THE DEVELOPMENT OF AN IDEAL CLAY BODY FOR THROWN WARE

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TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF ILLUSTRATIONS	v
Chapter	
I. INTRODUCTION	1
Statement of the Problem Scope of the Problem Method of Procedure Standards for Evaluating the Problem	
II. EXPERIMENTS PERFORMED WITH FIFTEEN CLAY BODIES	6
The Clay Bodies	
Composition of the Clay Bodies Experiments Performed Evaluation of the Clay Bodies	
Glazes for the Clay Bodies	
Composition of the Glazes Experiments Performed to Determine the Suitability of Four Glazes Evaluation of the Glazes in Relation to the Clay Bodies	
III. CONCLUSION	51
Evaluation of the Study Considerations for Further Experimentation	
BIBLIOGRAPHY	53

LIST OF TABLES

Table		Page
I.	Composition of Experimental Clay Bodies in Terms of Per Cents	10
II.	Percentage Results for Shrinkage Tests of the Fifteen Clay Bodies	16
III.	General Throwing Qualities of the Fifteen Clay Bodies	18
IV.	Adaptability Range of the Fourteen Acceptable Clay Bodies Relative to Satisfactory Wall Heights	20
V.	Adaptability Range of the Fourteen Acceptable Clay Bodies Relative to Satisfactory Wall Thickness	21
VI.	Color of Fifteen Clay Bodies	23
VII.	Percentages of the Coloring Agents Used in Each of the Eight Variations of Glaze B . .	34
VIII.	Defects of the Four Glazes on the Fourteen Acceptable Clay Bodies	39
IX.	Texture of the Four Glazes on the Fourteen Acceptable Clay Bodies	42
X.	Colors of the Four Glazes on the Fourteen Acceptable Clay Bodies	44

LIST OF ILLUSTRATIONS

Figure		Page
1.	Clay Bar for Calculating Clay Body Shrinkage	15
2.	Specimens of Glazes A, B, C, and D (left to right), on Clay Body No. 7	40
3.	Specimens of Glazes A, B, C, and D (left to right), on Clay Body No. 8	40
4.	Specimens of Glazes A, B, C, and D (left to right), on Clay Body No. 11	41
5.	Specimens of Glaze A on Clay Bodies, Nos. 2, 13, and 11 (left to right)	41
6.	Specimens of Glaze A on Clay Bodies, Nos. 1, 2, 3, 4, 6, 7, and 8 (left to right)	43
7.	Specimens of Glaze A on Clay Bodies, Nos. 9, 10, 11, 12, 13, 14, and 15 (left to right)	45
8.	Specimens of Glaze B on Clay Bodies, Nos. 4, 6, 7, 8, 10, 12, 13, and 14 (left to right)	45
9.	Specimens of Glaze C on Clay Bodies, Nos. 2, 3, 7, 8, 13, 14, and 15 (left to right)	46
10.	Specimens of Glaze D on Clay Bodies, Nos. 2, 4, 7, 8, 11, and 13 (left to right)	46

CHAPTER I

INTRODUCTION

Statement of the Problem

Although the potter's wheel has been used for more than 3,000 years, it still holds the fascination of the craftsman. The wheel provides the artist-potter with the best tool for building a pot from a ball of clay. Both throwing and jiggering methods employ the use of the wheel; however, the throwing method provides the more direct relationship between the potter and the clay. Moreover, as opposed to pots made completely by hand, thrown pieces can be built very quickly in a wide variety of circular shapes.

The present study of an ideal mixture for thrown ware is an outgrowth of a long-time personal interest developed during undergraduate work at North Texas State University. While a natural earthenware clay proved to be the best all-purpose clay for class use, it was not ideal for throwing. This suggested the problem: "The Development of an Ideal Clay Body for Thrown Ware." The steps leading to its solution are recorded in this paper.

Scope of the Problem

A clay body which would mature at a low temperature was sought, since many potters would not have facilities for high-temperature firing. Experimentation was limited to fifteen clay mixtures, each of which contained some Athens clay, the natural earthenware clay which has proved to be a good all-purose clay.[1] Besides the earthenware clay, varying proportions of the following three widely used clays were included: (1) ball clay, (2) kaolin,[2] and (3) fire clay.[3] Additional ingredients were potassium feldspar, nepheline syenite, talc, flint, frit No. 18,[4] and grog.[5] Four coloring oxides were used: nickel, cobalt, red iron, and black copper.

An alkaline and a lead glaze were mixed for use as basic glazes. To provide a range of colors, varying percentages of the following coloring agents were added to each glaze: cobalt and copper carbonate, red and black iron oxide, vanadium stain, and rutile. The resulting mixtures provided eight glazes of each type. In addition, Nelson's alkaline glaze[6] and an ash

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[1]Athens clay was obtained from the Athens Pottery and Tile Company, Athens, Texas.

[2]Tennessee ball clay No. 4 and Kingston kaolin were obtained from the Trinity Ceramic Supply, Inc., 9016 Diplomacy Row, Dallas, Texas.

[3]Acme fire clay was obtained from the Acme Brick Company, Denton, Texas.

[4]Frit No. 18 was obtained from the L. H. Butcher Company, 3628 East Olympic Boulevard, Los Angeles 23, California.

[5]Acme grog was ontained from the Acme Brick Company, Denton, Texas.

[6]Glenn C. Nelson, <u>Ceramics Reference Manual</u> (Minneapolis, Minnesota, 1958), p. 101.

glaze used in pottery classes at North Texas State University[7] were included without variations in proportions; thus, a total of eighteen glazes was prepared for experimentation.

Method of Procedure

Developing a satisfactory body for thrown ware involved the preparation of fifteen mixtures, including selections from the four basic clays plus fluxes and fillers. The components of each of the clay bodies were weighed dry in batches of 3,000 grams equaling 100 per cent. Each group of components was mixed with water to the correct consistency and wedged. A tile was made from each batch for testing shrinkage. Next, from each acceptable body, ten pots of varying height, width, and wall thickness were thrown to determine the clay mixture's flexibility and throwing quality. Each pot was impressed with an Arabic number corresponding to that of the clay body and biscuit-fired at 894 degrees centigrade (Cone 010). The results of each experiment were recorded and evaluated.

For better determining the limitations of the fifteen clay bodies, glaze tests were necessary. Using a basic alkaline and a basic lead glaze, a series of experiments was performed. Two-hundred-gram batches of each of the two basic glaze formulae were ground in a dry state in a ball mill.

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[7]The recipe for the ash glaze was obtained from Georgia Belle Leach, Assistant Professor of Art, North Texas State University, Denton, Texas.

Then, to eight twenty-gram batches of each ground basic glaze varying percentages of coloring agents were added. These were reground by hand, using a mortar and a pestle, and stored in waxed-paper sacks. For testing, each of the sixteen glazes was mixed with water to the right consistency for application with a brush. It was then applied to a biscuit-fired tile. The tile was labeled with a capital letter to indicate the basic glaze used; the letter was followed by a number indicating the type and percentage of coloring agent used. Then the glazed tile was fired. After firing, the glazes were evaluated and the results were recorded. The best glaze was chosen from the eight variations of each type and set aside for testing on thrown ware. The alkaline and ash glaze generally used in ceramic classes at the University were also tested on the thrown ware. Thus, four glazes--two alkaline, one lead, and one ash--were used in the final glaze experiments.

