

HIGH TEMPERATURE VITREOUS ENGOBES: A STUDY
IN THEIR FORMULATION AND CREATIVE USE

by 5791

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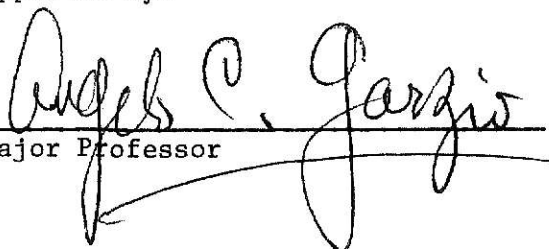
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PREFACE

The purpose of the study was to investigate the formulation of vitreous engobes for stoneware fired in reduction to Cone 8 (2300° F), and to assess their effectiveness as a decorative medium in conjunction with glazed areas and undecorated clay, thus providing a third surface, having somewhat the appearance of glaze or clay, yet with a unique quality of its own. It was further proposed to use one or more engobes, as appropriate, in a creative body of work.

Engobes or slips are suspensions of clay, in water, with other modifying ingredients such as fluxes or colorants, used to enhance the visual or tactile attributes of a ceramic object. They have been used to decorate pottery for at least 7,000 years, usually in a manner subordinate to the form.

The study may be divided into four parts; a review of the technical literature, a report and discussion of laboratory work on engobe formulation and, for the creative application of knowledge gained, the design, execution and installation of a ceramic mural. Finally, a personal appraisal of the work, and photographic presentation.

It was originally intended to utilize a clay body consisting in part of a local low-fire clay for a considerable part of the creative project. Laboratory work was completed but a selected clay body was used for only a relatively small portion of the mural, for reasons discussed in the text.

Sources of reference material include the Architecture Library, the Francis David Farrell Library, both of Kansas State University, the Manhattan Public Library and this writers' personal collection.

The reader is referred to the Glossary for a full explanation of terms.

CHAPTER I

REVIEW OF THE TECHNICAL LITERATURE

An engobe, or slip, is a coating of clay applied to ware prior to firing, usually at the leather hard state, in order to obtain a smooth surface on a rough clay body or to change the color of a clay body, with or without a covering glaze. The term is derived from the French, engober: to decorate with slip.¹

A discussion of engobes may be found in most publications covering the field of ceramics but the subject is often treated rather sketchily. Two valuable reference sources are the works of Daniel Rhodes and Cullen W. Parmelee. Rhodes (1957)² gives a brief but lucid chapter as applied to studio work, while the approach of Parmelee (1951)³ is that of the ceramic engineer and heavy clay products.

The terms engobe and slip are often used synonymously and indeed any differentiation may be arbitrary. Glenn Nelson (1970) makes the distinction that engobes are intended for use on greenware or bisque ware;⁴ slips are usually applied to plastic or leather hard clay. The term slip is also used to describe the more or less liquid nature of a mixture of ceramic materials, consisting largely of clay, in water.

¹Denis Girard et al., The New Cassell's French Dictionary (New York: Funk and Wagnalls Company, Inc., 1962).

²Daniel Rhodes, Clay and Glazes for the Potter (Philadelphia: Chilton Company, 1957), pp. 160-164.

³Cullen W. Parmelee, Ceramic Glazes, eds. E. D. Lynch and A. L. Friedberg (2d ed.; Chicago: Industrial Publications, Inc., 1951), pp. 241-269.

⁴Glenn C. Nelson, Ceramics (3d ed.; New York: Holt, Rinehart and Winston, Inc., 1970), p. 323.

Requirements

The physical properties required of an engobe, in order that it may be trouble free in service, are concerned with particle size, shrinkage, fit, physical integrity and vitrification. These are somewhat interdependant and are discussed below.

1. Particle size. Engobes will usually be prepared from glaze materials, i.e. 200 mesh or finer. This is required in order that materials may remain in suspension for a reasonable length of time. Ball clay finer than 200 mesh may be a cause of cracking after the high temperature fire;⁵ finely divided feldspar in suspension may yield sufficient alkali to alter the viscosity of a slip.⁶ This is not likely to present a real problem, as although engobes are usually of a higher viscosity than glazes, cracking during drying will indicate that the viscosity is excessive. Should viscosity prove to cause difficulty not controllable by decanting or adding water, the desired change may be effected by the addition of one half percent magnesium sulphate, or alumina sulphate,⁷ to thicken, or a deflocculant such as soda ash. H. E. Davis and J. S. Lathrop (1925) found that soda ash in amounts of less than 1 percent had no apparent fluxing effect (cone 4-5) and water content was reduced by 20-40 percent.⁸

2. Shrinkage and fit. The engobe must fit the clay body to which it is applied, in both drying and firing. In addition the engobe must be flexible enough to accommodate dimensional changes in the ware, during firing and

⁵Parmelee, op. cit., p. 260.

⁶Ibid., p. 252.

⁷Ibid.

⁸H. E. Davis and J. S. Lathrop, "A Study of Standard Finish Terra Cotta (Cone 4-5)," Journal of the American Ceramic Society, 8:27, January, 1925.

cooling. An engobe designed for use on leather hard clay, in which shrinkage will occur in drying, must have a greater degree of shrinkage than the ware to which it is applied, while engobes for greenware or bisque ware should have negligible shrinkage in drying. Relative shrinkage, or fit may be adjusted by the proportions of clay and free silica in the engobe or clay body, and are discussed below.

3. Physical integrity. An engobe should possess mechanical strength independent of the ware to which it is applied, so that it may be handled freely in the course of trimming, decoration and kiln loading. Mechanical strength may be achieved by the addition of a binder and is discussed below.

4. Vitrification. An engobe must be mature at a similar temperature to the clay upon which it is used. This may be effected by the judicious proportioning of flux, alumina and silica. At the same time it must resist being taken into solution by a covering glaze; this is controlled by selection of fluxes in the glaze and as lead is the chief offender this phenomenon is not a problem at stoneware temperatures.⁹

Materials

In it's simplest form an engobe may simply be the clay which is used for the ware; oxides are added and the resultant suspensions used as the decorative medium. The utility of such an engobe is rather limited;¹⁰

1. The engobe must be applied to freshly made pots; otherwise, if applied at a later stage it will almost certainly crack or peel off, as both engobe or clay body have the same rate of shrinkage on drying.

⁹Rhodes, op. cit., p. 163.

¹⁰Ibid., p. 160.

2. The only colors possible are those which are darker than the clay body.

In order to avoid these limitations engobes are compounded from a variety of materials and so designed that they have less shrinkage than the clay body upon which they are to be used. They are frequently made up of white firing clays so that full advantage may be taken of added coloring oxides.

H. G. Schurecht and J. F. McMahon (1937) caution that judicious selection of raw materials is essential to avoiding engobe or cover glaze defects; while these writers are concerned primarily with sprayed-on coats the effects of entrapped air is of importance in other application methods.

The adhesion between underslips and body or glaze is frequently broken in spots as a result of air being forced to the surfaces during spraying of successive wet coats of slip or glaze. These breaks, which do not always heal in firing, develop defects known as blisters, pin holes and round bare spots. This tendency may be reduced (1) by increasing the percentage of plastic clay in the underslip; (2) by spraying the underslip thinner; (3) by selecting more suitable ball clays; (4) by changing the raw materials and compositions of glazes; and (5) by using coarse in place of fine-grained bodies. It was found that blistering developed on bisque as well as on raw bodies. Many correlated glaze defects not visible on the dry specimens first appear after firing.¹¹

Coarse grain material in clay body or slip promotes retention of air pockets; if pores become filled with slip then blistering and possible consequent peeling from this cause will not occur.

The materials used in engobes may be categorized as follows:¹²

1. Clays. The clays used in engobes for stoneware are chosen for refractoriness, shrinkage traits and whiteness. Kaolin and ball clay are

¹¹H. G. Schurecht and J. F. McMahon, "Influence of Compositions of Underslips, Glazes, and Bodies on Blistering and Other Glaze Defects," Journal of the American Ceramic Society, 20:344, October, 1937.

¹²Rhodes, op. cit., p. 160.

usually used in combination as both possess complementary qualities of refractoriness, plasticity and shrinkage and fire white to a light buff. If more, or less shrinkage is required then the relative quantity of these clays may be adjusted without altering the chemical composition of the engobe. In most engobes the amount of these two clays together will total between 40 and 70 percent.¹³

2. Fluxes. Certain minerals are used to lower the fusion point of ceramic materials. Rhodes indicates that the best choice is feldspar¹⁴ but does not give a reason for his preference. Feldspar is a commonly used fluxing agent at high temperatures and indeed will form a glass without any additional materials. It also contributes alumina and silica to the mix.

3. Fillers. As a non-plastic ingredient to control shrinkage, calcinated clay, or more usually flint, may be used. Fifteen to thirty percent is usual in engobe compositions.¹⁵ Flint serves also as a refractory and whitener though in excess may be a cause of crazing.¹⁶

4. Hardeners. Borax or organic binders such as sugars or gums may be incorporated into an engobe to give some degree of protection from mechanical damage to the engobe layer prior to firing. The materials suitable for use as hardeners have inherent deficiencies. Borax is water soluble and may be depleted in use, absorbed into the clay body with the result that borax is not then available for binding, and possible over-vitrification of the body. Organic materials decompose and are a source of gas bubbles in the

¹³Ibid., p. 161.

¹⁴Ibid.

¹⁵loc. cit.

¹⁶Parmelee, op. cit, p. 247.

slip, and foul odors, although this process may be delayed by the addition of formaldehyde.¹⁷

5. Opacifiers. If used on a dark clay or one containing metallic particles which may bleed through the engobe coat, opacity may be increased by the addition of tin oxide or one of the commercial preparations of zirconium oxide such as Ultrox. A zirconium derivative would be preferable as tin is not only expensive but has a well known disastrous effect upon glazed ware when chromium is also present in the kiln, in a reducing atmosphere. Chromium and tin, even though in separate glazes tend to give a pink cast to the entire setting.¹⁸

Typical engobe compositions for stoneware are given by both Rhodes¹⁹ and R. T. Stull (1910),²⁰ cited by Parmelee, and although comparison is difficult as the two writers do not use precisely the same materials there is a general agreement. Rhodes comments that proportions are not critical, and that the formulation of an engobe suitable for a given clay body is not difficult. Soda ash in the amount of 1 percent has been omitted from Stull's limits in table 1, as has 5 percent of both borax and Zircopax in each of the compositions of Rhodes. Five percent of a leadless frit and 5 percent nepheline syenite have been omitted from the bisque composition of Rhodes. These materials were not common to both writers and made negligible difference to the overall picture.

¹⁷Rhodes, op. cit., p. 144.

¹⁸Ibid., p. 124.

¹⁹Ibid., p. 161.

²⁰R. T. Stull, "Notes on the Manufacture of Enamel Brick with some Investigations on Enamel Brick Slips," Transactions of the American Ceramic Society 12:711 (1910), cited by Parmelee, op. cit., p. 249.

