Fusion occurs when firing is continued until the entire body becomes viscous.

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[19]Laura Bellamy, "The Development of a Cone Four Ware From Materials That Are Easily Accessible to Central Washington College of Education," (unpublished Master's thesis, Central Washington College of Education, Ellensburg, Washington, 1956), p. 9.

[20]Hewitt J. Wilson, The Clays and Shales of Washington, Their Technology and Uses, University of Washington Engineering Experiment Station, Bulletin No. 18 (Seattle, Washington: University Press, 1922), p. 18.

CHAPTER IV

CHARACTERISTICS AND LOCATION OF SULTAN AND OTHELLO CLAY

Sultan clay. Sultan clay is found in the vicinity of Sultan, Washington. Easily accessible and convenient for digging purposes, the clay bed is approximately three miles in diameter, radiating from a point on highway 15 about one mile east of the city. The clay is bluish in color and easily distinguishable. It lies exposed in some parts of the Sultan area due to cuts in the roadway. Earth strata indicates that the clay strata runs about three feet thick for an undetermined distance.

The general characteristics of Sultan clay in its native state are as follows: (1) bluish in color, (2) quite heavy in weight, and (3) showing some evidence of sand. When the clay is wetted down and rubbed between the fingers, it feels quite plastic. In most areas surveyed, the clay appears to be quite free of such foreign matter as weeds, dirt, and rocks.

Othello clay. Othello clay is found in the vicinity of Othello, Washington. The clay bed from which the clay for this experiment was taken is one mile north of the city. It is approximately ten miles in diameter and lies one mile due north of the city. In the area where the clay sample was taken, clay was widely exposed and easily accessible. The exposed area showed the clay to be about nine feet thick for an undetermined length.

The general characteristics of Othello clay are as follows: (1) yellow in color, (2) quite light in weight, and (3) showing very little evidence of sand. When the clay was wetted down and rubbed between the fingers it felt quite plastic. The clay in its native state appeared to be quite free of dirt, rocks, and weeds.

CHAPTER V

GENERALLY ACCEPTED TESTING PROCEDURES AND TESTING PROCEDURES USED

In order to determine whether or not a clay body is suitable for pottery work, certain accepted testing procedures must be used. Tests for plasticity, dry and fired shrinkage, absorption, workability, and warpage are made on a clay body to determine its suitability. It may then be determined what additions, if any, are necessary to make it work well with the intended processes and at firing temperatures.

GENERALLY ACCEPTED TESTING PROCEDURES

Plasticity. Plasticity is the property which makes clay workable. It is difficult to measure, for it is largely a matter of opinion; the same clay may seem extremely plastic to one potter and only moderately so to another. The usually accepted procedure for testing plasticity is to take a small piece of clay and pull it into a thin cylinder about the size of a lead pencil. If this can be done the clay is said to be quite plastic. If it refuses to take such shape, breaking and crumbling, it is considered to be less plastic.[21]

Dry and fired shrinkage. To measure shrinkage, a tile is made out of clay, about six inches long, one inch wide, and one-fourth of an inch thick. On this tile a line is scored and two points measured exactly ten centimeters apart. The tile is allowed to dry, and the distance between the two points is re-measured, determining the dry shrinkage of the clay. Next the tile is fired to the predetermined firing point and the distance is measured again to determine the fired shrinkage. This shrinkage may be expressed in percentage as follows:

$$\frac{\text{original length minus } \begin{matrix}\text{dry length}\\ \text{fired length}\end{matrix}}{\text{original length}} \times 100 = \begin{matrix}\text{percentage}\\ \text{of}\\ \text{shrinkage}\end{matrix}$$ [22]

Absorption. Absorption of a fired clay body determines the density of the clay. In general, an absorption of five to ten per cent is satisfactory. An absorption above ten per cent is considered unsatisfactory because the ware will be too absorbent for use.

To test a clay body for absorption, a piece of fired clay is weighed and then placed in a pan of boiling water

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[21]John B. Kenny, *Complete Book of Pottery Making* (New York: Greenberg Publishing Company, 1949), p. 159.