Each of the four glazes was applied to two biscuit-fired pots made from each of the accepted clay bodies. The two remaining specimens in each biscuit-fired group were reserved for final experiments. For firing, the glazed pots were divided into four groups according to glaze. These groups were then equally divided into two smaller groups containing one pot of each clay body, making fourteen pots in each firing lot; thus, each glaze was tested on each clay body in two firings under conditions as nearly identical as possible. The two remaining specimens in each group were used to retest the best glazes resulting from the preceding firings. The firing temperature for the glaze experiments was 1060 degrees centigrade (Cone 04), the temperature at which low-fired bodies would mature.

Standards for Evaluating the Problem

Two primary concerns that were considered in determining a satisfactory body were the quality of the clay body and the perfection of the glaze. The clay body was judged on the basis of flexible throwing quality, minimum shrinkage, color, and texture. Since in the production of an ideal ware, the body and the glaze must be compatible, each glaze used in the experiments was evaluated as to fit, texture, and color in relation to each clay body.

CHAPTER II

EXPERIMENTS PERFORMED WITH FIFTEEN CLAY BODIES

The Clay Bodies

A clay body is achieved when two or more natural clays are combined or when mineral substances are added to a clay or clay mixture. The components of the clay bodies used in this study were selected to achieve plasticity, limited shrinkage, and other satisfactory working properties; to produce desirable color or texture; or to serve as fluxes or fillers.

Composition of the Clay Bodies

The following kinds of clay were selected for their contemplated usefulness to the composition of each clay body: earthenware clay, ball clay, kaolin, fire clay, and grog produced from fire clay.

Earthenware clay, one of the most common and practical clay for the potter, was used in each of the experimental clay bodies. The particular earthenware clay used was Athens clay, a very plastic gray clay which fires to a pink or buff color.

Ball clay was used in some of the experimental clay bodies to adjust their plasticity. Since ball clay is too plastic to be used alone, it frequently produces a good body when mixed with other clays.

Kaolin, a highly refractory clay, was combined with other clays to give the particular body hardness and to reduce shrinkage. Kingston kaolin was the variety used in some of the clay bodies comprised in this study.

Fire clay contains high amounts of alumina and silica, and slightly higher amounts of iron impurities than ball clay, plus fluxes such as magnesia, potash, and soda. It is very refractory or resistant to heat. Acme fire clay, which fires reddish-brown in color, was used in this study for textural interest it would add because of its refractory qualities and for color interest.

Grog is a clay which has already been fired and then re-ground; it may therefore be any one of a variety of types. Acme grog, made from Acme fire clay, was used in some of the clay bodies to strengthen the mixture and to create a rough texture.

In addition to the clays, various oxides, fluxes, and fillers were used in developing the clay bodies. Cobalt, nickel, and black copper--three commonly used coloring oxides--were included. Feldspar was added to some mixtures as a fluxing agent. In firing, feldspar melts and forms molten glass. This causes the particles of clay to cling together, thus increasing hardness. Nepheline syenite, an even more powerful fluxing agent than feldspar, was also tried in some of the clay bodies. Talc was added as an ingredient to increase resistance to thermal shock; also, another determining feature was that glazes usually have little or no delayed crazing on bodies containing talc. Likewise, flint, the main source of silica (SiO_2), was used in some bodies to counteract crazing. A frit is a partial or a complete glaze which is melted and then reground. Frit No. 18 was used in the experiments to prevent the solubility of borax, soda ash, and other such materials. The formula for frit No. 18 is as follows:

NaKo	.561	B_2O_3	.898	SiO_2	2.67
CaO	.352				
PbO	.086				

Table I shows the proportions in which the four clays and other materials were combined to form the fifteen clay bodies which were used in the experiments. Each body was assigned an Arabic code number and weighed in dry batches of 3,000 grams equaling 100 per cent. The components of the fifteen individual clay bodies are discussed below.

Clay body No. 1.--The composition of clay body No. 1 contained 50 per cent earthenware clay. Although earthenware is an all-purpose plastic clay, 15 per cent ball clay--which is also very plastic--was added. Then, to achieve hardness and to reduce shrinkage, 15 per cent kaolin was included in the mixture. For additional hardening qualities, 10 per cent potassium feldspar and 7.5 per cent frit No. 18 were used as fluxing agents. To counteract thermal shock and to prevent crazing of the glaze, 2.5 per cent talc was included in the body.

Clay body No. 2.--The composition of clay body No. 2, likewise, contained 50 per cent earthenware clay; however, the ball clay was increased to 25 per cent to form a more plastic body. For possible color and textural interest, 5 per cent fire clay was included. To achieve hardness, 10 per cent frit No. 18 was added. In order to counteract body and glaze crazing, 10 per cent flint was combined with the mixture.

Clay body No. 3.--In body No. 3 the earthenware clay was reduced to 30 per cent and the fire clay was increased to 20 per cent. In that the increased amount of fire clay would reduce the plasticity, 25 per cent ball clay was used as a corrective. To counteract crazing, 5 per cent talc and 10 per cent flint were included. Also, to insure a hardness, 10 per cent frit No. 18 was added to the components of the body.

Clay body No. 4.--To form a very plastic body, 35 per cent ball clay was added to a mixture of 15 per cent earthenware clay and 15 per cent fire clay in body No. 4. To counteract the shrinkage caused by the fine particles of ball clay, 10 per cent kaolin was included. The kaolin and 15 per cent frit No. 18 were used for their hardening qualities.

TABLE I

COMPOSITION OF EXPERIMENTAL CLAY BODIES IN TERMS OF PER CENTS

Ingredients in Terms of Per Cents	Experimental Clay Bodies														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ball Clay	15	25	25	35	20	10	15	9	..	25	20	15	10	20	15
Earthenware Clay	50	50	30	15	20	15	75	75	35	10	45	25	64	40	70
Fire Clay	..	5	20	15	..	40	..	..	50	50	10	..	5	15	..
Kaolin	15	..	..	10	20	..	9	9	..	..	..	25	..	5	10
Potassium Feldspar	10	..	..	..	..	..	..	..	..	5	10	..	..	..	..
Nepheline Syenite	..	..	..	..	..	..	..	..	..	..	..	10	..	..	..
Talc	2.5	..	5	..	5	..	..	..	..	..	..	10	5	5	..
Flint	..	10	10	10	20	10	..	5	..	..	15	15	5	5	5
Frit No. 18	7.5	10	10	15	15	10	..	..	15	10	..	..	10	10	..
Grog	..	..	..	..	..	15	..	..	..	..	..	..	..	..	..
Black Copper Oxide	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
Nickel Oxide	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
Cobalt Oxide	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
Red Iron Oxide	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..

To the above ingredients, 10 per cent flint was used to counteract body and glaze crazing.

Clay body No. 5.--In order to form still another very plastic mixture, clay body No. 5 combined equal parts of earthenware, ball, and kaolin clays; 20 per cent of each clay was used. The kaolin was used to counteract the shrinkage caused by the highly plastic ball clay. In addition to the clays, 5 per cent talc and 20 per cent flint were added to counteract body and glaze crazing. Frit No. 18--used in clay bodies numbered 1, 2, 3, and 4 to achieve hardness--was used in this body, but in a proportion of 15 per cent.

Clay body No. 6.--In clay body No. 6, 40 per cent fire clay was combined with 15 per cent earthenware clay. This combination, more colorful than the first five mixtures because of a higher percentage of iron oxide, was made more plastic by the addition of 10 per cent ball clay. Hardness of the body was increased by including 10 per cent frit No. 18. To counteract crazing, 10 per cent flint was added to the ingredients. The 15 per cent grog was added to the mixture primarily to strengthen the body, but also to give it a rough texture.