Table 1
Comparison of Recommended Percentages of Engobe
Constituents for Stoneware; Stull and Rhodes

Material	Stull			Rhodes		
	Damp	Dry	Bisque	Damp	Dry	Bisque
Kaolin	55-65	--	15-25	25	15	5
Ball clay	10	--	10	25	15	15
Calcined kaolin	--	--	--	--	20	20
Feldspar	5-30	--	15-55	20	20	20
Flint	0-30	--	15-50	20	20	20

Color

Color may be achieved in engobes by the addition of metallic oxides, as in a glaze. At stoneware temperatures those most suitable are the oxides and carbonates of iron, cobalt, copper manganese, chrome, and rutile, an impure form of titanium. Colors resulting from the addition of these oxides either singly, or in combination are similar to those developed by the metals when added to glazes, within the same temperature range and kiln atmosphere, but may not be expected to attain the same degree of intensity. Compared to a glaze, engobes are quite opaque and light is reflected from the pigmented layer rather than refracted within a glassy matrix. In an engobe, oxides must be added in greater quantity than to a glaze, for a comparable hue. A full range of color is developed only when covered by a suitable transparent glaze.²¹

²¹Rhodes, op. cit., p. 162.

Rhodes²² and Parmelee²³ suggest percentages of coloring oxides; their opinions differ widely though both are treating of the same temperature range. From the context it is probable that the figures of Rhodes are for use in conjunction with a cover glaze while the higher values of Parmelee may be used alone.

Table 2
Comparison of Recommended Percentages of
Coloring Oxides, Rhodes and Parmelee

Oxide	Rhodes	Parmelee
Iron oxide	2-6	5-15
Cobalt oxide	1	2-10
Manganese dioxide	3-6	5-20
Combination, for black:		
Iron oxide	3	--
Cobalt oxide	2	20
Manganese dioxide	2	20
Chrome oxide	--	10

The addition of oxides, which have a fluxing effect, in excess of eight percent may necessitate a decrease in the constituent fluxes of the engobe. Smaller additions of the highly refractory chrome may require an increase in engobe flux.²⁴

²²Ibid.

²³Parmelee, op. cit., p. 268.

²⁴Ibid.

Variations of color may be attributed to several causes, for example

- (1) Variations in the thickness of the engobe coat;
- (2) Variations in the kiln temperature;
- (3) The slip may be under-, or over-fired;
- (4) If glazed, the coat may be too thick or fired for too long a time;
- (5) The glaze may be too chemically active and, therefore, attacks the engobe too freely;
- (6) The action of the oxides of sulphur in the kiln gases; and
- (7) The effect of reduction by the kiln gases.²⁵

Vitreous Engobes

A compound consisting largely of alumina and silica but containing more clay than is usual in a glaze and which attains some degree of glassification at the maturing temperature of the body to which it is applied, may be called a vitreous engobe. Such an engobe, although achieving maturity will retain the visual and tactile qualities of clay, and will not have the roughness of surface associated with an immature glaze.

Rhodes states that vitreous engobes are similar to glazes in their composition, and that 10-20 percent clay is usual, with a corresponding increase in the amount of flint.²⁶ Nelson recommends less than 25 percent clay if the engobe is intended for use on bisque ware.²⁷ Such engobes, with low drying shrinkage are best suited to application to greenware and bisque ware, with a resultant limitation in decorative techniques which may be employed. In addition engobes of this type, if they are to be glazed and are applied to bisque ware usually require a binder or hardener in their composition as they are glazed in the raw state and may flake off when loosened by water in the glaze.

²⁵Ibid., p. 269.

²⁶Rhodes, op. cit., p. 163.

²⁷Nelson, op. cit., p. 323.

Davis and Lathrop make the following recommendations regarding vitreous engobes.

- (1) A low clay content causes crazing
- (2) Too high clay content decreases vitrification and only between the limits of 30% to 50% can good vitreous engobes be obtained
- (3) Cornwall stone in quantities under 50% is beneficial. More than this produces crazing
- (4) Good slips are obtainable with feldspar content up to 35% and perhaps higher
- (5) Flint makes the slip more refractory and has a strong tendency to produce crazing.
- (6) Whiting in even very small amounts, decreases the firing range and up to 5% acts as a refractory
- (7) The addition of soda ash in the amount ordinarily used as an electrolyte has no apparent fluxing action.²⁸

A vitreous engobe with high flint content may suffer the defect of crazing. In a glaze silica becomes fused and does not change in volume during cooling. An engobe however retains some of the characteristics of a clay body and if silica remains in the crystalline phase it undergoes a dimensional change, at 573° C. Contraction of the clay body may be insufficient to put the engobe into compression with the subsequent crazing of the engobe layer. This may be compensated by a reduction of flint and increase of clay and flexes, in the engobe. "Numerous engobe compositions have been published containing flint, i.e., free silica, in a wide variety of proportions,"²⁹ and the problem may be apparent only where there is an uneven thickness of engobe such as edges and internal angles.³⁰ Engobe defects are discussed in greater detail below.

²⁸H. E. Davis and J. S. Lathrop, op. cit., pp. 27-28.

²⁹Parmelee, op. cit., p. 265.

³⁰Ibid., p. 260.

Preparation

The constituents of an engobe must be completely in suspension and remain so for a reasonable length of time; the use of finely ground materials is most beneficial in this matter, bearing in mind the detrimental effect of excessive grinding.

The material should be screened free of lumps and slaked in a sufficient quantity of water so that all particles may become thoroughly wetted. Excess water may be decanted at a later time though this should be kept to a minimum as insufficient fusion may be traceable to loss of the alkali content of feldspar previously discussed. The addition of a small amount of deflocculant may be beneficial in this matter, and the resultant increase in the fluidity of the slip will also facilitate the escape of trapped air bubbles. "The advantages of the use of 'thinning' electrolytes are apparent; the gas bubbles escape more easily and less water is present in the slip yet it remains suitably fluid."³¹ The slip is of course screened prior to use.

Defects

Engobe defects of concern to the studio potter are relatively few and have already been discussed to some extent. Rhodes comments that engobes usually have very wide tolerances in composition, application and firing range.³² Parmelee, concerned with industrial practices in a variety of circumstances elucidates every conceivable problem in that field.³³

³¹Ibid., p. 263.

³²Rhodes, op. cit., p. 160.

³³Parmelee, op. cit., pp. 257-266.

The optimum degree of maturity and whiteness is not difficult to achieve and most engobe defects relate to the question of fit and manifest themselves as cracking or peeling of the engobe coat on application or after firing. Causes of cracking and peeling, together with the remedy, are as follows:

1. Excessive shrinkage due to:
 - a) Too much plastic material. Some of the ball clay may be replaced by calcined ball clay or kaolin.
 - b) Too thick an application. The large amount of water is responsible for relatively greater shrinkage. Thicken the slip by decanting or previously deflocculate with small quantity, 0.2 to 0.3 percent soda ash.³⁴
 - c) The use of excessively ground materials; such as slip must necessarily contain a large amount of water in relation to the solid material held in suspension.
2. Lack of mechanical strength
 - a) Too much non-plastic material. Replace some of the kaolin with ball clay.
 - b) The use of excessively fine materials.
 - c) Ware design which contributes to an uneven thickness of the engobe coat, thus producing strain.
3. Too rapid drying. Cracks which develop in the engobe will not heal. Cracks in the ware will continue through the engobe during firing.
4. Engobes applied to ware with a dusty or greasy surface will have poor contact with clay body. Ware should be wiped with a damp sponge prior to application of engobe.
5. Engobes applied to greenware, bisque ware, or a second application to an engobe which has been 'fired-on' may lack intimate contact, and flake off prior to firing.
6. Pinholes and blisters are caused by gas trapped in or under the engobe, and may be obviated by careful selection of materials and attention to preparation and application.
7. The causes and resolution of the related problems of crazing and shivering present an anomalous situation in the study of engobes as these materials share characteristics of both clay body and glaze formulations, yet are neither.

³⁴Ibid., p. 252.

Concerning crazing, in an engobe, Parmelee recommends³⁵

1. Reduce flint and increase clay or fluxes.
2. Reduce feldspar and increase clay.

In the matter of shivering, Parmelee states

The role of free silica and siliceous clays in causing shivering, ... has been extensively discussed in ceramic literature.... Shivering, as previously defined, connotes the spalling of the slip (and glaze) coat from the body, carrying with it substantial portions of the body.... Because of the unfortunate misuse of terms, it is difficult to interpret some of the literature pertaining to these matters....agree that the presence of excessive amounts of free silica or siliceous clays in the body is the usual cause of shivering, per se.³⁶

It may be inferred that the solution in this case would be to increase the silica content of the engobe or increase the flux in the clay body.

Methods of Application

Engobes may be applied by the familiar glaze techniques of dipping, pouring, brushing, spraying, or by means of a slip trailer or syringe.

Because of the trait of shrinkage in drying engobes are usually applied to leather hard clay by any of the above techniques; an even, compact coat is most readily achieved by dipping or pouring, while brushing requires some experience. A sufficiently heavy application may be difficult to obtain by this last method on leather hard clay as the first coat does not become dry and is dragged off by the brush on successive coats.

Application at the leather hard stage not only ensures good adhesion between engobe and clay body but also allows full exploitation, with crisp delineation, of the sgraffito technique which involves cutting a design through the engobe to reveal the clay body beneath. In addition the engobe

³⁵Ibid., p. 265.

³⁶Ibid., p. 259.

coat may be fired-on and is thus not prone to damage through handling during subsequent decoration, neither will the engobe be loosened by the wetting action of a raw glaze.³⁷

Decoration on greenware or bisque ware is less satisfactory because of difficulties associated with shrinkage of the engobe or other mechanical damage.

Discussion

It is apparent, in reviewing the literature that engobes behave as clay bodies in matters of shrinkage and the effect of free silica upon their characteristics, yet also share some of the attributes of glaze in formulation, fit, usage and methods of application. Furthermore the literature consistently employs the terminology of glaze technology to processes and effects.

The logical extension would be to apply the methods of glaze formulation in order to assess the potential value of an engobe. Engobe composition is not nearly so critical as that of a glaze, and is concerned more with relative shrinkage than subtleties of flux-alumina-silica relationships. Expression of the constituent materials as a molecular formula may give a useful basis, with experience, for comparison of proposed engobes or if problems of fit should arise.

³⁷Rhodes, op. cit., p. 163.

CHAPTER 2

LABORATORY INVESTIGATIONS

Objectives

The term engobe is preferred to refer only to a slip compounded of two or more clays, often of varying plasticity, fluxes, non-plastic fillers, coloring oxides, opacifiers and binders. In the current study the following characteristics were sought in an engobe suitable for use on stoneware fired to Cone 8 (nominal 2300° F).

1. The engobe should be trouble free in application to raw (leather hard) clay, greenware, (dry but unfired clay) and bisque ware (ceramic objects fired to somewhat less than the maturing temperature of the clay body).
2. After application the engobe should be resistant to mechanical damage and non friable after bisque firing.
3. The engobe should become vitreous at Cone 8 (nominal 2300° F); the degree of fusion should be sufficient to avoid the rather rough, dry appearance characteristic of engobes and yet retain the visual and tactile qualities of clay so that a cover glaze is not required.
4. The engobe should possess sufficient opacity to allow coloring oxides to be added without the resultant color being affected by the color of the clay body beneath.

In the following pages the term 'peeling' is used if there was some buckling of the engobe coat upon drying, showing that the engobe was shrinking less than the clay body. 'Cracking' on the other hand is the result of the engobe shrinking more than the clay body. These phenomena were usually manifest prior to firing, thus the terms 'shivering' and 'crazing' were not used.

Methods and Materials

Throughout the study the prefix 'E' to designate 'engobe', and a numerical sequence, was applied to the tests. They were compounded to fit a stoneware body with cumulative shrinkage, in three equal stages, of approximately 14 percent. Later tests, formulated for the same clay body, bear the prefix 'M' and were prepared and tested specifically for the mural executed for the creative portion of the thesis requirement.