[22]*Ibid.*

for at least one hour. It is then taken from the water, any surface moisture removed, and again weighed. Its percentage of absorption may be calculated by the use of the following formula:

$$\frac{\text{wet weight minus weight dry}}{\text{weight dry}} \times 100 = \begin{array}{l}\text{per cent}\\ \text{absorption}\end{array}$$ [23]

Warpage. Warpage occurs when the clay is not sufficiently porous. Since there is no way for the water to leave, distortion takes place in drying and during firing. Warpage is determined by making test tiles similar to those used in the absorption tests. The tiles are placed in the kiln so that the ends rest upon two kiln props. When the test tiles begin to bend, the kiln has reached the maximum temperature which the clay will stand without deforming.[24]

Workability. Most potters will agree that a wheel clay should have enough plasticity to yield to moderate pressure without cracking and enough strength to prevent falling of reasonably thin walls. Through experience the potter derives his own personal reactions towards the clay. He tests it according to the way it feels, yields to his

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[23] *Ibid*., p. 158.

[24] *Ibid*., p. 157.

touch, how it rises under pressure, how it flares, and how much it will take before it warns him he has reached the limit.

In testing the wheel characteristics, personal evaluation of the clay was made according to the previous mentioned criteria by Mr. Glenn Hogue, Mr. Stan Healea, and the author. In addition to these personal evaluations, the desirable and undesirable characteristics were discussed. Evaluations and final conclusions were then made.

TESTING PROCEDURES USED

The testing in this experiment included: (1) blending and preparing the clay for test purposes, (2) measuring the dry and fired shrinkage, (3) calculating the amount of absorption of the fired clays, (4) testing for plasticity, and (5) determining the amount of warpage of the fired pieces.

Blending and preparing the clay. The clay bodies were mixed in percentages of wet weight. A total of ten ounces of each clay and their blends was weighed out, accuracy being maintained up to one ounce. After the clays and their blends were weighed out in these proportions they were wedged together. The various proportions were then mixed thoroughly to insure uniform structure when testing.[25] It was then rolled out into a long column about an inch thick and cut off in a six inch roll. The roll of clay was then placed on a piece of paper and sticks were placed on both sides of it. Next it was rolled out between two sticks to an even quarter of an inch thickness, the usual thickness of pottery ware.

A strip of clay about an inch and a half in width and twelve centimeters in length was cut out. Ten centimeters were measured off on the tile and a mark placed at each end of the ten centimeters. Each clay and its blend was made and marked this way, and two samples of each were made to insure accuracy.

<u>Dry and fired shrinkage</u>. After the strips of clay, or test samples, were made and allowed to dry, the original ten centimeters marked on the test samples were measured again. The total dry shrinkage was then calculated by the following formula:

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[25] 100% Sultan clay
75% Sultan clay-25% Othello clay
60% Sultan clay-40% Othello clay
50% Sultan clay-50% Othello clay
40% Sultan clay-60% Othello clay
25% Sultan clay-75% Othello clay
100% Othello clay

$$\frac{\text{original length minus } \genfrac{}{}{0pt}{}{\text{dry length}}{\text{fired length}}}{\text{original length}} \times 100 = \text{percentage of shrinkage}$$[26]

The test samples were next put into an electric kiln, fired, and removed from the kiln. The original ten centimeters marked on the test samples were again measured. The total fired shrinkage was calculated by the same formula used in determining dry shrinkage, substituting fired length for dry length.

Absorption. Next, the percentage of absorption was determined. After the test clay samples were fired, they were weighed, placed in a pan of boiling water for at least one hour, then taken from the water and again weighed, after surface moisture was removed. The percentage of absorption was then calculated by the following formula:

$$\frac{\text{weight wet minus weight dry}}{\text{weight wet}} \times 100 = \text{percentage of absorption}$$[27]

Plasticity. To test the clays for plasticity the following procedures were used. From each clay and their combinations a handful of clay was taken. The sample piece of clay was wetted and pulled into a thin cylinder about the size of a lead pencil. If breaking or crumbling