Clay body No. 7.--Clay body No. 7 was a simpler mixture than those described above in that it contains only four ingredients: three clays and a coloring agent. The earthenware clay was increased to 75 per cent and the ball clay to 15 per cent; 9 per cent kaolin was included to reduce the shrinkage and to increase hardness. For color, 1 per cent black copper oxide was added.

Clay body No. 8.--Another simple mixture resulted in body No. 8. It contained 75 per cent earthenware clay and 9 per cent kaolin. The ball clay was reduced to 9 per cent, while 5 per cent flint was added to counteract body and glaze crazing. For coloring oxides, 1 per cent nickel and 1 per cent cobalt were combined with the components.

Clay body No. 9.--The simplest mixture used in the experiments was body No. 9, which contained only two clays and a frit. The combination of clays was 35 per cent earthenware for plasticity and 50 per cent fire clay for color and texture. The 15 per cent frit No. 18 was added to these clays as a hardening agent.

Clay body No. 10.--As in body No. 9, the mixture of body No. 10 contained 50 per cent fire clay for color and texture; however, the earthenware clay was decreased to 10 per cent and 25 per cent ball clay was included for additional plasticity. For hardening qualities 5 per cent potassium feldspar and 10 per cent frit No. 18 were combined with the clays.

Clay body No. 11.--Body No. 11 was somewhat comparable to body No. 2. The earthenware clay was reduced from 50 to 45 per cent and the ball clay from 25 to 20 per cent, while the kaolin was increased from 5 to 10 per cent and the flint from 10 to 15 per cent. For a hardening ingredient, 10 per cent potassium feldspar was used instead of 10 per cent frit No. 18.

Clay body No. 12.--This body contained the highest amount of kaolin, 25 per cent, which was combined with 25 per cent earthenware and 15 per cent ball clay to achieve a very hard body. To these clays 10 per cent nepheline syenite, a very active flux, was added. Also 10 per cent talc and 15 per cent flint were combined to counteract body and glaze crazing.

Clay body No. 13.--Like bodies No. 7 and No. 8, body No. 13 was primarily earthenware clay; it contained 64 per cent. However, 5 per cent fire clay was added as well as 10 per cent ball clay. In addition to the clays, 5 per cent talc and 5 per cent flint were used to counteract crazing. To increase its hardness, 10 per cent frit No. 18 was also included. To add to the iron content supplied by the fire clay, 1 per cent red iron oxide was combined with the mixture.

Clay body No. 14.--In comparison with body No. 13 the ingredients of body No. 14 were as follows: the earthenware clay was reduced to 40 per cent, while the ball clay was increased to 20 per cent and the fire clay to 15 per cent. To these clays 5 per cent kaolin was added to increase hardness and to reduce shrinkage. The other ingredients, with the exception of the coloring oxide, were the same as those of body No. 13: 5 per cent talc, 5 per cent flint, and 10 per cent frit No. 18.

Clay body No. 15.--Body No. 15, like body No. 8, was predominantly earthenware--70 per cent. Also, this body contained comparable amounts of the other ingredients, with the exception of coloring oxides: 15 per cent ball clay, 10 per cent kaolin, and 5 per cent flint.

Experiments Performed

Tests for shrinkage.--The shrinkage of clay is related to its grain structure and, therefore, also to plasticity. Clays with very fine particles, such as kaolin and ball clay, may shrink as much as 8 per cent in the initial drying process; while clays with larger particles, such as earthenware and fire clay usually shrink about 5 per cent. Total fired shrinkage for some clays exceeds 10 per cent. Each of the fifteen clay bodies under examination was tested for drying shrinkage, firing shrinkage, and total shrinkage.

Test for drying shrinkage.--From each of the fifteen bodies, a bar of wedgedclay 14 centimeters long by 4 centimeters wide by about 1 centimeter thick was made in a wooden mold. On this bar, a sharp scratch just a little longer than 10 centimeters was made. Scratches were made across the first mark to show a length of 10 centimeters (See Fig. 1). The bars were allowed to dry; then, the distance between scratches was measured on each bar and recorded. The following formula was used to figure the per cent of linear shrinkage of each bar during drying:

$$\text{Per Cent Linear Shrinkage} = \frac{\text{Plastic Length - Dry Length}}{\text{Plastic Length}} \times 100.$$

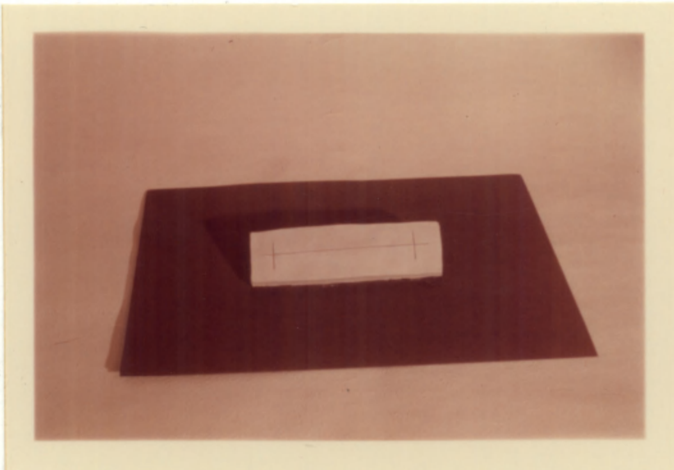

Fig. 1.--Clay bar for calculating clay body shrinkage.

Test for firing shrinkage.--The above mentioned bars were then fired at 894 degrees centigrade (Cone 010), and the followimg formula was used to determine the fired shrinkage of the individual specimens:

$$\text{Per Cent Linear Shrinkage} = \frac{\text{Dry Length - Fired Length}}{\text{Dry Length}} \times 100.$$

Test for total shrinkage.--The following formula was used to obtain the per cent of total shrinkage for each specimen:

$$\text{Per Cent Linear Shrinkage} = \frac{\text{Plastic Length - Fired Length}}{\text{Plastic Length}} \times 100.$$

The results of the shrinkage tests performed on the fifteen clay bodies are shown in Table II. Six bodies--numbered 1, 2, 8, 11, 12, and 13--each had a total shrinkage of 6 per cent; one body, No. 4, had 6.5 per cent; three

TABLE II

PERCENTAGE RESULTS FOR SHRINKAGE TESTS
OF THE FIFTEEN CLAY BODIES

Clay Body	Dry Shrinkage	Fired Shrinkage	Total Shrinkage
1	5.5	.529	6.0
2	5.5	.529	6.0
3	6.0	1.060	7.0
4	6.0	.532	6.5
5	3.5	3.627	7.0
6	8.5	1.650	10.0
7	9.0	1.099	10.0
8	5.5	.529	6.0
9	6.5	3.743	10.0
10	7.0	2.690	9.5
11	5.5	.529	6.0
12	5.5	.529	6.0
13	5.5	.529	6.0
14	8.5	1.650	10.0
15	6.0	1.060	7.0

bodies--numbered 3, 5, and 15--had 7 per cent; one body, No. 10, had 9.5 per cent; and four bodies--numbered 6, 7, 9, and 14--had 10 per cent.

It is desirable not to have a great amount of shrinkage; there are fewer chances for warping or cracking to occur in the ware if total shrinkage does not exceed 10 per cent. All the experimental clay bodies were acceptable as to their total per cent of shrinkage.

Test for throwing quality.--In that no potter is able to throw a pot that is beyond the limits of the clay, it is important that the body be as flexible as possible. The clay must be plastic enough to hold a shape when soft and thin, yet must have enough rough materials to give the strength needed to maintain the form of tall shapes. Smooth and fine-grained clay will not stand up in large or tall forms. A pot twelve inches or more in height needs more "tooth" to its body in order to give it the necessary consistency to make it stand. Grog is a common material used to add this bone-like structure to a body.