All engobe tests were fired in reduction to Cone 8. Whenever possible, related materials or a series of different materials undergoing comparative tests, were fired together.

Engobes E1, E2 and E3. Initially three engobes were prepared, based upon proportion, suggested by Rhodes and previously cited, for application to the three clay states, raw (E1), greenware (E2) and bisqueware (E3) as Table 3. The recommended 5 percent borax, to diminish the risk of mechanical damage

Table 3
Percentage Composition, Engobes E1, E2 and E3

<u>Material</u>	<u>E1</u>	<u>E2</u>	<u>E3</u>
<u>Kaolin</u>	25	15	5
<u>Ball Clay</u>	25	15	5
<u>Calcined Kaolin</u>	--	20	10
<u>Nepheline Syenite</u>	15	15	10
<u>Potash Feldspar</u>	--	--	10
<u>Talc</u>	5	5	5
<u>Flint</u>	20	20	35
<u>Superpax</u>	5	5	5

prior to firing was omitted due to problems associated with the solubility of that substance; it was not missed. The three engobes were each applied to the three clay states; after bisque firing a glaze with no known application problems was applied to one half of the tile; the other half was left unglazed for comparison and evaluation of color.

Tables 4, 5 and 6 summarize the mechanical status of the three engobes at various clay states.

1. When dry, following application to leather hard, greenware and bisqued clay.

2. After bisque fire of engobe applied to leather hard clay and greenware.

3. After glaze application to bisque ware, glaze dry.

4. After firing to Cone 8.

The positive sign (+) indicates that there was either no problem or no aggravation of a previously manifest problem.

Table 4
Physical Status of Engobe E1

Clay State	On Application	After Bisque	Glaze Application	At Cone 8
Leather hard	+	+	+	+
Greenware	+	+	+	+
Bisque ware	+	--	+	+

Engobe E1 brushed on quite smoothly, was not friable at any stage and was a fairly good white color.

Table 5
Physical Status of Engobe E2

Clay State	On Application	After Bisque	Glaze Application	At Cone 8
Leather hard	Peeled	Further peeling	Further peeling	+
Greenware	+	+	+	Minimal cracks
Bisque	+	--	Minimal cracks	+

Peeling was caused by the engobe shrinking more than the clay body. Cracking on bisque ware was caused by the engobe being loosened from test tile by water content of the glaze. Additional cracking in Cone 8 fire caused by unequal shrinkage of engobe and clay.

Table 6
Physical Status of Engobe E3

Clay State	On Application	After Bisque	Glaze Application	At Cone 8
Leather hard	Peeled	Further peeling. Friable	+	+
Greenware	+	+	+	Cracked
Bisque ware	+	--	Minimal cracking	Further cracking

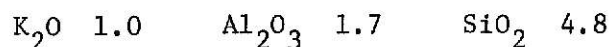
Causes of peeling and cracking as discussed for E2.

For reasons of mechanical failure only the engobe E1 could be considered as a potential base for further tests. Although satisfactory in application it was felt that some improvement in color and degree of fusion would

be desirable. While this would have been quite feasible, a fourth engobe, of a simpler composition, was tested.

Engobe E4. Review of the technical literature revealed that an engobe may be regarded as a specialized, somewhat immature glaze. From the previous three experiments it was evident that a material with a high degree of shrinkage was required for the clay body upon which the engobe was to be used. Previous experience indicated that a white firing stoneware body based upon recommendations of Rhodes,³⁸ had a known shrinkage of 17 percent when made up from glaze materials (200 mesh or finer).

To the extent that an engobe may be considered to be an immature glaze with rather special properties and characteristics, this composition, engobe E4, has the molecular formula



The batch formula:

Ball clay	30
Kaolin	40
Potash Feldspar	15
Flint	10

Compared to E1 this formula, while slightly reducing the flux content of the material (by five percent) increased the major plastic content (ball clay) by five percent and increased the total clay content from 50 percent to 70 percent.

Application proved to be trouble free on all clay states and there was

³⁸Rhodes, op. cit., p. 42.

no problem when applying glaze to the raw engobe. As expected, the increase in kaolin and ball clay improved the whiteness of the fired engobe.

This engobe was tested with metallic coloring oxides, singly and in combination, in varying percentages, for a total of 19 tests. The results are summarized in Table 7 below.

Table 7
Oxide Tests, E4, Without Cover Glaze

Test #	Oxide	%	Color
E4 Base	--	--	White
1	Red Iron Oxide (ferric)	2	Black
	Black Cobalt Oxide	2	
	Manganese Dioxide	2	
1a	Red Iron Oxide (ferric)	8	Warm Black
	Black Cobalt Oxide	1	
	Manganese Dioxide	3	
1b	Red Iron Oxide (ferric)	5	Black
	Black Cobalt Oxide	2	
	Manganese Dioxide	6	
2	Black Cobalt Oxide	1	Blue
3	Red Iron Oxide (ferric)	0.5	Grey Blue
	Black Cobalt Oxide	1	
4	Red Iron Oxide (ferric)	1	Light Tan
5	" " " "	3	Light Brown
6	" " " "	8	Rich Brown
7	Manganese Dioxide	6	Dark Brown
8	Chrome Oxide	2	Grey-green
8a	" "	3	" "
8b	" "	4	" "

Table 7 (continued)

Test #	Oxide	%	Color
9	Black Cobalt Oxide	0.5	Grey-blue
	Black Copper Oxide	1	
10	Black Iron Oxide (ferrous)	6	Brown
12	Cobalt Carbonate	1	Grey-green
	Chrome Oxide	2	
	Ultrox (Zirconium Oxide)	6	
13	Black Cobalt Oxide	1	Brown-black
	Red Iron Oxide (ferric)	3	
	Copper Carbonate	4	
14a	Black Copper Oxide	3	Grey-green
	Chrome Oxide	1	
14b	Black Copper Oxide	2	Grey-green
	Chrome Oxide	2	
14c	Black Copper Oxide	1	Grey-green
	Chrome Oxide	3	

Tests with the oxides indicated were also carried out using five transparent or translucent glazes, the results of which lie beyond the scope of this study. In general however the engobes were most effective with either a single or double application of either a semiopaque white glaze or one having some degree of inherent color.

Oxide tests 1, 1b, and 1c, were an attempt to obtain a good, rich, solid black; this was achieved with 1b. Tests in the 8 and 14 series sought to achieve green. This was not achieved due to the refractory nature of chrome and also the fact that full intensity is not realized without a cover glaze; an increasing percentage of chrome produced greens of slightly deeper tone but at the same time, surface texture became unduly harsh.

Other oxide combinations gave a range of blues, blacks and browns, of a wider range in actuality than the written word is able to describe.

Although the color range achieved was satisfactory within the limitations of the oxides used the unglazed surface quality of the engobe was still quite harsh, and a variation on the E4 engobe was formulated.

Engobe E4A. The engobe E4A is the same as E4, with the addition of five percent dolomite, for additional fluxing. Dolomite was selected as the flux, rather than simply increasing the feldspar, for three reasons

1. By introduction of a different flux, the desired effect would be achieved by a lesser amount of additional material, as more complex mixtures fuse more readily, and at a lower temperature than any of the component fluxes.³⁹
2. A relatively small increase in feldspar, of any type, which may still not have delivered the required extra fluxing, necessitating a further increase, would have upset the quantitative ratio of alumina and silica.
3. Excluding the feldspars, available fluxes useful at high temperatures are the oxides and carbonates of sodium, potassium, calcium, magnesium, zinc, barium, lithium and strontium.

Mineral sources of sodium and potassium other than the feldspars, are water soluble and were not considered (soda ash, borax, boric oxide, pearl ash). The carbonates of lithium and strontium were eliminated because of high cost.

Zinc oxide has a limited usefulness in the area of response to coloring oxides, while both zinc and barium in large amounts, over 0.3 molecular equivalents tend to cause a rough surface in a glaze. In a material which

³⁹Eutectic effect.

is inherently not smooth, such as an engobe the limit would presumably be lower.

The remaining possible materials were thus calcium and magnesium, which could have been obtained from whiting, CaCO_3 ; magnesium carbonate, MgCO_3 ; talc, $\text{MgO} \cdot 4 \text{SiO}_2 \cdot \text{H}_2\text{O}$; and dolomite, $\text{CaCO}_3 \cdot \text{MgCO}_3$.

Whiting, when present as the chief flux has good color response but tends to give a glossy surface texture; in small amounts it may behave as a refractory. Manganese carbonate produces a smooth 'fat' surface incompatible in large amounts with the essential quality of clay, which is the chief visual characteristic of an engobe. Talc was not considered as that material would have changed the ratio between alumina and silica. Dolomite, introducing two additional fluxes, each with desirable properties yet neither one dominant, and with no additional silica, remained, and appeared to be the ideal choice.

The new base engobe applied without difficulty and was fired to Cone 8; comparison with the original base, E4, indicated that still greater fluxing would enhance appearance and tactile qualities.

Engobe E4B. An increase of dolomite to ten percent resulted in an engobe which fused satisfactorily yet retained the quality of a clay surface, rather than having the appearance of an underfired glaze. Application traits did not appear to be affected by the additional non-plastic material. Color tests with the oxides in Table 7 were also essentially unchanged, even though the addition of ten percent dolomite did in effect radically change the nature of the engobe. From potassium being the chief flux it now played a lesser role. In addition, the alumina/silica ratio was slightly changed due to the relative decrease in the amount of feldspar as an ingredient in

relation to the batch weight. This may be clearly seen by a comparison of the molecular formulae for the original base, E4, and the third variation of that base, E4B.

<u>E4</u>	K ₂ O	1.0	Al ₂ O ₃	1.7	SiO ₂	4.8
<u>E4B</u>	MgO	.4				
	CaO	.4	Al ₂ O ₃	1.9	SiO ₂	5.9
	K ₂ O	.2				

Engobe E4B was considered satisfactory, with the reservation that further tests should be carried out in an effort to attain a wider range of color, and possibly a slight increase in vitrification. These are described in the 'M' series, below.

Before such tests were carried out, the feasibility of formulating a suitable engobe based upon pyrometric cone compositions was investigated. Engobes E5A and E5B. David Green (1963) published a table of typical molecular compositions of pyrometric cones. The formula of a hypothetical cone 10/11, selected because of a deformation temperature slightly higher than a typical stoneware firing would be:⁴⁰

K ₂ O	.3	Al ₂ O ₃	1.1	SiO ₂	11.0
CaO	.7				

Two engobes were prepared, E5A and E5B, compounded with kaolin and ball clay respectively in order that the influence on application or appearance, of non-plastic and plastic clays, without being modified by each other, might be observed.

⁴⁰David Green, Understanding Pottery Glazes (London: Faber and Faber Limited, 1963), p. 109.

Table 8
Batch Composition, Engobes E5A and E5B

Material	E5A	E5B
Potash Feldspar	16.7	16.7
Whiting	7.0	7.0
Kaolin	20.6	----
Ball Clay	----	20.6
Flint	45.7	45.7

As anticipated, the engobes varied widely in application characteristics.

Engobe E5A, containing only the relatively non-plastic, low shrinkage kaolin, peeled off completely upon drying after application to both leather hard clay, greenware and bisque ware. Tests were discontinued, as the material was obviously unsatisfactory.

After drying, engobe E5B, containing ball clay, showed slight deterioration due to a low rate of shrinkage even though ball clay was used, when applied to leather hard clay. The engobe was successfully applied to greenware and bisque ware.

Fired to Cone 8 the test of E5B produced one of those anomalies so trying to the potter. The engobe layer applied at the bisque state was glassified, while the other two were not; as the engobe did not contain any soluble material it must be presumed that this was caused by adventitious heat flow in the kiln. In a second test the phenomenon was not repeated.