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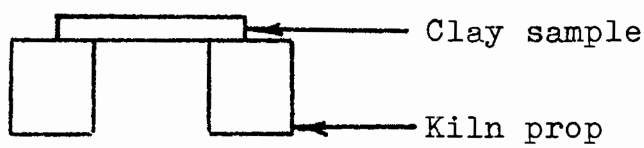
[26] Kenny, *loc. cit.*

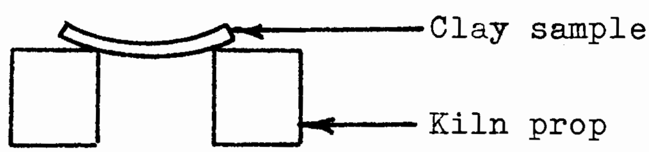
[27] *Ibid.*, p. 158.

did not occur during this process, the clay sample was considered quite plastic. If breaking or crumbling did occur the clay sample was considered less plastic.[28]

<u>Warpage</u>. When the original clay test samples were fired, tests for warpage were also determined. The test samples were placed in the kiln so that the ends of the clay samples rested upon two kiln props. This allowed any warpage that might occur during the firing of the clay samples to take place. The illustration will show an example of the way the test samples were placed in the kiln.



The clay test samples were then fired to a predetermined temperature and cooled. They were then observed for warpage. Warpage was determined by the amount of sag in the center of the clay sample. An example of a clay which has warped considerably is illustrated below:



[28] *Ibid.*, p. 160.

The amount of warpage that occurred during firing was measured.

<u>Workability</u>. To determine the workability, both clays and their combinations were tested on the potter's wheel for the following qualities: yielding to pressure, tendency to crack, holding the shape given it, and versatility (ability to hold a variety of shapes).

Tests were made by Professor Glenn Hogue, Mr. Stan Healea, and the author on the clays and those combinations that were most desirable as a result of their preliminary wet and fired tests.

CHAPTER VI

TEST RESULTS

The following pages of tables show the results of tests performed on each clay and their combination. Table I gives the results of the wet and dry characteristics of each clay and its combination. Table II gives the results of the fired qualities of each clay and its combination. Table III shows the wet and dry results of each clay and its combination, retested with various proportions of silica added. Table IV gives the results of the fired qualities of each clay and its combination, retested with various proportions of silica added.

Specific tests conducted on each clay and their combination were as follows: (1) degree of plasticity, (2) linear shrinkage expressed in percentage, (3) percentage of absorption of the fired clay, (4) warpage evidenced after each firing of the test pieces of clay, and (5) their workability.

The first tests conducted on the two clays and their combinations are shown in Table I, page 25. The wet and dry characteristics of the two clays were measured and observed. Table I shows the following: both clays and their combinations; the linear shrinkage of both clays

TABLE I

WET AND DRY QUALITIES OF SULTAN AND OTHELLO CLAY

AND THEIR COMBINATIONS

Clay	Linear Shrinkage in percentage of wet length	Plasticity	Color
100% Sultan	6.5	Average*	Dark Blue
75% Sultan 25% Othello	7.5	Average	Dark Blue
60% Sultan 40% Othello	8.5	Average	Dark Blue
50% Sultan 50% Othello	9.0	Good*	Light Bluish-Black
40% Sultan 60% Othello	9.0	Good	Dark Yellow
25% Sultan 75% Othello	10.5	Excellent*	Medium Yellow
100% Othello	11.0	Excellent	Light Yellow

*Average: Tendency to crumble and fall apart when pulled to a pencil-like shape when wet.

Good: Occasionally will crumble and fall apart when pulled to a pencil-like shape when wet.

Excellent: Shows no signs of falling apart or crumbling when pulled to a pencil-like shape when wet.

and their combinations expressed in a percentage; the various qualities of plasticity of both clays and their combinations; and the color of both clays and their combinations in the wet state. The 100 per cent Sultan clay shrank six and five-tenths per cent, least of all of the ones tested. The plasticity was only average. The color of 100 per cent Sultan clay was dark blue in the wet state.

By mixing twenty-five per cent Othello clay to seventy-five per cent Sultan clay the shrinkage became seven and five-tenths and plasticity was still average. The color of this combination was dark blue in the wet state.