From each acceptable body, ten pots of varying height, width, and wall thickness were thrown to determine each clay mixture's flexibility and throwing quality. Each pot was impressed with an Arabic number corresponding to that of the clay body and biscuit-fired. The general throwing quality of each clay body is shown in Table III. The basis for evaluation included the flexibility range of wall height and thickness, throwing quality, and general response of the clay to manipulation by the potter. Six divisions--excellent, very good, good, fair, poor and not acceptable--were used for classifying the clay bodies. One body, No. 11, was classified as excellent; one body, No. 7, as very good; nine bodies--Nos. 2, 3, 4, 8, 10, 12, 13, 14, and 15--as good; two bodies--Nos.

TABLE III

GENERAL THROWING QUALITIES OF THE FIFTEEN CLAY BODIES

Clay Body	Excellent	Very Good	Good	Fair	Poor	Not Acceptable
1	..	..	..	..	X	..
2	..	..	X	..	..	..
3	..	..	X	..	..	..
4	..	..	X	..	..	..
5	..	..	..	..	..	X
6	..	..	..	X	..	..
7	..	X	..	..	..	..
8	..	..	X	..	..	..
9	..	..	..	X	..	..
10	..	..	X	..	..	..
11	X	..	..	..	..	..
12	..	..	X	..	..	..
13	..	..	X	..	..	..
14	..	..	X	..	..	..
15	..	..	X	..	..	..

6 and 9, as fair; one body, No. 1, as poor; and one body, No. 5, as not acceptable. Therefore, No. 5 was eliminated from further experiments.

In order that the possibilities of each clay body be better understood, tests were made to determine the satisfactory range of wall height for each body. The results of these experiments are shown in Table IV. The adaptability range of satisfactory wall heights for each body is indicated by an "X". One body--No. 1--was adaptable for only small wall heights; seven bodies--Nos. 6, 8, 9, 12, 13, 14, and 15--for only small and medium wall heights; and six bodies--Nos. 2, 3, 4, 7, 10, and 11--for small, medium, and tall heights.

Additional studies of the adaptability range of satisfactory wall thickness were performed to determine the limits of the clay bodies. The adaptability range of satisfactory wall thickness for each of the fifteen clay bodies is presented in Table V. The range of wall thickness of each clay body is indicated by an "X". Each of the clay bodies was satisfactory for walls 1/2 inch to 1/8 inch thick. Five clay bodies--Nos. 11, 12, 13, 14, and 15--were satisfactory for 1/16 inch walls.

A good throwing clay should not absorb water too readily while being worked. If a great amount of water is needed to build a pot, it is more difficult for the ware to hold its shape because of the softness of the body. Also the ease of throwing is considerably hampered by the necessity of adding excessive amounts of slip. Thus, the ease of throwing is in a degree dependent upon the amount of slip that is needed as

TABLE IV

ADAPTABILITY RANGE OF THE FOURTEEN ACCEPTABLE CLAY
BODIES RELATIVE TO SATISFACTORY WALL HEIGHTS

Clay Body	Small (3" or Less)	Medium (3" to 8")	Tall (8" to 12")
1	X	..	..
2	X	X	X
3	X	X	X
4	X	X	X
6	X	X	..
7	X	X	X
8	X	X	..
9	X	X	..
10	X	X	X
11	X	X	X
12	X	X	..
13	X	X	..
14	X	X	..
15	X	X	..

a lubricant to form thrown ware. Eight clay bodies--Nos. 2, 4, 7, 10, 11, 12, 14, and 15--required an ideal amount of slip while they were being thrown. Three clay bodies--Nos. 3, 8, and 13--required a satisfactory amount of slip. Three clay bodies--Nos. 1, 6, and 9--required great amounts of slip; they were less satisfactory bodies in regard to throwing ease.

TABLE V

ADAPTABILITY RANGE OF THE FOURTEEN ACCEPTABLE CLAY BODIES RELATIVE TO SATISFACTORY WALL THICKNESS

Clay Body	1/16"	1/8"	1/4"	1/2"
1	..	X	X	X
2	..	X	X	X
3	..	X	X	X
4	..	X	X	X
6	..	X	X	X
7	..	X	X	X
8	..	X	X	X
9	..	X	X	X
10	..	X	X	X
11	X	X	X	X
12	X	X	X	X
13	X	X	X	X
14	X	X	X	X
15	X	X	X	X

The general impression of a clay body at this stage results from the personal experience of the potter as he builds the form. This, in addition to the appraisal of the finished product, results in the final evaluation of the body. The most workable clay bodies were Nos. 7 and 11.

<u>Color and texture of the clay bodies</u>.--Greenware may present color variations of gray, red, or brown. Fired clay may be pure white, gray, light tan, buff, red, orange-red, brown, dark brown, or black. The iron in the clay or the body produces the browns and reds. Most clays fire to buffs, pinks, reds, or browns; however, the temperature at which a clay is fired will determine its specific color. A clay fired at one temperature will produce one color while the same clay fired at another temperature will sometimes produce another color. The greenware color and the biscuit color, at Cone 010, of each clay body are shown in Table VI.

The texture of clay may be smooth or rough. This texture may be of two sorts, tactile or visual. In a tactile sense, all the clay bodies developed for use in this study were smooth. Visually, eight clay bodies--Nos. 2, 3, 4, 6, 7, 9, 10, and 14--had the appearance of being rough because of flecks of darker or lighter colors, which gave the illusion of a pitted surface; but they had the desirable quality of being pleasantly smooth to the touch.

Grog, used in body No. 6 in order to create a rough texture, did not produce the desired tactile result.

Evaluation of the Clay Bodies

The individual clay bodies were evaluated as to their shrinkage, throwing quality, color, and texture.

TABLE VI

COLOR OF THE FIFTEEN CLAY BODIES

Clay Body	Greenware Color	Biscuit Color
1	Light Buff	Off-White
2	Dark Buff	Tan with Brown Flecks
3	Red Brown	Orange Buff with Brown Flecks
4	Red Brown	Light Red Buff with Brown Flecks
5	Dark Gray	Gray
6	Dark Red Brown	Warm Red Brown
7	Dark Gray	Light Buff with Brown Flecks
8	Dark Blue Gray	Blue
9	Dark Red Brown	Red Brown with Light and Dark Flecks
10	Dark Red Brown	Light Red Brown with Dark Flecks
11	Light Gray	Light Buff
12	Light Gray	White
13	Dark Gray Brown	Brown
14	Dark Gray	Light Buff with Red and Brown Flecks
15	Gray Pink	Off-White

Clay body No. 1.--This body had a very low percentage of shrinkage as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. Yet, despite this ideal shrinkage factor, the body had limitations in its throwing quality as it was only adaptable to small thrown ware. It required great amounts of slip to make it take shape on the wheel. Its color was light buff in the greenware stage and fired to an off-white. It appeared and felt smooth and its tactile texture was pleasing. Owing to its very poor throwing quality, it was classed as a poor clay body for thrown ware, in spite of its other commendable qualities.

Clay body No. 2.--This body had a very low percentage of shrinkage as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. The adaptability of the throwing range was wide in that small to tall shapes were thrown with a minimum amount of slip needed to shape the ware. Its color was dark buff in the greenware state and fired to an interesting tan with brown flecks. Its tactile texture was smooth, but visually it appeared rough or pitted, resulting in an esthetically satisfying surface. Owing to its limited shrinkage, good throwing quality, and pleasant color and texture, it was judged to be a good clay body for thrown ware.