Engobes E6 through E10. Following upon experience with the E5 series a number of engobes were prepared with the chemical composition of a series of pyrometric cones, within a range which might be expected to yield a workable

engobe. The range selected was cone 6 through cone 10; molecular⁴¹ and batch formulae are summarized in table 9. As ball clay appeared to satisfactorily fulfill the clay requirement in E5B, that material was used in the series E6 through E10. On leather hard clay there was minimal mechanical deterioration. There was slight further loss of engobe after bisque firing. The engobes themselves were sintered but there was poor adhesion to the clay body, which was considered normal for a low shrinkage vitreous engobe applied to raw clay. There was no peeling or cracking of the engobe when applied to greenware and they were not friable after bisque fire. Engobes applied to bisque ware showed no sign of disintegration.

Table 9

Molecular and Batch Formulae, Engobes E6 through E10

All Cones	6	7	8	9	10
K ₂ O .3	Al ₂ O ₃ .6	Al ₂ O ₃ .7	Al ₂ O ₃ .8	Al ₂ O ₃ .9	Al ₂ O ₃ 1.0
CaO .7	SiO ₂ 6.6	SiO ₂ 7.7	SiO ₂ 8.8	SiO ₂ 9.9	SiO ₂ 11.0
Whiting	70	70	70	70	70
Potash Feldspar	166.8	166.8	166.8	166.8	166.8
Ball Clay	77.4	103.2	129.0	154.8	180.6
Flint	232	306	360	414	468
Batch	546.2	646.0	725.8	805.6	885.4

Fired to Cone 8 all engobes were vitrified to some extent. The series was discontinued for the following reasons:

⁴¹Ibid.

1. Slight difficulty in application by brush; too much non-plastic material.⁴²
2. Mechanical deterioration of the engobe when applied to leather hard clay.
3. Vitrification had occurred to the extent that the engobes had the appearance of a slightly underfired glaze.
4. Slight yellow cast of the fired engobe, due to exclusive use of ball clay.
5. Engobe E4B appeared to be satisfactory, both on test tiles and in service.

Engobe E11. The E11 series was a variation on the theme of attempting to form an engobe in the manner of a glaze yet possessing characteristics such as plasticity, shrinkage and the physical appearance of clay. To this end a simple line blend of two materials was investigated; kaolin, a highly refractory clay, and albany slip clay, a fusible clay which melts to a greenish-black glaze at stoneware temperatures. A vitreous black engobe was sought.

	E11-1	E11-2	E11-3
Albany slip	70	50	30
Kaolin	30	50	70

The compositions were applied successfully to leather hard, greenware and bisque clay. Fired in reduction to Cone 8:

E11-1	Dull brown glaze
E11-2	Dull brown vitreous engobe
E11-3	Warm buff vitreous engobe

⁴²Professor A. C. Garzio has suggested that the addition of two percent bentonite would probably increase brushability.

Black was not achieved and the series was discontinued although Ell-3 was a buff vitreous engobe which indicates aesthetic possibilities. All three compositions worked well in combination with transparent or translucent glazes.

'M' Series. A critical appraisal of the E series tests revealed that very few of them satisfied the second criterion in regards to suitability for use as a surface cover, by themselves; the 'M' series was a final attempt to rectify this:

1. Selected compositions from the E4B series were used by themselves, for comparison with previous tests, and with additional opacifying and fluxing agents.
2. Base engobe E4B with previously untested combinations of coloring oxides.
3. Engobe Ell-3 as originally tested and with additional flux.
4. Two tests incorporating Tuttle Creek clay, a local ferruginous surface clay, with kaolin, based upon the Ell series.

Compositions are shown in table 10, half of each tile was given a base coat of white engobe but this did not appear to have any marked effect upon color, due to the essentially opaque nature of engobes.

Table 10

Composition and Color Response, 'M' Series Engobes

Test #	Composition	%	Alone	White base
M1	E4B Base	--	White/buff	No change
M2	E4B + Ultrox	5	White. Peeled	No change
M3	E4B + Dolomite	5	Buff	White

Table 10 (continued)

Test #	Composition	%	Alone	White base
M4	E4B + Dolomite	10	Grey. Peeled	Peeled
M5	E4B 1B	--	Black	No change
M6	E4B 1B + Dolomite	5	Black	No change
M7	E4B 2	--	Pale blue	Medium blue
M8	E4B 2 + Dolomite	5	Medium blue	Darker
M9	E4B 7	--	Medium brown	Lighter
M10	E4B 7 + Dolomite	5	Medium brown	Lighter
M11	E4B 9	--	Grey-blue	Pale blue
M12	E4B 9 + Dolomite	10	Grey-blue	Pale blue
M13	E4B + Cobalt Oxide and Chrome Oxide	2	Green-blue	No change
M14	Dolomite	10		
	E4B + Cobalt Oxide and Chrome Oxide	2 5	Green-blue	No change
M15	E11-3	--	Warm buff	No change
M16	E11-3 + Dolomite	5	Warm buff	No change
M17	Tuttle Creek Clay	30		
	Kaolin	70	Light tan	No change
M18	Tuttle Creek Clay	30		
	Kaolin	70	Light tan	No change
	Dolomite	5		

Additional fluxes also had no apparent effect upon color of the control tiles; there was slight increase in sheen of the fired surface.

Discussion

Formulation of engobes to fit a given clay body, in the leather hard, greenware and bisque states was not difficult, by application of the known traits of plastic, non-plastic, fusible and refractory ceramic materials. An engobe was produced which adhered well to unfired clay, and which could be applied in a second coat prior to bisque fire. Although shrinkage after bisque firing was approximately 10 percent the engobe base possessed sufficient flexibility to be used at that time although occasionally minimal peeling occurred. Four engobes of the base E4B were used by an estimated fifty undergraduate and graduate students in the ceramics department for one semester prior to the writing of this study. These were the engobes E4B-1B; E4B-2; E4B-7; and E4B-9, usually with a cover glaze.

Vitreous engobes, suitable for use without a cover glaze had been achieved in the E4B series; a moderate increase in dolomite content, five to ten percent resulted in a more mature engobe. Some of these were slightly rough in texture, yet fused and in no degree porous.

Color range was limited to the earth colors as might be expected in high temperature work; the tones were muted and did not achieve full density without the use of a cover glaze. Exceptions to the earthy quality were tones of blue and green, achieved by the addition of cobalt and chrome.

The writer feels that the E4B base engobes, as tested, without a cover glaze are best suited to sculptural forms, which are least likely to be finger marked by handling. Engobes in the 'M' series appear to be suitable for any purpose, possessing excellent qualities in regard to application and a unique surface character, having a slight sheen yet claylike in density, to the touch.

Recommendations

Based upon the extent of laboratory investigations described, the following recommendations are made:

1. Insofar as the bisque state is the least satisfactory so far as decorative techniques are concerned, and in this study occasionally was the cause of the problem of the non-adhesion of engobe, it is unlikely that an engobe will be readily found which may be applied to all clay stages, due to differing shrinkage requirements.
2. If it is considered essential to have a vitreous engobe which may be applied to all clay states, a modification of the series E6 through E10 may prove responsive to the addition of ball clay; this would alleviate to some extent the four deficiencies.
3. Cool tones may perhaps be intensified by the addition of barium carbonate as a flux. As tin is now little used by studio potters, zinc may also be beneficial.

A Stoneware Body

It was hoped that the creative portion of the thesis requirement would be executed in a clay body comprised of fireclay plus the ferruginous surface clay found in the vicinity of the Tuttle Creek Dam and the Big Blue River, on the boundary between Riley and Pottawatomie Counties, Kansas.

Upon learning that the removal of clay (or anything) from state or federal land is prohibited by law, the intention was abandoned and the body formulated was used only to a limited extent in the mural.

Tuttle Creek clay is of a very fine particle size, contains a small amount of non-plastic material in the form of limestone nodules, and flint fragments. At cone 08 (nominal 1750° F) in oxidation the color is a bright orange-red; the clay melts to a stiff brown glass at cone 8 in reduction. Maturity as a clay body occurs at cone 1 (2060° F); color at this temperature, in oxidation, is a slightly glossy, rich iron brown.

A total of eighteen bodies were tested using equal quantities of two Missouri fireclays. The A. P. Green Company of Kansas City, Missouri supply dry milled fireclay. Hawthorne bond clay is distributed by L. & R. Specialties, Springfield, Missouri. These were used in combination with from two to fifty percent Tuttle Creek clay.

Fired in reduction to cone 8 there was no bloating. The mean of three tiles of each composition showed cumulative shrinkage of 12 to 13.5 percent while absorbtion ranged 0.8 to 1.5 percent with no readily discernible correlation between these two phenomena. Up to 30 percent low-fire clay content, the fired color varied widely and appeared to be related solely to the position of the test tile within the kiln. From 30 to 50 percent Tuttle Creek clay content, tiles scattered throughout the kiln showed an increasing richness of color, being darker with an increasing percentage of ferruginous clay.

The clay bodies threw well with the reservation that above 40 percent Tuttle clay, wet strength is low; in addition, stickiness of the clay makes cleanup somewhat difficult.

CHAPTER 3

STUDIO PROJECT: THE MURAL

A stoneware mural was selected for the studio project as being a legitimate form of expression for a worker in clay and a significant continuation of the learning process. It was also a departure from the more traditional role of the potter as a provider of utilitarian ware, a fulfiller of physical needs.

Design

After having spent the past several years living in a region of forests, mountains and lakes, the writer was somewhat unprepared for the gentler aspects of the Kansas landscape. With the coming of fall, crops were harvested, leaves withered, died, enjoyed a passing splendor, and were gone. The land waited. The forces of nature are supremely indifferent to the works of man and soon all but the cities was occupied, without stealth, without violence, without reason, by snow; and man rejoiced in the simplicity of it, or became (once again) resigned, seeing the season only as a time to be endured rather than welcoming the renewed challenge to see and feel the beauty of their land.

At this time of year sheltered areas may lie deep under drifted snow, while more exposed tracts are swept clean by a scourging wind, revealing the soil, black, and red. Waters are stilled yet under a winter sun a hint of intense summer blue remains. Architecture of rocky bluffs is made manifest in ever changing intricacy as snow falls, drifts and melts. Viewed thus, the scale small enough that individual relationships of form may be discerned, there is an impact upon the senses that may perhaps not be recognized

when surrounded by walls of rock and glaciers which are a familiar presence. Delight in natural forms is enhanced by oblique rays of the winter sun, itself but a shadow of summer glory yet charged with significance as the prime supporter of life.

The WINTER mural was created in an attempt to give visual form to these feelings.

Administrative officers of the Kansas State Union, the social, cultural and recreational student facility of Kansas State University, Manhattan, indicated that they would look favorably upon a proposal for adding visual stimulation. They suggested two areas where a mural might be mounted. In addition it was agreed that the cost of materials up to one hundred dollars would be made available and that the wall would be suitably prepared and a baseboard provided and installed. The wall at the entrance to the Stateroom Cafeteria was chosen. At the time the wall was 20 x 8 1/2 feet and covered with a zebra-stripe wallpaper. The width available for the mural was reduced to 18 1/2 feet prior to commencement of the design, by the planned addition of a folding door. The alternative site was the west wall of the corridor fronting the Catskeller.

Size of the mural was planned to be limited to 60 square feet of baseboard for four reasons.