The combination of sixty per cent Sultan clay and forty per cent Othello clay shrank eight and five-tenths per cent, was average in plasticity and dark blue in color. The combination of fifty per cent Sultan clay and fifty per cent Othello clay shrank nine per cent, the plasticity increased to good, and the color changed to light bluish-black. The combination of forty per cent Sultan and sixty per cent Othello shrank nine per cent, plasticity was good, and the color changed to dark yellow. The combination of twenty-five per cent Sultan and seventy-five per cent Othello shrank ten and five-tenths per cent, plasticity was excellent, the color was a medium yellow. One hundred per cent Othello clay shrank the most, eleven per cent, but the plasticity was excellent. Its color was light yellow.

Table II shows the results of the fired tests of the two clays and their combinations. Characteristics included are: (1) linear shrinkage in percentage of plastic length at cone 010, cone 07, cone 04, and cone 03; (2) the absorption in percentage of dry weight at all four temperatures; and (3) the warpage evidenced at all four temperatures.

One hundred per cent Sultan clay shrank seven and five-tenths per cent at cone 010, ten per cent at cone 07, eleven per cent at cone 04, and fifteen per cent at cone 03. There was eighteen and three-tenths per cent absorption at cone 010, fourteen and nine-tenths per cent at cone 07, eleven and seven-tenths per cent at cone 04, and two and five-tenths at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04 , and severe warpage at cone 03.

The clay combination of seventy-five per cent Sultan clay and twenty-five per cent Othello clay shrank nine and five-tenths per cent at cone 010, ten per cent at cone 07, eleven per cent at cone 04, and eighteen per cent

TABLE II

FIRED QUALITIES OF EACH CLAY AND THEIR COMBINATION

Clay	Total linear shrink in % plastic length				Absorption in % dry weight				Warpage*			
	C/010	C/07	C/04	C/03	C/010	C/07	C/04	C/03	C/010	C/07	C/04	C/03
100% S#	7.5	10.0	11.0	15.0	18.3	14.9	11.7	2.5	None	None	Some	Severe
75% S 25% O	9.5	10.0	11.0	18.0	18.1	14.8	11.0	.6	None	None	Some	Severe
60% S 40% O	10.0	10.0	12.0	19.0	17.9	14.7	10.2	.3	None	None	Some	Severe
50% S 50% O	10.0	12.0	13.0	18.0	17.5	13.9	10.0	.2	None	None	Some	Severe
40% S 60% O	10.0	10.0	12.0	19.0	17.2	13.6	10.0	.2	None	None	Some	Severe
25% S 75% O	11.0	12.0	14.0	20.0	17.2	12.2	10.0	.0	None	None	Some	Severe
100% O	11.2	13.0	15.0	20.2	15.4	11.3	8.4	.0	None	None	Some	Severe

S = Sulton O = Othello

* None: No evidence of warpage.
Some: Evidence of warpage and will need some correction for practical pottery use.
Severe: Too impractical for use at this temperature.

at cone 03. The percentage of absorption of this combination was eighteen and one-tenth per cent at cone 010, fourteen and eight-tenths at cone 07, eleven per cent at cone 04, and six-tenths of a per cent at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04, and severe warpage at cone 03.

The combination of sixty per cent Sultan clay and forty per cent Othello clay shrank ten per cent at cone 010, ten per cent at cone 07, twelve per cent at cone 04, and nineteen per cent at cone 03. The amount of absorption of this clay combination was seventeen andnine-tenths per cent at cone 010, fourteen and seven-tenths per cent at cone 07, ten and two-tenths per cent at cone 04, three-tenths of a per cent at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04, and severe warpage at cone 03.

The combination of fifty per cent Sultan clay and fifty per cent Othello clay shrank ten per cent at cone 010, twelve per cent at cone 07, thirteen per cent at cone 04, and eighteen per cent at cone 03. The percentage of absorption of this combination was seventeen and five-tenths per cent at cone 010, thirteen and nine-tenths per cent at cone 07, ten per cent at cone 04, and two-tenths per cent at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04, and severe warpage at cone 03.