Clay body No. 3.--This body had a low percentage of shrinkage as the drying shrinkage was 6.0, the firing shrinkage 1.060 and the total shrinkage 7.0. The throwing range was wide in that it was adaptable to small, medium, and tall shapes. A minimum amount of slip was needed to form the ware. Its color was red brown in the greenware state and fired to a desirable orange buff with brown flecks. Visually it appeared rough or pitted, but it was smooth to the touch, resulting in a pleasing visual and tactile combination. Because of its limited shrinkage, wide throwing range, and interesting color it was evaluated as good for thrown ware.

Clay body No. 4.--This body had a low percentage of shrinkage as the drying shrinkage was 6.0, the firing shrinkage .532, and the total shrinkage 7.0. The throwing range was wide in that small to tall shapes were thrown with a minimum amount of slip. Its color was red-brown in greenware state and fired to a pleasant light red buff with brown flecks. Visually, it appeared rough or pitted, but its tactile texture was smooth, producing a desirable surface. Because of its limited shrinkage, wide throwing range, and interest in color and texture the clay body was classed as good for thrown ware.

Clay body No. 5.--This body had a low percentage of shrinkage as the drying shrinkage was 3.5, the firing shrinkage 3.627, and the total shrinkage 7.0. The drying and firing shrinkage ratio was unusual, as more shrinkage usually occurs in the initial drying than in the firing. This body felt like putty and was extremely hard to wedge. It was impossible to center a ball of this clay body on the wheel. Its color was dark gray in the green state and fired to a lighter gray. In that the clay would not hold a shape on the wheel, it was not acceptable for thrown ware. Thus this body was eliminated from further experiments.

Clay body No. 6.--This body had one of the higher percentages of shrinkage as the drying shrinkage was 8.5, the firing shrinkage 1.650, and the total shrinkage 10.0. This body had the limitation of being adaptable only to shapes of small and medium size; also, it required large amounts of slip in the process of shaping. Its color was dark red-brown in the greenware state and fired to a pleasing warm red-brown. Its visual texture was rough or pitted, but its tactile texture was smooth, resulting in a pleasant surface to both sight and touch. As this body had a limited throwing quality and needed excessive slip for throwing, it was classed as only a fair clay body for thrown ware.

Clay body No. 7.--This body also had one of the higher percentages of shrinkage as the drying shrinkage was 9.0, the firing shrinkage 1.099, and the total shrinkage was 10.0. The body had a wide range of throwing adaptability, as small to tall shapes were thrown with a minimum amount of slip. Its color was dark gray in the greenware state and fired to an unusual light buff with brown flecks. Its visual texture was rough or pitted while its tactile texture was smooth, providing a very satisfying surface. In that no cracking or warping was apparent from shrinkage in the experiments and in that the throwing quality was very good, this interestingly colored clay body was classified as very good for thrown ware.

Clay body No. 8.--This body had a low percentage of shrinkage as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. Its throwing range was best adapted to small and medium shapes. The body required only a minimum amount of slip to make it workable on the wheel. Its color was dark blue gray in the greenware state and fired to a dull blue. Its visual and tactile textures were smooth. Because of low shrinkage, ease of throwing, and unusual color, the clay body was considered good for thrown ware.

Clay body No. 9.--This clay body was also one of the bodies which had a high percentage of shrinkage as the drying shrinkage was 6.5, the firing shrinkage 3.743, and the total shrinkage 10.0. This body was adaptable to small and medium shapes. A large amount of slip was required to form ware on the wheel. Its color was dark red-brown in the greenware state and fired to an interesting red-brown with light and dark flecks. Its visual texture was rough or pitted, and its tactile texture was smooth, which produced a desirable surface for ware. In that this clay had a very interesting color and a fair throwing quality, it was judged to be a fairly good body for thrown ware.

Clay body No. 10.--This body had a high percentage of shrinkage as the drying shrinkage was 7.0, the firing shrinkage was 2.690, and the total shrinkage was 9.5. This body was adaptable to a wide throwing range, as small to tall shapes can be formed with a minimum amount of slip. Its greenware color was dark red-brown, which fired to light red-brown with dark flecks. Visually, it was rough or pitted, however, it felt smooth; thus, it resulted in a pleasing surface. In that the color was interesting and a wide range of shapes could be thrown with ease, the body was evaluated as good for thrown ware.

Clay body No. 11.--This body had a very low percentage of shrinkage, as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. This body had a wide throwing range, as small to tall shapes could be thrown with only a minimum amount of slip. Its light gray color in the greenware state fired to a pleasant light buff color. Its visual and tactile texture was smooth. As all aspects of this mixture were excellent, the body was evaluated as excellent in every respect for thrown ware.

Clay body No. 12.--This body had a very low percentage of shrinkage as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. The throwing range of this body was adaptable to small and medium shapes. It required only a minimum amount of slip to form a shape on the wheel. Its color was light gray in the greenware state and fired to white. Its texture appeared and felt smooth. Owing to its limited shrinkage, ease of throwing, white color, and smooth texture, this mixture was judged to be a good body for thrown ware.

Clay body No. 13.--This body had a low percentage of shrinkage as the drying shrinkage was 5.5, the firing shrinkage .529, and the total shrinkage 6.0. Its throwing range was most adaptable to small and medium shapes. The body required a rather large amount of slip to produce thrown shapes. It color was dark gray brown in the greenware state and fired to a pleasing brown. Its texture was smooth. The rich brown color, limited shrinkage, and rather good throwing quality caused the clay body to be classified as good for thrown ware of limited size range.

Clay body No. 14.--This body was one that had a high percentage of shrinkage as the drying shrinkage was 8.5, the firing shrinkage 1.650, and the total shrinkage 10.0. The most adaptable throwing range for pots of this body was from small to medium heights. This clay body needed only a minimum amount of slip to make it workable on the wheel. Its color was dark gray in the greenware state and fired to a pleasing light buff with red and brown flecks. Its visual texture was rough and pitted although its tactile texture was smooth. The ease of throwing, pleasing color, and good texture contributed to the evaluation of this body as good for pieces of small to medium size.

Clay body No. 15.--In this clay body the percentage of shrinkage was somewhat low, as the drying shrinkage was 6.0, the firing shrinkage 1.060, and the total shrinkage 7.0. The adaptable throwing range was from small to medium shapes.

The body required only a minimum amount of slip to build forms on the wheel. Its color was gray pink in the greenware state and fired to an off-white. Its texture was smooth. Owing to the limited shrinkage, ease of throwing, and pleasing texture, the clay body was classified as good for thrown ware of limited size.

Glazes for the Clay Bodies

To render a pot waterproof and to enhance its esthetic appeal, a glaze is applied to its surface. A glaze is a continuous layer of glass, or glassy crystals, on the surface of a ceramic body. The glaze is usually applied as a suspension of the glaze-forming ingredients in water, which dry on the surface of the pot in a layer. Upon firing, the ingredients react and melt to form a thin layer of glass.[8]

Composition of the Glazes

The ingredients of a glaze are a combination of refractory and fusible materials. The refractory materials used in this study were ball clay, calcined kaolin, china clay (kaolin), flint, whiting, and bentonite.