1. That area would allow the baseboard to be cut from two standard 8 x 4 foot sheets of plywood with some material remaining for contingencies.
2. With approximately three inches overlap all round, so that the baseboard would not be seen, the area could be accommodated in three glaze firings in a 20 cu. ft. kiln, in sections approximately 8 x 11 inches.
3. Cost of materials other than baseboard and wall paint would be limited to approximately one hundred dollars.

4. The project could be completed within a reasonable period of time. Four weeks were available between spring semester and summer session and it was anticipated that the execution would require the full time use of most of the space and all kilns in the ceramics department.

Several formats were drawn to scale. The configuration of one panel 5 x 6 feet mounted horizontally, with two panels 5 x 3 feet mounted vertically, with regular spacing, was chosen. This was the most pleasing of the layouts (Plate I) and related to Man in proportion and scale.

In order to allow at least a one inch overlap around the baseboard, and taking into account the fact that the clay body to be used had a total shrinkage of approximately 14%, it was calculated that each section of base tile should measure $7 \frac{3}{4} \times 10 \frac{3}{4}$. These would shrink five percent in drying and thus it would be possible to accommodate four tiles to a shelf 11 x 28 inches in the large gas kiln. Thus an area of a small panel would measure $46 \frac{1}{2} \times 75 \frac{1}{4}$ inches wet and consist of six tiles horizontally and seven tiles vertically. When completed it would measure approximately 39 x 74 inches. Individual tiles to be mounted with screws.

After a number of preliminary drawings a scale model, in color, of cardboard and spackling compound was accepted, with the reservation that the center panel should be less complex in organization.

A schematic presentation of the panels is shown in Plates II and III. In keeping with the theme of winter, the surface decoration is subdued and achieved by three engobes from the present study, one basic glaze and iron oxide sprayed onto otherwise undecorated clay. Viewed from left to right the panels are subtitled SUN, LAND, and SNOW.

Although the winter landscape very often appears serene there is yet a quality of savage strength contained within it. Simple flared cylinders,

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EXPLANATION OF PLATE I

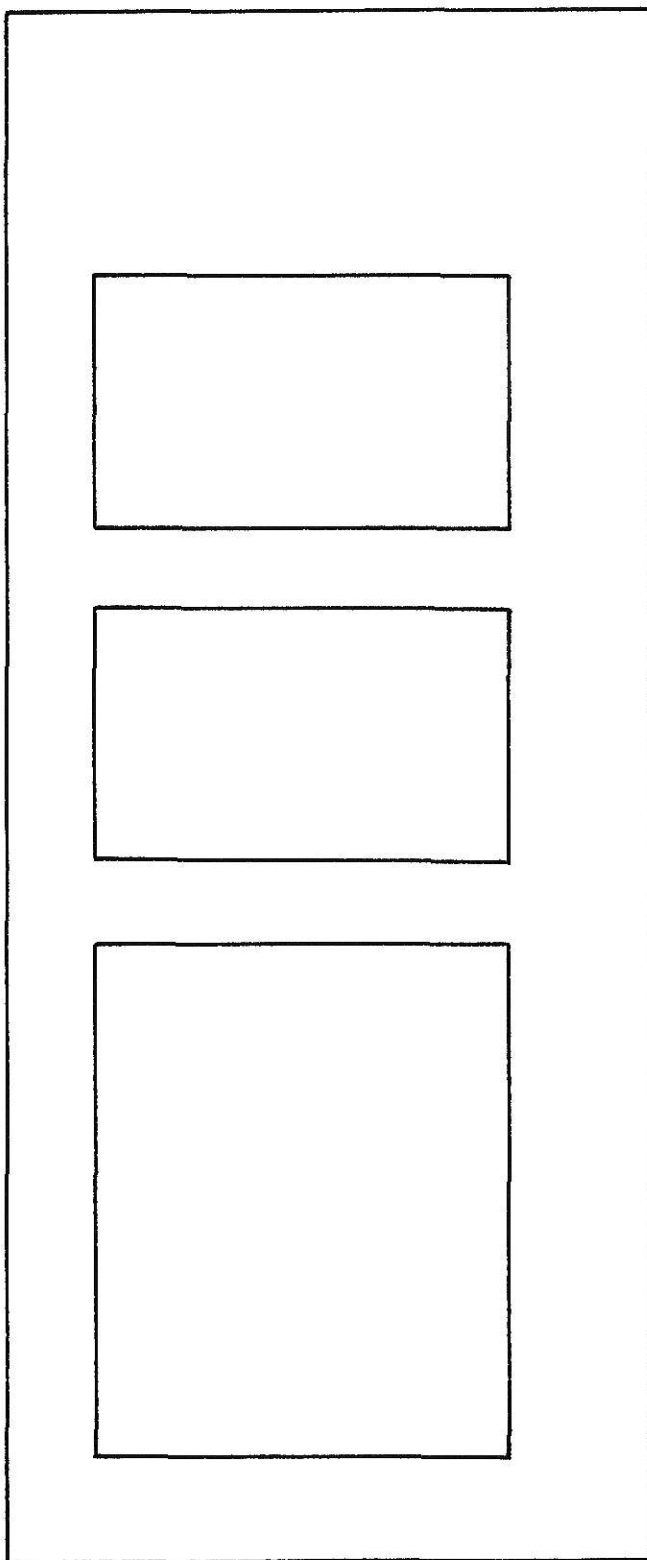
CONFIGURATION OF PANELS ON THE WALL

The panels appear displaced to the left as it was planned to install a sliding door, taking up 18 inches, on the right hand side of the wall.

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WITH DIAGRAMS
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PLATE I



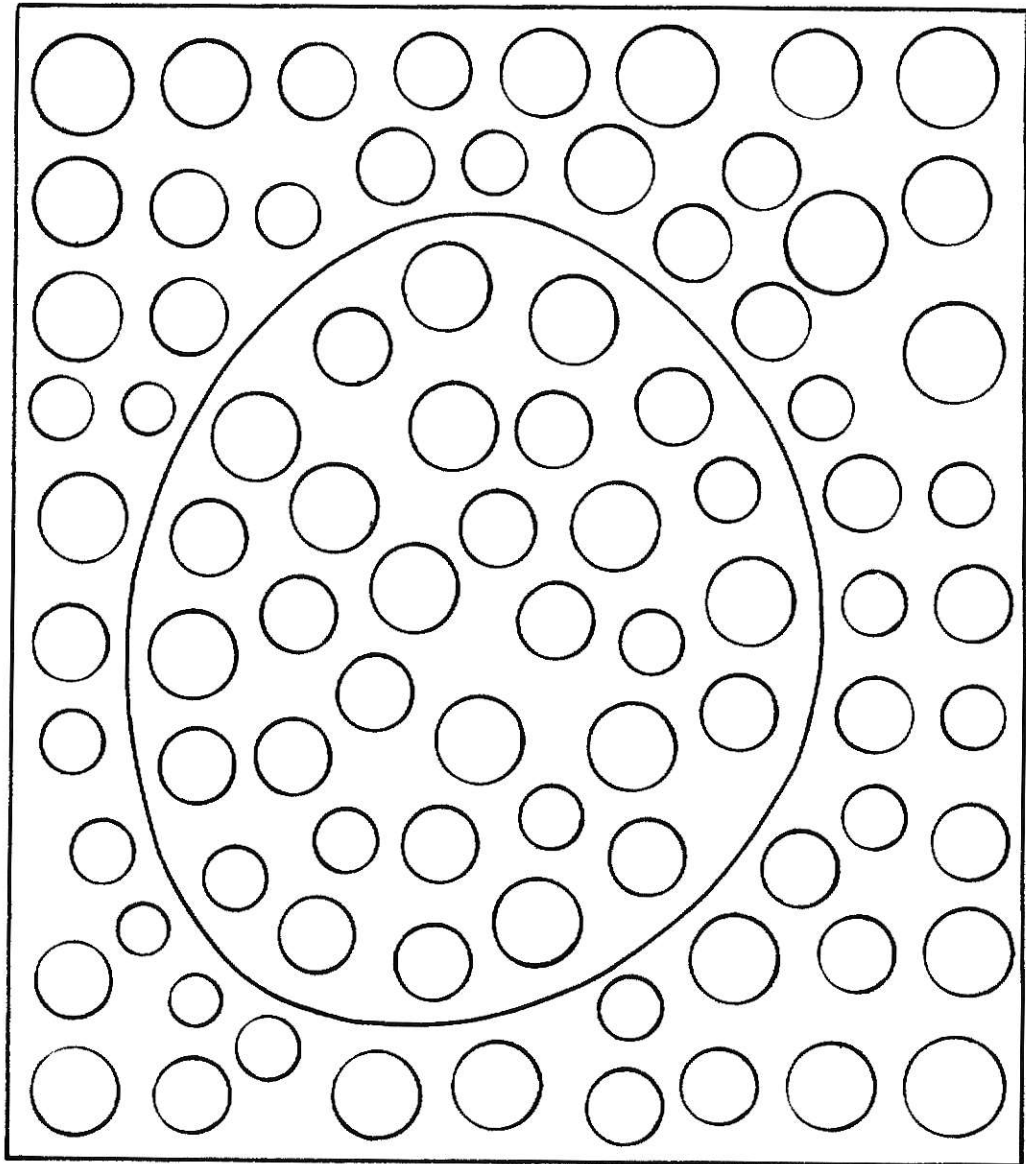
EXPLANATION OF PLATE II

SCHEMATIC DESIGN OF SUN PANEL

Wheel thrown cylinders, with everted lips or flared bases in an overall kinaesthetic composition.

The central area of Fireclay sprayed with iron oxide; surround decorated with black engobe and white glaze.

PLATE II



EXPLANATION OF PLATE III

Fig. 1. SCHEMATIC DESIGN OF LAND PANEL

- A. Flat tiles sprayed with iron oxide; earth
- B. White glazed tiles with clusters of wheel thrown shapes; the works of man received back into the land with the advent of winter.
- C. Flat tiles with a covering of black vitreous engobe; rock.
- D. Vertical ribs decorated with blue and vitreous engobe and turquoise glaze; water
- E. Superimposed massive slabs, white glaze; winter landscape

Fig. 2. SCHEMATIC DESIGN OF SNOW PANEL

Top and bottom sections of white glazed tile, with wheel thrown elements; man made structures. Circular area, a sun motif, raised up from general level of baseboard. Vertical ribs, of unglazed clay. Textured area, partially glazed or raw clay, principally black engobe; winter landscape.