The combination of forty per cent Sultan clay and sixty per cent Othello clay shrank ten per cent at cone 010, ten per cent at cone 07, twelve per cent at cone 04, and nineteen per cent at cone 03. The percentage of absorption of this combination was seventeen and two-tenths per cent at cone 010, thirteen and six-tenths per cent at cone 07, ten per cent at cone 04, and two-tenths per cent at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04, and severe warpage at cone 03.

The combination of twenty-five per cent Sultan clay and seventy-five per cent Othello clay shrank eleven per cent at cone 010, twelve per cent at cone 07, fourteen per cent at cone 04, and twenty per cent at cone 03. The percentage of absorption of this combination was seventeen and two-tenths at cone 010, twelve and two-tenths at cone 07, ten at cone 04, and zero at cone 03. There was no evidence of warpage at cone 010 or cone 07, some warpage at cone 04, and severe warpage at cone 03.

The clay body of 100 per cent Othello clay shrank eleven and two-tenths per cent at cone 010, thirteen per cent at cone 07, fifteen per cent at cone 04, and twenty and two-tenths per cent at cone 03. The percentage of absorption of this clay was fifteen and four-tenths at cone 010, eleven and three-tenths at cone 07, eight and four-tenths at cone 04, and zero at cone 03. There was no evidence of warpage at cone 010 or cone 07, but there was some warpage at cone 04, and severe warpage at cone 03.

After these preliminary wet and fired tests on the two clays and their combinations it was found that there was a considerable amount of warpage and shrinkage evidenced at cone 04. It was hoped that a suitable clay body could be found that would mature at cone 04. It was then decided that silica would be added in various proportions to the two clay bodies and their combinations to correct the warpage evidenced and the high amount of shrinkage at cone 04. The results of these tests are shown in Tables III and IV.

Table III shows the wet and dry characteristics of the two clays and their combinations with proportions of five, fifteen, and twenty-five per cent silica added to each. Both clays and their combinations were measured for total linear shrinkage in per cent of wet length with proportions of five, fifteen, and twenty-five per cent silica added, and plasticity of both clays and their combinations

TABLE III

WET AND DRY CHARACTERISTICS OF BOTH CLAYS

AND ITS COMBINATION WITH SILICA ADDED

Clay	Total Linear Shrinkage in % of Plastic Length			Plasticity		
	5% Silica	15% Silica	25% Silica	5% Silica	15% Silica	25% Silica
100% Sultan	6.0	6.0	6.0	Good	Average	Average
75% Sultan 25% Othello	6.0	6.0	5.0	Good	Good	Average
60% Sultan 40% Othello	7.0	6.0	6.0	Good	Average	Average
50% Sultan 50% Othello	7.0	7.5	8.0	Good	Good	Average
40% Sultan 60% Othello	7.0	7.6	8.4	Good	Good	Average
25% Sultan 75% Othello	9.0	9.0	8.9	Excellent	Good	Average
100% Othello	12.0	10.0	9.0	Excellent	Good	Good

with proportions of five, fifteen, and twenty-five per cent silica added.

The clay body of 100 per cent Sultan clay shrank six per cent with all porportions of silica added. The plasticity of this clay was good with five per cent silica, and average with fifteen per cent and twenty-five per cent silica.

The combination of seventy-five per cent Sultan and twenty-five per cent Othello shrank six per cent with both the five per cent and fifteen per cent silica, and five per cent with twenty-five per cent silica added. The plasticity was good with five and fifteen per cent silica added, and average with twenty-five per cent silica added.

The combination of sixty per cent Sultan and forty per cent Othello clay shrank seven per cent with five per cent silica, and six per cent with both fifteen per cent and twenty-five per cent silica added. This combination showed good plasticity with five per cent silica and fifteen per cent silica added, but only average plasticity with twenty-five per cent silica added.

The combination of fifty per cent Sultan clay and fifty per cent Othello clay shrank seven per cent with five per cent silica, seven and five-tenths per cent with fifteen per cent silica, and eight per cent with twenty-five per cent silica added. The plastic qualities of this combination were good with five and fifteen per cent silica added, but only average with twenty-five per cent silica added.