A refractory glaze material has the quality of resisting the effects of high temperature and contains considerable amounts of alumina and silica. The alumina content is an important factor in a successful glaze, as it controls the

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[8]Glenn C. Nelson, Ceramics (New York, 1960), pp. 15-16.

fluidity of the melting glaze and enables it to withstand the temperatures needed to mature the body. Greater amounts of alumina were used to increase the hardness of the glaze, and give resistance to abrasions and acids. Silica was used in the glaze as it has the effects of raising the melting point, decreasing its fluidity, increasing resistance of glaze to water and chemicals, increasing hardness and tensile strength, and reducing the coefficients of thermal expansion of the glaze. Ball clay and kaolin were used as silica compounds. The clay also acts as a floatative in the raw glaze batch, helping to keep the other ingredients from settling to the bottom of the slip. Clay helps to give the glaze coat on the ware a toughness which makes it less apt to be smeared or damaged during placing in the kiln.

Flint, another refractory glaze ingredient, was used as a main source of silica as it is insoluble, chemically inert, abundant, and inexpensive. Whiting, or calcium carbonate, which is the most common source of calcium oxide in glazes, provided still another refractory material. Bentonite, an extremely plastic clay formed by decomposed volcanic ash and glass, was used to aid glaze suspension rather than as a refractory element.

The fusible glaze materials are those ingredients which melt or liquefy when the glaze is fired. The fusible materials used in the study were white lead, lithium carbonate, wood ash, feldspar, and nepheline syenite. Finely ground particles of white lead were used as they kept the ingredients from settling rapidly in the glaze mixture and aid the fusing of the materials; however, a disadvantage is that the dust, being poisonous is dangerous when proper handling and ventilating precautions are not taken. Lithium carbonate was used because it frequently causes a brilliant color response, thus obviating the necessity of resorting to soluble materials or frits. Its main disadvantage being that it is expensive when used in great amounts. Wood ash, which contains several alkalies, such as potash and soda, was used because it has a relatively low fusion point. Feldspar was used in one of the glazes because of its low melting point. Nepheline syenite was also used as it is a very useful body flux in glazes where a low maturing temperature is desired.

In addition to these individual ingredients, frit No. 80, a melted and reground glaze was used. The formula for frit No. 80 is as follows:

BaO 1.00 B_2O_3 .537 SiO_2 .497

Two of the four types of low-temperature glazes used in this experimentation were alkaline glazes which depend on alkalies such as sodium, potassium, or lithium. Because either transparent or opaque color can be achieved with this type of glaze, it is very tempting to the potter; however, the disadvantages are many in that it is a soft and easily scratched glaze which is almost impossible to fit to a clay body without crazing.

A raw and a fritted glaze of this type were tested. The raw glaze, Nelson's formula (See footnote 6, p. 2), was given the code A in the experiments. The recipe, in gram weights, is given below:

Glaze A Raw Alkaline Glaze (Cone 04)

Lithium Carbonate . . .	26.9
Kaolin	13.6
Flint	53.9
Bentonite	2.8
Copper Carbonate	3.7

Glaze A was tested only on thrown pots of each clay body as it had proved to be a satisfactory glaze as to fit, color, and texture when used in previous ceramic experiments.

The fritted alkaline glaze used for experimentation was given the code B. The recipe, given in gram weights, is as follows:

Glaze B Fritted Alkaline Glaze (Cone 04)

Frit No. 80	75.0
Flint	10.0
Whiting	5.0
China Clay	10.0

Glaze B was used in preliminary tests on tiles to determine a glaze color to test on thrown pots. A 200-gram batch of the basic alkaline glaze was ground in a dry state in a ball mill. Then, to provide a range of colors for testing the basic alkaline glaze, varying percentages of the following coloring agents were added to eight 20-gram batches of the basic glaze: cobalt and copper carbonate, red and black iron oxide, vanadium stain, and rutile. Table VII gives the percentages of the coloring agents used in each of the eight variations of glaze B.

TABLE VII

PERCENTAGES OF THE COLORING AGENTS USED IN EACH OF THE EIGHT VARIATIONS OF GLAZE B

Coloring Agents in Terms of Per Cents	Glaze Variations							
	1	2	3	4	5	6	7	8
Cobalt Carbonate	½	..	..	..	..	..	..	½
Copper Carbonate	..	4	..	..	..	2	..	..
Red Iron Oxide	..	..	5	..	4	..	..	..
Vanadium Stain	..	..	..	6	..	..	..	..
Black Iron Oxide	..	..	..	..	..	..	5	..
Rutile	..	..	..	..	..	..	..	1

Each of these variations was individually reground by hand, using a mortar and pestle, and stored in waxed-paper sacks. For testing, each of the eight glazes was mixed with water to the right consistency for application with a brush. It was then applied to a biscuit-fired tile. Each tile was fired and labeled with a capital letter to indicate the basic glaze used; the letter was followed by a number indicating the type and percentage of coloring agent used. After firing, it was observed that the eight color variations were as follows: B1, light blue; B2, green; B3, warm brown; B4, brownish yellow; B5, yellowish brown; B6, pale green; B7 warm dark brown; and B8, dull blue. These eight glazes were recorded and evaluated; in that the coloring agents did not add a definite interest or improvement to the glaze, it was decided to use the basic glaze without a coloring oxide. As well as waterproofing the specimen, the transparency of the glaze allowed the color of a clay body to show through. Thus, these preliminary tests were set aside and the basic glaze was used to run a series of tests on pieces made from each clay body.

Lead glazes are given the name of the flux which is used in them; white or red lead. This type of glaze is very desirable as it is reliable, easy to control, colorful, and durable enough for most purposes. Its main disadvantage is that it is poisonous, thus care should be taken to avoid breathing the dust or getting particles in the mouth.

Two raw lead glazes were used for experimentation. One of these glazes, an opaque glaze, was assigned a code of C. To determine a glaze color to test on thrown ware of each clay body, a series of preliminary tests were made. The same procedure and the same percentages of the same coloring agents were used for these tests as for those performed with the fritted alkaline glaze previously discussed (See pp. 33-34). The eight color variations for the lead glazes were as follows: C1, light blue; C2, light green; C3, yellow brown; C4, dull yellow; C5, warm yellow brown; C6, light green; C7, warm dark brown; and C8, pale milky blue. These eight glazes were recorded and evaluated; it was decided that the warm dark brown glaze was a better color for a shiny glaze than were the lighter colors. Thus, C7 was merely assigned the letter C to be tested on thrown ware of each clay body, and the remaining preliminary tests set aside. The following recipe, given in gram weights, is for glaze C.

Glaze C Raw Opaque Lead Glaze (Cone 04)

White Lead	52.1
Nepheline Syenite	20.3
Flint	18.7
English China Clay . .	3.0
Whiting	5.8
Tin Oxide	4.9
Black Iron Oxide . . .	4.9

The other glaze used for experimentation on pots built from each clay body was Leach's raw mat glaze containing white lead and wood ash (See footnote 7, p. 3). This glaze was given the code of D. The recipe is given in gram weights as follows:

Glaze D Raw Mat Glaze (Cone 04)

White Lead	150.0
Wood Ash	26.0
Feldspar	82.0
Kentucky Ball Clay.	15.0
Calcined Kaolin . .	20.0
Copper Carbonate. .	5.9
Red Iron Oxide . .	5.9

Experiments Performed to Determine the Suitability of Four Glazes

Each of the four glazes discussed above was applied to two of the ten biscuit-fired pots made from each of the fourteen acceptable clay bodies. The two remaining specimens in each biscuit-fired group were reserved for further glaze experiments. All pots were fired to 1060 degrees centigrade (Cone 04). For firing, the 112 glazed pots were divided into four groups of twenty-eight pots according to glaze. These groups were then equally divided into two smaller groups containing one pot made of each clay body, making fourteen pots in each of the eight firing lots. Thus, each glaze was tested on each clay body in two firings under the same conditions in order to detect possible differing reactions of identical specimens. The two firings produced the same results.