PLATE III

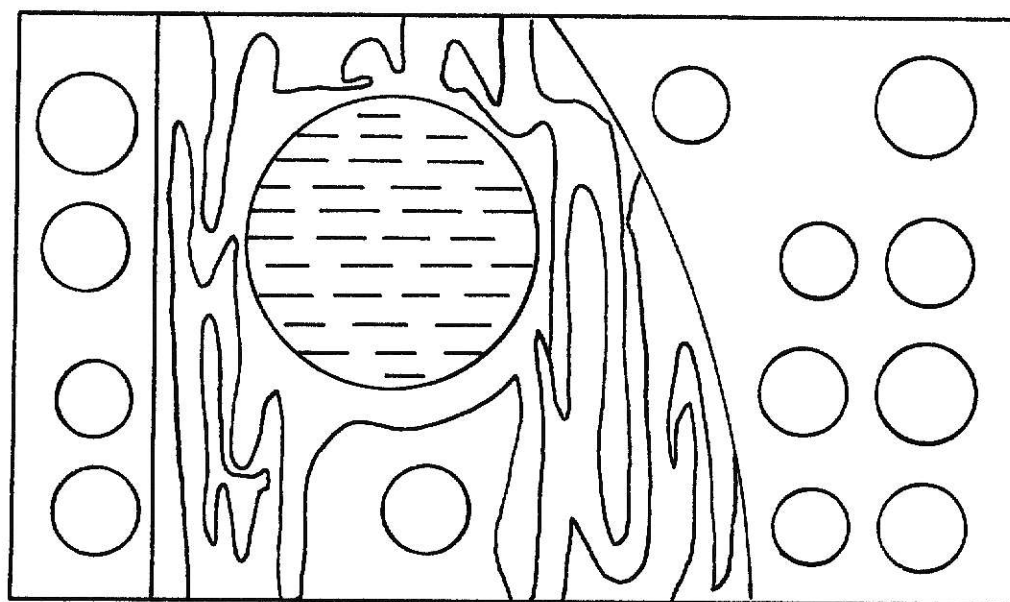


Fig. 2

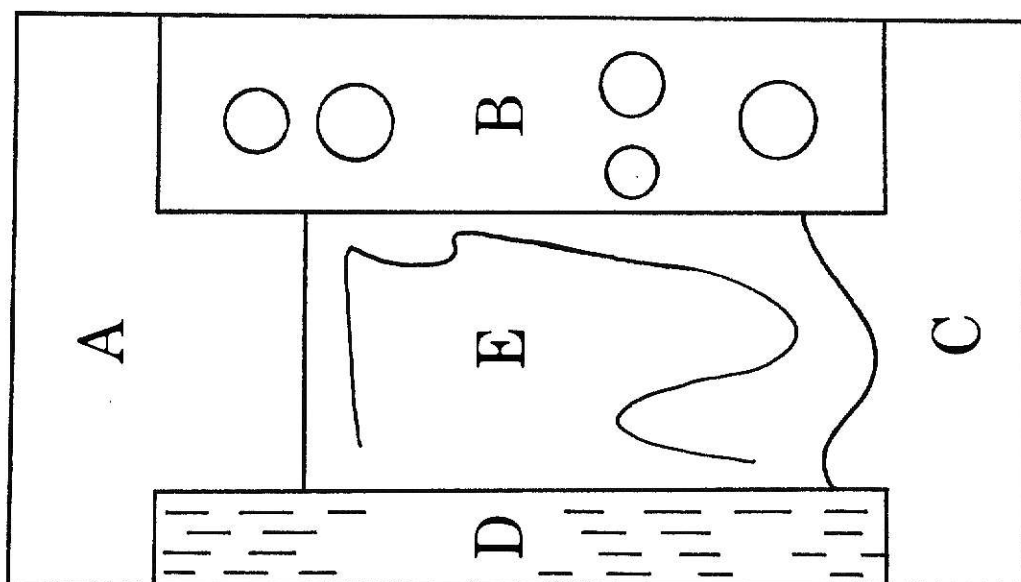


Fig. 1

thrown on the potters wheel were selected as a prime decorative motif as these are one of the most powerful basic natural forms, and when mounted horizontally contain within their depths an element of mystery and power. A complementary quality of febrile energy and shifting movement was to be achieved by juxtaposition of small clay slabs mounted on edge close together, giving an interplay of light and form. In yet another area large, massive superimposed slabs, glazed white would symbolize snow covered land while glazed domed areas and stark, flat, rust colored and black tiles would be representative of the earth.

Execution

In order to have adequate working space without totally disrupting the ceramics area while classes were in session the mural was constructed in the four week period between the end of the spring semester and the start of the summer session 1971.

A log was kept of time actually spent working with clay, including mixing clay, throwing, assembling, trimming and firing, which was in excess of 260 hours.

Materials. Materials used are described below. Because of the previously discussed problem of collecting clay from federal or state property, it was planned to use the regular clay body of the ceramics department for the major part of the mural. Due to short supply of bond clay it was recommended that dry milled fireclay be used; although this was not the body upon which engobes were tested, shrinkage rate was essentially the same, approximately 14%.

1. Eight hundred pounds of dry milled fireclay plus five percent feldspar was prepared in the Walker pug mill, and allowed to age for at

least three days before using. Considering the nature of the material and short aging period, it was surprisingly plastic in use.

2. Six hundred pounds of clay body prepared with 50% Tuttle Creek clay, 25 pounds fireclay and 25 pounds bond clay.
3. Five pounds of clay body consisting of 50% Endicott clay, a red-burning stoneware clay, and 50% dry milled fireclay.
4. Approximately 20 pounds (9,500 grams) glaze of the writers formulation:

Dolomite	64.4
Whiting	5
Potash Feldspar	139
Kaolin	64.5
Flint	90

Five hundred grams of this was used as a turquoise glaze by the addition of 0.35 percent black cobalt oxide and 0.6 percent chrome oxide. The remaining 9,000 grams was made into a white, matt glaze by the addition of five percent ultrox.

5. Approximately 15 pounds (7000 grams) of the previously described E4B-1B engobe, and 300 grams each of the M14 and E4B-2 engobes.
6. Suspension of red iron oxide in water, approximately 25 grams.

In addition 1 1/2 pounds of paraffin wax was used in decorating processes; two quarts of latex paint was used to prepare the baseboard, to which tiles were attached by approximately 400 round head wood screws.

Equipment. Tools used included the potters wheel and other equipment of the potters craft. Wooden planks, hammer and nails, newspaper were utilized in construction and preparation of a retaining frame during mural assembly; drying racks were improvised; both gas and electric kilns were used.

Frame. Two frames, of three-quarter inch board were laid out and nailed to a wooden floor. The method shown in Plate IV, with boards overlapping at the ends so that it was not necessary to cut the boards to an exact length.

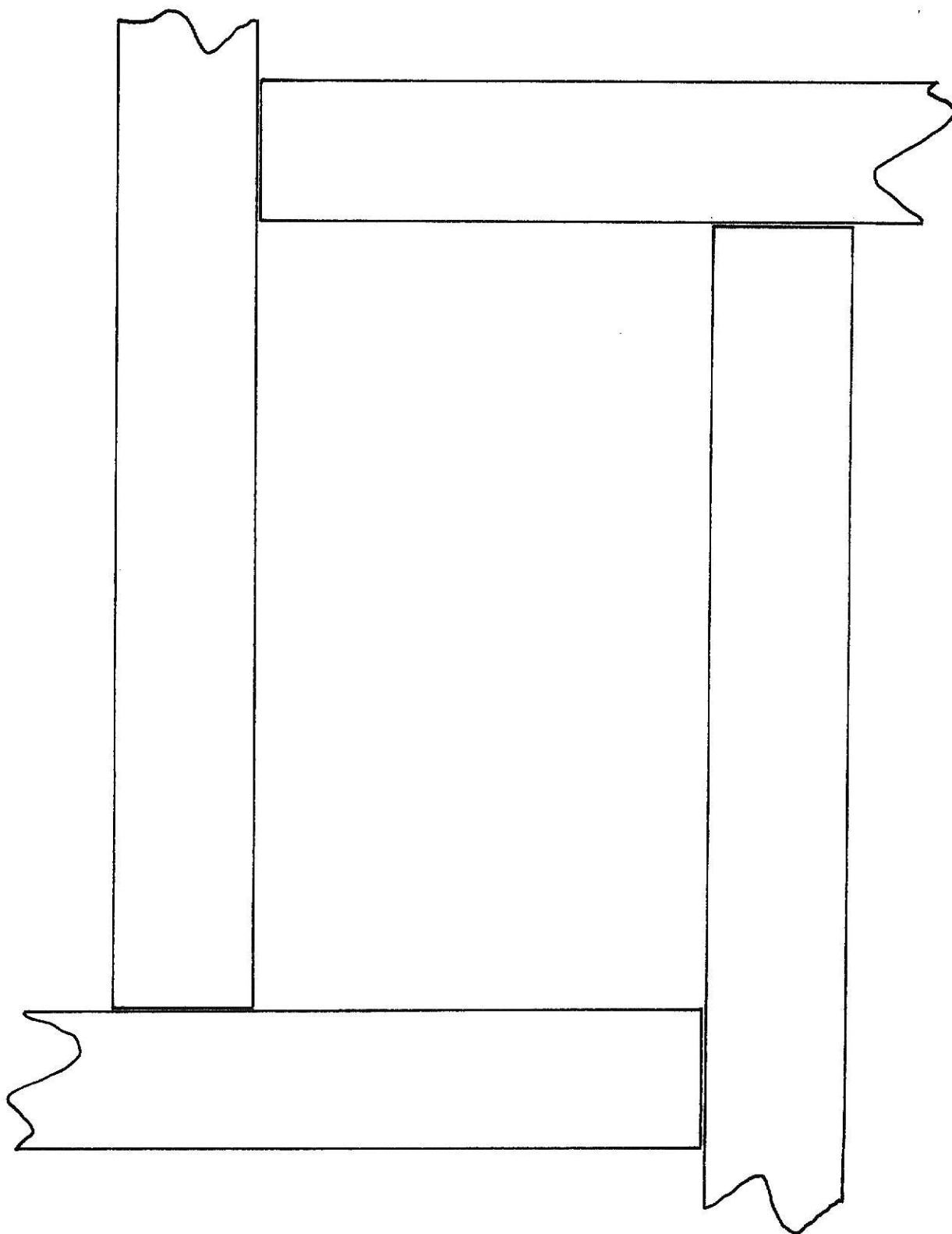
Tile Base. In order to minimize warping and cracking, clay tiles must be free of stress in the forming process; rolling does not fulfil this requirement as directional strains are set up and rectangular tiles tend to dry in

EXPLANATION OF PLATE IV

LAYOUT OF FRAME

By overlapping planks in the configuration shown it was not necessary to cut them; the proportions desired may be readily secured and are infinitely variable.

PLATE IV



the configuration of an irregular parallelogram. The floor was covered with newspaper, so that clay would not stick to it; the frame was then filled by forcibly throwing handfuls of clay to the floor, to disperse air pockets, thumbing together and then scraped smooth. The completely filled frame was then lightly marked off in $7 \frac{3}{4} \times 10 \frac{3}{4}$ inch rectangles. In order to reach the center a plank was laid across the boards forming the sides of the frame. Bernard Leach (1945)⁴³ suggests that tiles be cut half way through and separated at the leather hard stage. This was not followed as the area was so large and in addition some areas were to have attached elements or strong texture which would have made it difficult to guide the knife. Variations to this method of basic preparation were as follows:

SUN. The panel at left was prepared as described, half of the panel each frame. A full size paper template was used to delineate the boundary of the roughly circular central area, folded so that the two segments would line up when assembled. The clay base was then cut right through to the floor with a potters knife, in order to lessen the danger of cracking during initial shrinkage.

LAND. After filling with clay as described, superimposed clay slabs were attached to the central area. Sections were then cut right through to the floor.

SNOW. Upper and lower thirds of the right hand panel were prepared as described. The central third, of heavily textured clay, was built up directly, while the cut out circular motif was constructed separately. Top and bottom sections were cut through, to receive thrown elements, while the textured area was cut completely through, following as much as possible the direction of the form.

Construction. The tile base was allowed to stiffen for two days prior to attachment of thrown and small slab elements, which would tend to dry out more rapidly than the thick base tile. During this time thrown and slab elements were prepared. The construction of individual panels is discussed

⁴³ Bernard Leach, A Potters Book (2d ed. London: Faber and Faber Ltd., 1945), pp. 97-99.

below.