The combination of forty per cent Sultan clay and sixty per cent Othello clay shrank seven per cent with five per cent silica, seven and six-tenths per cent with fifteen per cent silica, and eight and four-tenths per cent with twenty-five per cent silica added. The combination showed good plasticity with five and fifteen per cent silica added, but only average plasticity with twenty-five per cent silica added.

The combination of twenty-five per cent Sultan clay and seventy-five per cent Othello clay shrank nine per cent with five and fifteen per cent silica, and eight and nine-tenths per cent with twenty-five per cent silica added. This combination showed excellent plasticity with five per cent silica, good plasticity with fifteen per cent silica, and average plasticity with twenty-five per cent silica added.

The clay body of one hundred per cent Othello shrank twelve per cent with five per cent silica, ten per cent with fifteen per cent silica, and nine per cent with twenty-five per cent silica added. This clay body showed excellent plasticity with five per cent silica, and good plasticity with fifteen and twenty-five per cent silica added.

Table IV shows the fired test results of the two clays and their combinations with proportions of five, fifteen, and twenty-five per cent silica added. Both clays and their combinations were fired at cone 04 only. They were then measured and observed for total linear shrinkage in per cent of wet length, percentage of absorption of the fired test pieces, and any evidence of warpage. The one hundred per cent Sultan clay shrank eight per cent with five per cent silica, eight per cent with fifteen per cent silica, and seven per cent with twenty-five per cent silica added.

The percentage of absorption was eleven and nine-tenths per cent with five per cent silica, fourteen per cent with fifteen per cent silica, and sixteen and eight-thenths with twenty-five per cent silica added. There was no evidence of warpage.

The combination of seventy-five per cent Sultan clay and twenty-five per cent Othello clay shrank eight per cent with five and fifteen per cent silica, and eight per cent with twenty-five per cent silica added. The percentage of absorption of this combination was ten per cent with five per cent silica, thirteen and six-tenths with fifteen per cent silica, and sixteen and two-tenths

TABLE IV

FIRED QUALITIES OF BOTH CLAYS AND THEIR COMBINATIONS, WITH SILICA ADDED

Clay	Total Linear Shrinkage in % of Plastic Length			Percentage Absorption			Warpage		
	Cone 04			Cone 04			Cone 04		
	5% Silica	15% Silica	25% Silica	5% Silica	15% Silica	25% Silica	5% Silica	15% Silica	25% Silica
100% Sultan	8.0	8.0	7.0	11.9	14.0	16.8	None	None	None
75% Sultan 25% Othello	8.0	8.0	8.0	10.0	13.6	16.2	None	None	None
60% Sultan 40% Othello	12.0	9.0	8.0	9.3	13.2	15.7	None	None	None
50% Sultan 50% Othello	15.0	12.0	9.0	9.0	12.6	15.6	Some	Some	Some
40% Sultan 60% Othello	16.0	12.3	10.0	9.0	12.2	15.4	Some	Some	Some
25% Sultan 75% Othello	16.1	13.0	12.0	8.7	11.6	13.8	Some	Some	Some
100% Othello	16.4	13.4	13.0	8.0	10.6	13.4	Some	Some	Some

per cent with twenty-five per cent silica added. There was no evidence of warpage.

The combination of sixty per cent Sultan clay and forty per cent Othello clay shrank twelve per cent with five per cent silica, nine per cent with fifteen per cent silica, and eight per cent with twenty-five per cent silica added. The percentage of absorption of this combination was nine and three-tenths with five per cent silica, thirteen and two-tenths per cent with fifteen per cent silica, and fifteen and seven-tenths per cent with twenty-five per cent silica added. Here again there was no evidence of warpage.

The combination offifty per cent Sultan clay and fifty per cent Othello clay shrank fifteen per cent with five per cent silica, twelve per cent with fifteen per cent silica, and nine per cent with twenty-five per cent silica added. The percentage of absorption was nine with five per cent silica, twelve and six-tenths with fifteen per cent silica added, and fifteen and six-tenths with twenty-five per cent silica added. There was some evidence of warpage with all of the various proportions.