The four glazes were tested on each clay body to determine fit, texture, and color.

Glaze fit.--A glaze which fits a clay body admirably is smooth--without wrinkles, breaks, or holes--and pleasant to the touch and sight; it is one which does not possess the following defects or flaws: crazing, shivering, crawling, pitting and pinholing, blistering and blebbing, underfiring or overfiring.

Crazing, the development of a fine network of cracks in the finished glaze, is a common glaze flaw. These cracks may be present when the ware is taken from the kiln or they may develop days or months later. The expansion and contraction of the glaze are main causes of crazing; it is induced by heat shock.

Shivering is a flaw which is the reverse of crazing. Its effect may be compared to a sidewalk which buckles and rises from the ground. Thus shivering occurs when a glaze is under too great compression, which causes it to separate from the clay body.

Crawling, a defect in which the glaze parts during melting and leaves bare spots of clay exposed, is often attributed to the application of glazes over unclean biscuit ware; but it can also be caused by the shrinking and cracking of the raw glaze on the biscuit ware.

Pitting and pinholing are more definite glaze defects, as they are more directly caused by the composition of the glaze or the firing cycle rather than by the condition of the clay body. These small or sometimes larger holes are more frequently found in mat glazes.

Blistering and blebbing are the results of the clay as well as the glaze. Blistering is most evident inside a bowl where excessive lead glaze has formed a pool. Blebs are raised bumps which appear on the surface of glazed ware. They are caused by air pockets which lie just below the surface of the clay.

Underfiring and overfiring are the most usual glaze flaws. Underfiring results in a harsh, scratchy surface; overfiring results in an unpleasantly shiny glaze.

The glaze characteristics discussed previously were used as standards to determine the fit of the four glazes on each clay body. These results are shown in Table VIII. The findings show that three bodies--Nos. 7, 8, and 11--were most

TABLE VIII

DEFECTS OF THE FOUR GLAZES ON THE FOURTEEN ACCEPTABLE CLAY BODIES

Clay Body	Glaze A	Glaze B	Glaze C	Glaze D
1	S	Cz	..	..
2	Of, Cz	Cz	..	..
3	S	Cz	..	..
4	Of, Cz	Cz	..	..
6	Of, B, Cz	Cz	..	Uf
7	..	Cz	..	..
8	..	Cz	..	..
9	Of	Cz, Bb	..	..
10	Of	Cz	..	..
11	..	Cz	..	..
12	S	Cz	..	Cz
13	Of	Cz	..	..
14	S	Cz	..	..
15	Cr	Cz	..	..

Cz--Crazing; S--Shivering; Cr--Crawling; B--Blistering; Bb--Blebbing; Uf--Underfiring; Of--Overfiring.

satisfactory as to the fit of the glazes tested (See Figs, 2, 3, and 4). Three bodies--Nos. 9, 10, and 13--show a degree of promise in regard to glaze fit. Eight bodies--Nos. 1, 2, 3, 4, 6, 12, 14, and 15--needed body or glaze adjustment to make them acceptable.

Fig. 2.--Specimens of glazes A, B, C, and D (left to right), on clay body No. 7.

Fig. 3.--Specimens of glazes A, B, C, and D (left to right), on clay body No. 8.

Glaze texture.--Glazes are considered to have a texture which, if mature, is of two natures--transparent to opaque, and bright to mat. The transparent quality is clear and colorless; while the opaque quality is frosty like obscure glass. A bright glaze has a surface that tends to shine or

Fig. 4.--Specimens of glazes A, B, C, and D (left to right), on clay body No. 11.

Fig. 5.--Specimens of Glaze A on clay bodies Nos. 2, 13, and 11 (left to right).

reflect; while a mat glaze has a dull surface. The fired results of each clay body are shown in Table IX. It is interesting to note that the same glaze reacts differently on various clays. Glaze A is an example of the effect of the body on the texture of the glaze. Fig. 5 shows examples

TABLE IX

TEXTURE OF THE FOUR GLAZES ON THE FOURTEEN ACCEPTABLE CLAY BODIES

Clay Body	Glaze A	Glaze B	Glaze C	Glaze D
1	O, S-M	T, B	O, B	O, M
2	O, S-M	T, B	O, B	O, M
3	O, S-M	T, B	O, B	O, M
4	O, B	T, B	O, B	O, M
6	O, S-M	T, B	O, B	O, M
7	O, M	T, B	O, B	O, M
8	O, M	T, B	O, B	O, M
9	O, S-M	T, B	O, B	O, M
10	O, B	T, B	O, B	O, M
11	O, M	T, B	O, B	O, M
12	O, M	T, B	O, B	O, M
13	O, M	T, B	O, B	O, M
14	O, S-M	T, B	O, B	O, M
15	O, M	T, B	O, B	O, M

T--Transparent; O--Opaque; B--Bright; M--Mat; S-M--Semi-Mat.

of this effect on bodies numbered 2, 13, and 11. Glaze A, on six bodies--Nos. 1, 2, 3, 6, 9, and 14--fired to an opaque and a semi-mat texture; three bodies--Nos. 4, 10, and 13--fired to an opaque and a bright texture; and five bodies--Nos. 7, 8, 11, 12, and 15--fired to an opaque and a mat texture.

<u>Glaze color</u>.--Color in glazes may be due to the color of the clay, slip, or underglaze as seen through a transparent glaze; or glazes may be colored by metallic oxides which are dissolved in them. The combination of both clay and glaze make a wide range of color possible. This is quite evident in the results of the fifteen clay bodies and the four glazes used in this study. See Table X. The most noticeable range of color is found in glaze <u>A</u>. (See Figs. 6 and 7.) Three clay bodies--Nos. 7, 8, and 15--are dark gray-blue; two bodies--Nos. 11 and 12--are blue green to blue-green gray; and nine bodies--Nos. 1, 2, 3, 4, 6, 9, 10, 13, and 14--are the blue that would ordinarily be expected to result from the composition of the glaze.

Fig. 6.--Specimens of glaze <u>A</u> on clay bodies, Nos. 1, 2, 3, 4, 6, 7, and 8 (left to right).

The color of the body can be seen through the transparency of glaze <u>B</u> (See Fig. 8). The body colors revealed

TABLE X

COLORS OF THE FOUR GLAZES ON THE FOURTEEN ACCEPTABLE CLAY BODIES

Clay Body	Glaze A	Glaze B	Glaze C	Glaze D
1	Blue	Clear	Mingled Brown	Green
2	Blue	Clear	Mingled Brown	Green
3	Blue	Clear	Mingled Brown	Green
4	Blue	Clear	Mingled Brown	Green
6	Blue	Clear	Mingled Brown	Green
7	Dark Gray Blue	Clear	Mingled Dark Brown	Dark Green
8	Dark Gray Blue	Clear	Mingled Dark Brown	Dark Green
9	Blue	Clear	Mingled Brown	Green
10	Blue	Clear	Mingled Brown	Green
11	Blue Green to a Gray-Blue Green	Clear	Mingled Brown	Green
12	Blue Green to a Gray-Blue Green	Clear	Mingled Brown	Green
13	Blue	Clear	Mingled Brown	Green
14	Blue	Clear	Mingled Brown	Green
15	Dark Gray Blue	Clear	Mingled Brown	Green

Fig. 7--Specimens of glaze A on clay bodies Nos. 9, 10, 11, 12, 13, 14, and 15 (left to right).