SUN. (Plate VIII) Cylindrical elements were thrown on the potters wheel, using wooden bats for the larger pieces so as to avoid distortion. When leather hard they were laid out to cover five or six tiles at a time and arranged so that integration and a continuity of design was achieved. Cylinder and tile were scored, smeared with slip, rammed together and the seam smoothed over with the thumb. Preliminary trials had shown that it was not necessary to 'weld' the two clay surfaces together. Plate V Fig. 1 shows a section under construction and is typical of the method used throughout the work. In order to reach the central portion, a board was placed across the level clay surface, resting upon the sides of the frame. Holes for screws were punched with a pencil after completion of assembly of each individual tile.

LAND. (Plate IX) Cylindrical elements were attached as described above. The ribbed vertical relief at the left side is composed of thinly rolled clay slabs which were attached with slip. Clay slabs were attached with slip to the central area during initial layout of the panel. After assembly screw holes were punched as previously described.

SNOW. (Plate X) Construction of the tile base and strongly textured area were accomplished at the same time, as described above. Wheel thrown elements were attached by scoring and with slip, with an area cut out of the tile so that air would not be trapped in hollow stems and domes as this would cause cracking during drying or bursting during bisque or glaze fire. The circular sun motif was constructed separately, of a clay body containing 50% Tuttle Creek clay, and 50% fireclay; this clay body has a rate of shrinkage similar to the one used for the rest of the panel. The lighter colored uprights are a body of 50% Endicott clay and 50% fireclay.

Drying. After assembly the panels were allowed to stiffen for a further two days, by which time the base tile was dried out to the leather hard state. The rear face of each tile was cut out in grooves so as to reduce weight and minimize warping. Textured parts of the SNOW panel were carved out at the rear, while thick sections which could not conveniently be hollowed out, or which needed to provide support were pierced with a pointed wooden tool in order to reduce the effective thickness. Edges of tiles were bevelled so that if slight warping occurred they would still fit together at the edges. Screw holes were enlarged with a quarter inch twist drill. The second key

EXPLANATION OF PLATE V

Fig. 1. DETAIL OF ASSEMBLY

Tile base and thrown elements scored and attached with slip, following standard practice. Clay surfaces did not need to be 'welded' together as the sections could be rammed into intimate contact and the joint smoothed over with the thumb.

Fig. 2. DRYING

When able to support their own weight without deformation tiles were placed across two kiln posts to achieve maximum air circulation.

**THIS BOOK
CONTAINS
NUMEROUS
PICTURES THAT
ARE ATTACHED
TO DOCUMENTS
CROOKED.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

PLATE V

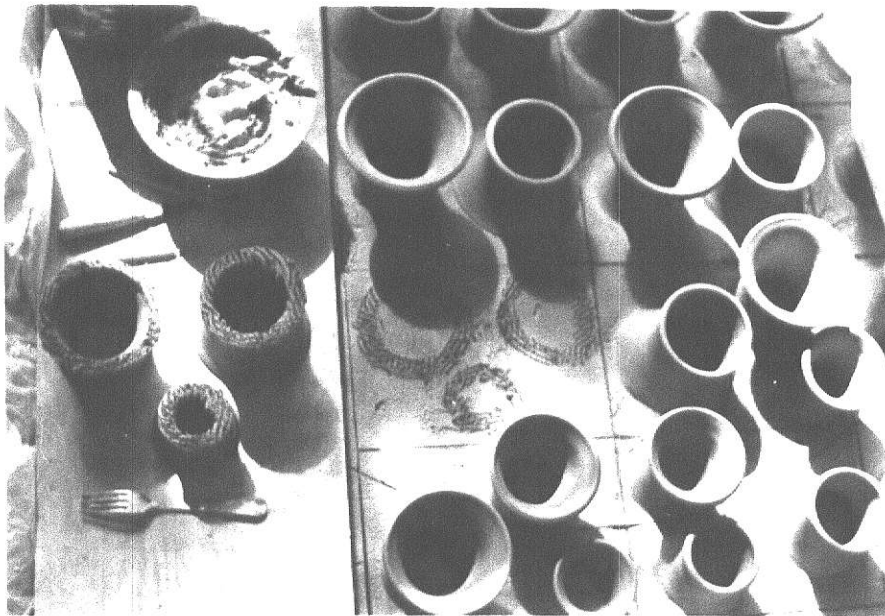


Fig. 1

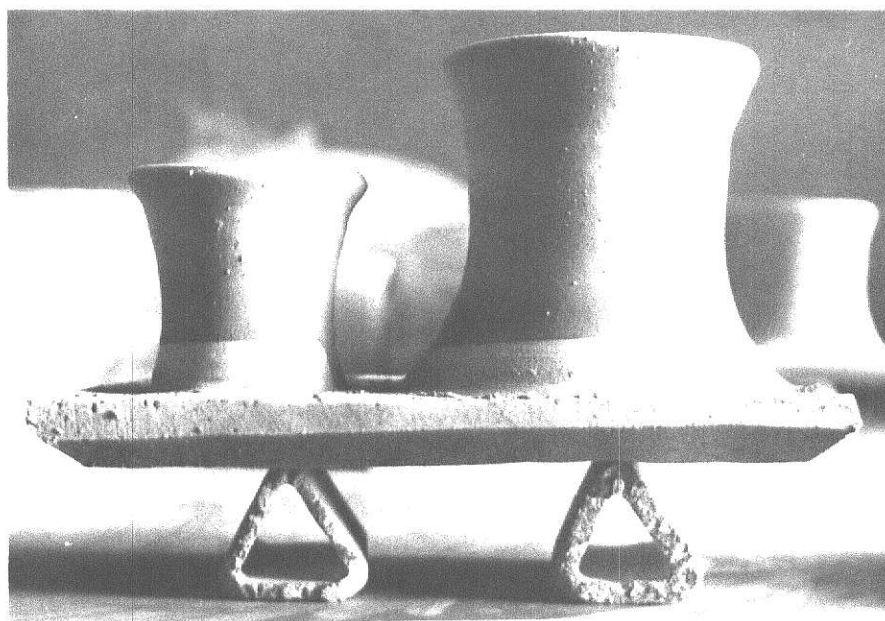


Fig. 2

to minimal warping is slow drying. This was achieved, following application of engobe if necessary, in the leather hard stage, in periods of up to ten days, placed upon wire-rack refrigerator shelves. Later, tiles were placed over two kiln posts for support, as shown in Plate V Fig. 2 in order to achieve air circulation. Flat tiles without added clay elements were turned frequently, although even they were sufficiently heavy to dry without a great deal of warping.

Decorative Techniques. Sections to be decorated were dipped or engobe was applied with a brush in the leather hard state, after trimming. A second application was given after bisque fire as the initial coat then appeared rather thin in places; this led to a shivering of the black engobe from some cylinders after cooling from the glaze fire. This was proven to be due largely to a too heavy build up of engobe on rims as the problem did not recur in subsequent firing of cylinders from which the second layer was scraped off rims. The possibility of points of stress in the clay cannot be totally discounted. Other tiles were dipped in hot paraffin wax after bisque fire, which coated the base and screw holes prior to glaze application by dipping or pouring. Raw clay was sprayed by means of an inexpensive garden spray applicator, with a thin suspension of red iron oxide in water.

Firing. All tiles were bisque fired; this was accomplished by one firing in each of two gas kilns, of 10 and 20 cubic foot capacity respectively and four firing in each of two electric kilns, three and six cubic foot capacity. Gas kilns were fired to cone 06 (1830° F), while temperature in electric kilns was estimated by color. As most sections were quite thick, heat was raised very slowly, usually after several hours of preheating, and there were only two minor mishaps, the blow-out of a section from the rear and

corner of one tile, which was later repaired with moulding plaster, and the separation of a portion of one heavily textured tile which was re-attached with glaze.

Glaze firing was to cone 8 (2300° F) and proceeded without incident except for the previously mentioned black engobe shivering. Sections decorated with blue engobe were re-fired with a cover glaze because of too thin application of the initial coat. Three glaze firings were required, in the 20 cubic foot gas kiln.

Installation

Three baseboards, one measuring 6 x 5 feet and two 5 x 3 feet, and one 19 1/2 inch diameter disc, all of three quarter inch A/D interior grade plywood, were provided by the building maintenance section of the Kansas State Union. Completed tiles were laid out on an appropriate base and when satisfactorily arranged, the locations of screw holes were marked with pencil. During these procedures it was evident that the overall clay shrinkage was approximately three inches less than had been anticipated. Advantage was taken of this by placing tiles on each panel flush with the top edge to ensure that they would be straight and level when mounted. Tiles of the large panel were placed flush with the left edge, thus leaving the extreme left vertical row of tiles to be mounted upon an extra, five inch wide board. A five inch deep addition was required at the bottom of each panel. There was a 2 1/4 inch overhang at the sides of each panel and the baseboard was not exposed to view. Guide holes for screws were drilled with a one-eighth inch bit and the boards were painted white or black, as appropriate to the area.

Kansas State Union maintenance personnel stripped and washed the wall,

applied two coats of Davis Paint Company color Z 48-14 (Ensign), a dark, greyed blue, flat latex finish, and mounted the baseboards to the cement block wall 18 inches apart, 12 inches from the ceiling, 25 inches from the floor, with 1/4 inch flat head countersunk toggle bolts. Ceiling and floor are not exactly parallel though this is not immediately apparent; the floor is one half inch lower on the left side.

Tiles were mounted with #9 round head wood screws 1 1/4, 1 1/2 and 2 inches long, depending upon thickness of the tile. Prior to installation screws were mounted in soft clay and spray painted gloss white or matt black so as to be unobtrusive.

Each mural panel was mounted and completed separately; as guide holes had been drilled very little rearrangement of tiles was required although it was necessary to grind off glaze on the edges and corners of some tiles in order to obtain a good fit. Guides for tiles mounted to the five inch additions were drilled at the site. The sun motif of the SNOW panel was mounted upon a plywood disc and brought forward from the plane of the baseboard by three strips of three-quarter inch plywood.

Mounted, the SUN panel measured 6'9" x 5'6", the LAND and SNOW panels being 5'6" x 3'4 1/2" each, to give a total area of 74 1/4 square feet. Spacing between the panels was 13 1/4 inches. By the terms of agreement with Kansas State Union administration, appropriate lighting was to be installed under advisement by the Department of Interior Architecture, and the surrounding area was to be redecorated; this has not been completed at the time of writing.

Recommendations

It is almost superfluous to point out that planning and execution of a complex creative effort is not to be undertaken lightly, yet the rewards of successful completion are commensurate and indeed exceed the physical and mental energy expended. A mediocre, pleasant or outstanding design may be achieved readily enough and the extent to which the artist hews to or ignores established principles of form and color are a matter of personal taste and creative maturity.

The following recommendations are made concerning technical matters:

1. Tiles in the leather hard state must be handled with great care as a minimum of edge or corner distortion will make it difficult to achieve a close fit.
2. Slow drying to minimize warping and cracking.
3. When using engobes apply a sufficient thickness at the leather hard stage so that it is not necessary to re-coat after bisque, with attendant risk of peeling, cracking or shivering.
4. If the mural is to be assembled without grout clean edges of tiles free of glaze so that good fit may be obtained.
5. Check that floor and ceiling are parallel and that wall corners are vertical; this is not usually the case.

CHAPTER 4

A PERSONAL STATEMENT:

PRESENTATION OF THE MURAL

Man lives by symbols and signs. Speech and the written word are clues; grunts, and squiggles on a page often fall short of explaining or communicating what is in the originators mind. It is only when words express what is felt, when endeavoring to verbalize a concept, that true communication exists. Even then the interpretation of what is said may be subject to, and modified by nuances of tone, timing and each persons' idea of just what a word means. By the same token, art cannot be satisfactorily explained; the artist or critic may verbalize at length, and may help by presenting fresh evidence or point of view but in the final analysis the value of a piece of art to the individual is dependent upon the impact which it carries. Art must be experienced.