The combination of forty per cent Sultan clay and sixty per cent Othello clay shrank sixteen per cent with five per cent silica, twelve and three-tenths per cent with fifteen per cent silica, and ten per cent with twenty-five per cent silica added. The percentage of absorption was nine with five per cent silica, twelve and two-tenths with fifteen per cent silica, and fifteen and four-tenths with twenty-five per cent silica added. There was some evidence of warpage with all the various proportions.

The combination of twenty-five per cent Sultan clay and seventy-five per cent Othello clay shrank sixteen and one-tenth per cent with five per cent silica, thirteen per cent with fifteen per cent silica, and twelve per cent with twenty-five per cent silica added. The percentage of absorption was eight and seven-tenths per cent with five per cent silica, eleven and six-tenths with fifteen per cent silica, and thirteen and eight-tenths with twenty-five per cent silica added. There was some evidence of warpage with all the various proportions.

The clay body of one hundred per cent Othello clay shrank sixteen and four-tenths per cent with five per cent silica, thirteen and four-tenths per cent with fifteen per cent silica, and thirteen per cent with twenty-five per cent silica added. The percentage of absorption of Othello clay was eight per cent with five per cent silica, ten and six-tenths with fifteen per cent silica, and thirteen and four-tenths with twenty-five per cent silica added. There was some evidence of warpage with five and fifteen per cent silica but only a slight amount of warpage with twenty-five per cent silica added.

RESULTS OF WORKABILITY TESTS

The one hundred per cent Sultan, seventy-five per cent Sultan and twenty-five per cent Othello, and sixty per cent Sultan and forty per cent Othello clays were selected as the most desirable in the preliminary fired and wet testing. These were then tested for workability on the potter's wheel to determine which was most suitable.

When one hundred per cent Sultan clay was tested on the potter's wheel for workability, it yielded well under pressure, but tended to crack when pulling up a long cylinder; it held the shape given it well, although there was a tendency for bowl shapes to fall rather easily. Most of the other shapes tried seemed satisfactory.

The combination of sixty per cent Sultan and forty per cent Othello clay yielded well under pressure but tended to crack when pulling up a long cylinder; most of the shapes tried were satisfactory, except bowl shapes, which tended to fall when large ones were attempted.

The combination of seventy-five per cent Sultan and twenty-five per cent Othello clay yielded well under pressure, showed no evidence of cracking when pulling up a cylinder, held all shapes given it, and was very versatile in all shapes attempted.

CHAPTER VII

CONCLUSIONS

It was the intention of the author to develop a suitable clay body from Sultan clay, Othello clay, or a combination of the two. Preliminary tests of the two clay bodies showed desirable characteristics for a good pottery clay. Through a discussion with Professor Glenn Hogue and Mister Stan Healea, certain findings and recommendations were made regarding the two clays and their various combinations. It then became necessary to test the two clays and their combinations to determine their wet and fired characteristics. Each clay and its combination was tested for dry and fired shrinkage, plasticity, absorption, warpage, and workability.

It was found that one hundred per cent Sultan clay had the lowest amount of shrinkage, whereas one hundred per cent Othello clay was the most plastic, one hundred per cent Sultan clay the least plastic. In testing both clays and their combinations for absorption, it was found that one hundred per cent Sultan clay had the highest amount of absorption and one hundred per cent Othello was the least absorbent. The one hundred per cent Sultan clay showed the least warpage, one hundred per cent Othello clay showed the most.

When the two clays and their combinations were retested with silica added, there was considerably less warpage and shrinkage, although the addition of greater amounts of silica decreased the plastic qualities of both clays and their combinations. When the two clays and their combinations were tested for workability on the potter's wheel, clays made up of seventy-five per cent Sultan clay and twenty-five per cent Othello clay, and sixty per cent Sultan clay and forty per cent Othello clay seemed most desirable.

The combination of seventy-five per cent Sultan clay and twenty-five per cent Othello clay was selected as the most suitable clay body for the following reasons: the total amount of linear shrinkage was the least; there was a reasonably low percentage of absorption; there was no evidence of warpage; and when used on the potter's wheel it yielded better to pressure, tended to crack less, held the shape given it, and was more versatile.

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