Fig. 8--Specimens of glaze B on clay bodies Nos. 4, 6, 7, 8, 10, 12, 13, and 14 (left to right).

and enhanced by this glaze are as follows: body No. 1, off white; body No. 2, tan with brown flecks; body No. 3, red-buff with brown flecks; body No. 4, light red-buff with brown flecks; body No. 6, earthy red-brown; body No. 7, light blue-green; body No. 8, blue; body No. 9, red-brown with lighter and darker flecks; body No. 10, light red-brown with darker flecks; body No. 11, light buff with small dark flecks; body No. 12, white; body No. 13, brown; body No. 14, buff with red and brown flecks; body No. 15, off white.

The body color has affected the color of glaze C. It is most noticeable in bodies 7 and 8 (See Fig. 9). Also body color shows through in the variations of glaze D on these two bodies (See Fig. 10).

Fig. 9.--Specimens of glaze C on clay bodies No. 2, 3, 7, 8, 13, 14, and 15 (left to right).

Fig. 10.--Specimens of glaze D on clay bodies Nos. 2, 4, 7, 8, 11, and 13 (left to right).

Glaze tests for the remaining twenty-eight pots.--The two remaining biscuit-fired pots of each clay body were used to retest the two of the original four glazes which were best suited to the particular mixture as to fit, color, and texture. The glazes used on the pots of each clay body were as follows: clay body No. 1, glazes C and D; clay body No. 2, glazes C and D; clay body No. 3, glazes C and D; clay body No. 4, glazes C and D; clay body No. 6, glazes C and D; clay body No. 7, glazes A and C; clay body No. 8, glazes A and C; clay body No. 9, glazes C and D; clay body No. 10, glazes C and D; clay body No. 11, glazes A and C; clay body No. 12, glazes C and D; clay body No. 13, glazes B and C; clay body No. 14, glazes C and D; and clay body No. 15, glazes A and C. Thus, glaze C was retested on each of the fourteen clay bodies; glaze D on nine bodies--Nos. 1, 2, 3, 4, 6, 9, 10, 12, and 14; glaze A on four bodies--Nos. 7, 8, 11, and 15; and glaze B on one body, No. 13. The firing conditions were the same as those of the first two firings of each glaze. The retesting of the two specimens of each clay body produced the same results as those in the first two firings.

Evaluation of the Glazes in Relation to the Clay Bodies

Each glaze was evaluated as to fit, texture, and color in relation to the results of tests performed, using ten pots made from each clay body. It will be recalled that glaze A had various defects as to fit except on three bodies--Nos.

7, 8, and 11. Variations of texture from bright to mat were found in this opaque glaze when used on the different clay bodies. Also the different bodies caused the color to range from blues to blue greens. In addition it will be remembered that glaze B crazed on each specimen tested. Also it produced a transparent shiny surface on each pot. Glaze C achieved a desirable fit on each clay body and produced a shade of mingled brown on each clay body. Furthermore, each pot produced a shiny surface when this opaque glaze was used. Glaze D fit each body with two exceptions. Clay body No. 6 appeared underfired and clay body No. 12 crazed. The green color varied from light to dark green on two bodies--Nos. 7 and 8. This opaque glaze produced a mat surface on each pot tested.

Clay body No. 1.--Glazes C and D were both satisfactory for use on this body as they were free of defects and possessed a pleasing texture and color. Glazes A and B were undesirable as glaze A shivered and glaze B crazed.

Clay body No. 2.--Glazes C and D were successful on body No. 2 as they were free of defects and had a pleasing texture and color. Glazes A and B both crazed on this body.

Clay body No. 3.--As on bodies No. 1 and No. 2, glazes C and D were desirable because they were free of defects and had a pleasing texture and color. Glaze A shivered and glaze B crazed.

Clay body No. 4.--Glazes C and D were free of defects and had a pleasant texture and color when used on this body. Glazes A and B crazed. Also, glaze A appeared shiny and overfired.

Clay body No. 6.--Glaze C was the only glaze of the four tested which was free of defects. Glaze D seemed to be somewhat underfired. Glaze A blistered and glaze B crazed.

Clay body No. 7.--Glazes A, C, and D were free of defects and had a pleasant texture and color when tested on this body. Glaze B crazed, as it did on all other experimental bodies.

Clay body No. 8.--Glaze results for body No. 8 were the same as for body No. 7. Glazes A, C, and D were satisfactory and glaze B crazed.

Clay body No. 9.--Glazes C and D were free of defects when tested on this body. Glaze A was apparently overfired. Glaze B crazed.

Glaze body No. 10.--The results of glaze tests were the same for body No. 10 as for body No. 9. Glazes C and D were free of defects. Glaze A was overfired. Glaze B crazed.

Clay body No. 11.--As on bodies No. 7 and No. 8, glazes A, C, and D were free of defects on body No. 11. On this body glaze B crazed.

Clay body No. 12.--Glaze C was the only glaze of the four tested that was free of defects. Glazes B and D crazed. Glaze A shivered.

Clay body No. 13.--Glazes *C* and *D* were free of defects and had a pleasant texture and color when tested on this body. Glaze *A* had the appearance of being overfired. Glaze *B* crazed only slightly.

Clay body No. 14.--Glazes *C* and *D* were more desirable for this body as they were free of defects and had pleasant textures and colors. Glaze *A* shivered and glaze *B* crazed.

Clay body No. 15.--Glazes *C* and *D* were free of defects on this body and produced pleasant textures and colors. Glaze *A* crawled and glaze *B* crazed.

CHAPTER III

CONCLUSION

Evaluation of the Study

This study developed two very desirable clay bodies for thrown ware. They were clay bodies No. 7 and No. 11. Each of these bodies was outstanding as to throwing qualities of flexibility, plasticity, and ease of shaping ware. Also neither body had an excessive amount of shrinkage; so cracking or warping of the ware did not occur. Both bodies had interesting color and texture. Three of the four glazes tested on the two bodies proved to be satisfactory as to fit, color, and texture; on the other hand, glaze B crazed as it did on all of the other clay bodies tested.

The experiments also produced eight bodies--Nos. 2, 3, 4, 8, 10, 13, 14, and 15--which were satisfactory mixtures within limitations. Four of these bodies--Nos. 2, 3, 4, and 10--were adaptable for throwing a wide range of small to tall shapes; however, the fit of the glaze was not desirable as crazing, shivering, and overfiring occurred. Body No. 8 proved to be a most interesting body for glazes; however, it was limited to small and medium shapes. Three bodies--Nos. 13, 14, and 15--were adaptable to only small and medium shapes and glaze defects occurred in some cases.

Four bodies--Nos. 1, 6, 9, and 12--had defects which caused them to be less satisfactory than those mentioned above for thrown ware. Body No. 1 was only adaptable for throwing small shapes, and some glaze defects occurred. The three remaining bodies of this classification--Nos. 6, 9, and 12--were adaptable for throwing small and medium shapes; however, many glaze defects developed with the four glazes used.

One body, No. 5, was not acceptable for thrown ware. It would not hold a shape on the wheel; therefore, it was eliminated from further experiments.

Considerations for Further Experimentation

Further tests could be made in order to broaden the color and texture range of the two best clay bodies--Nos. 7 and 11. Also, further experimentation might improve the acceptable bodies, making them adaptable for throwing a wider range of shapes and improving the qualities needed for a good glaze fit, color, and texture. In addition, these bodies should be tested at different firing temperatures in order to find the ideal temperature each would need to mature.

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