The nature of art and meaning in art have been the subject of philosophical speculation during the past 2500 years of Western thought. The term 'significant form' has been given by Clive Bell (1913) to that quality that an object possesses so that it is called art.

What quality is common to Sta. Sophia and the windows at Chartres, Mexican sculpture, a Persian bowl, Chinese carpets, Giotto's frescoes at Padua, and the masterpieces of Poussin, Piero della Francesca, and Cézanne? Only one answer seems possible--significant form. In each, lines and colours combined in a particular way, certain forms and relations of forms, stir our aesthetic emotions. These relations and combinations of lines and colours, these aesthetically moving forms, I call 'Significant Form'; and 'Significant Form' is the one quality common to all works of visual art.⁴⁴

⁴⁴Clive Bell. Art (New York: Frederick A. Stokes Company, 1913), p. 8.

It should be noted that significant form refers to a quality possessed by objects rather than a universal awareness. Significant form must be felt and any judgement is subjective. Objects may have significant form but not necessarily recognized as such in the same way, or by everyone.

Since the invention of photography in 1824 (by the Frenchman, Niépce) provided a simulacrum of reality, artists have turned once again to meaning. When speaking of art there is often a misconception that meaning and value are synonymous with accurate representation, rather than what the artist is trying to express. Feelings which cannot be verbalized are given form in the arts; in abstract or non-representational works. In his examination of the state of 20th century art, Roy McMullen (1968) writes of representation:

The most common error of antimodernists is to assume that the referent must be a reasonably accurate reproduction of something visible which we can recognize immediately and consciously. A little reflection will reveal that it need not be that at all. The ancient philosophical critics were, of course, right in thinking of art as an 'imitation' of nature, since ultimately there is no other source for a referent. But Paul Klee was also right, or partly so anyway, in his frequently quoted assertion that 'art does not reproduce the visible, it renders visible.' One need not be a Freudian or a Jungian to admit that the nature which is imitated in a painting may be something hidden or half hidden in the individual or collective unconscious.⁴⁵

The role of meaning in art may be clarified by reference to music, an area of creative activity where the essence of the art is form, the relationships of pitch and harmony. Music is "about" music. Similarly, sculpture is principally "about" three dimensional forms in space, and painting is arrangement of color and shape contained within a plane. The title or referent of visual art may serve to link form and emotional response or, at

⁴⁵Roy McMullen, Art, Affluence and Alienation (New York: Frederick A. Praeger, 1968), p. 148.

the opposite extreme, may serve only to identify a work, baldly descriptive labels such as have been used in classical music for the past several centuries.

The mural entitled WINTER, the design and execution of which have been described, and which is presented photographically in the following pages, is an attempt to create the feeling of that season and the relationship of man to his environment. It is not in any way descriptive of any specific winter scene, although textured areas obviously relate to what happens when snow lies on rock. The intention was to give form to the mental images experienced by the artist and to make manifest the dichotomy of serenity and power suggested by the concept, winter. If the viewer is deafened by sounding brass trumpets as was one spectator contemplating the SUN panel during installation, so be it; a response was elicited, an aesthetic, emotional experience was felt.

EXPLANATION OF PLATE VI

General view of the installation at entrance to
the Stateroom, Kansas State Union.

The bust at left 'My Emmy' is by J. Cranston
Heintzelman.

PLATE VI



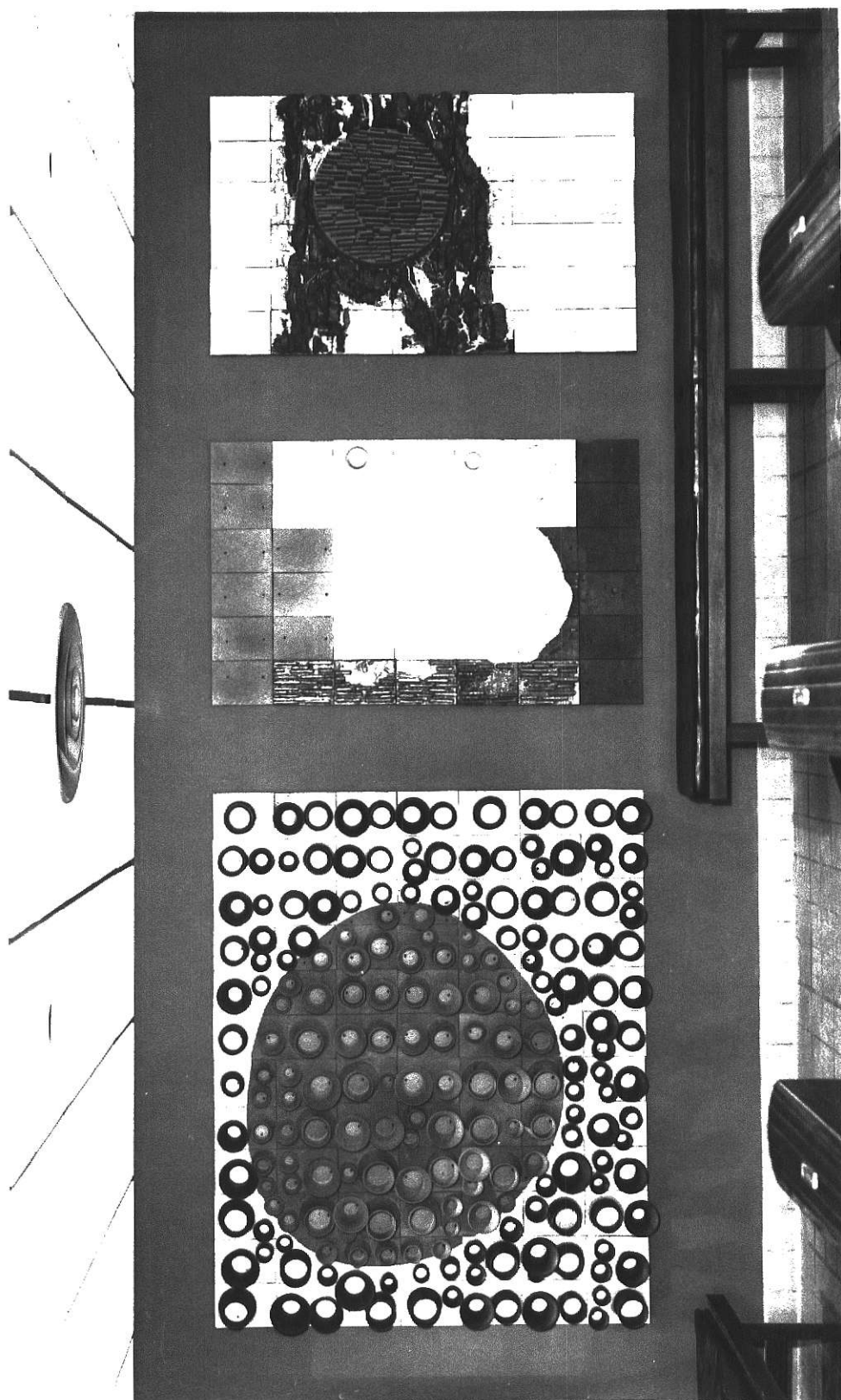
EXPLANATION OF PLATE VII

THE MURAL, WINTER

Reduced stoneware decorated with engobes, glazes and sprayed iron oxide over raw clay. Total area 74 1/4 square feet.

From left to right the panels are subtitled SUN, LAND, and SNOW.

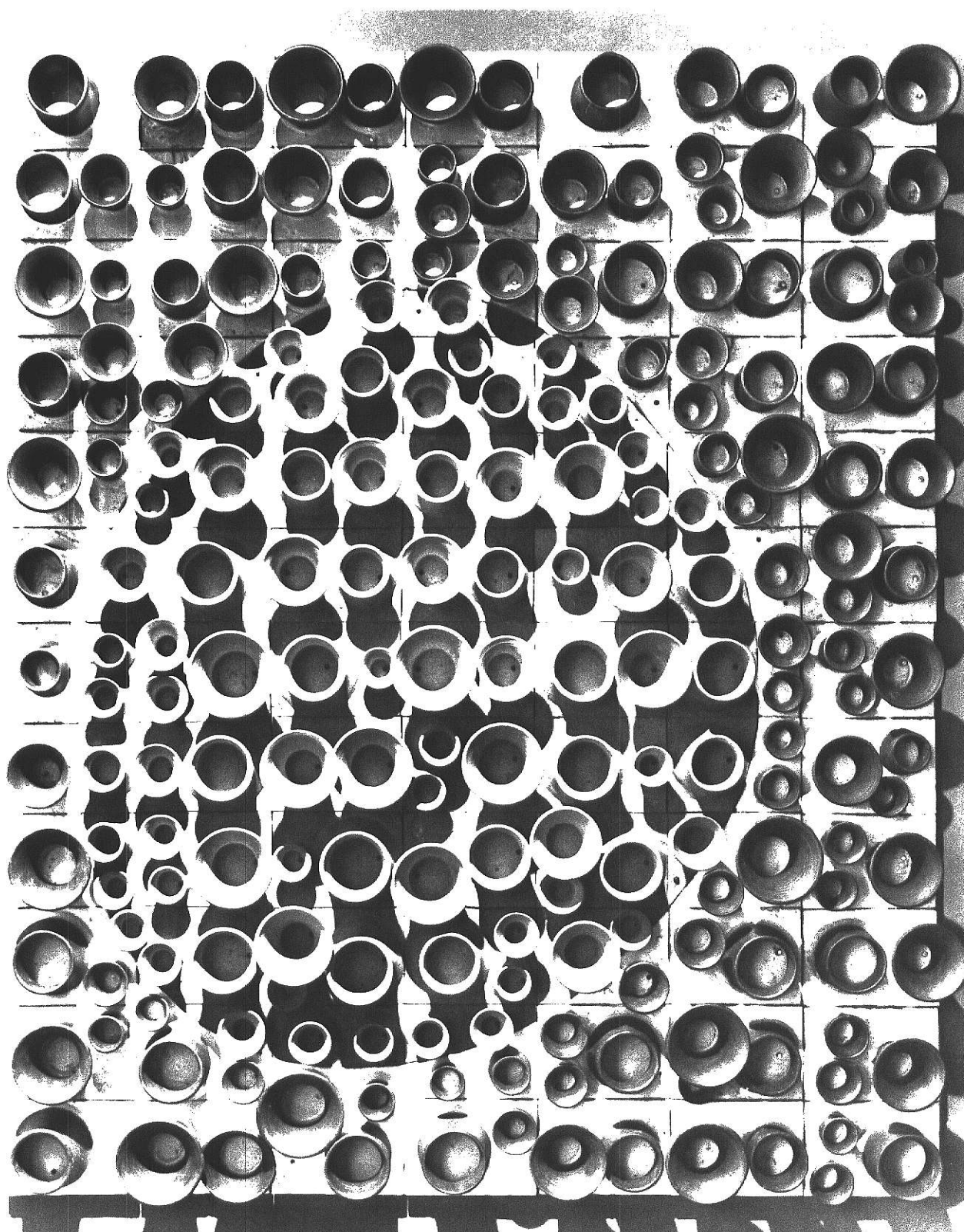
PLATE VII



EXPLANATION OF PLATE VIII

SUN. 6'9" x 5'6"

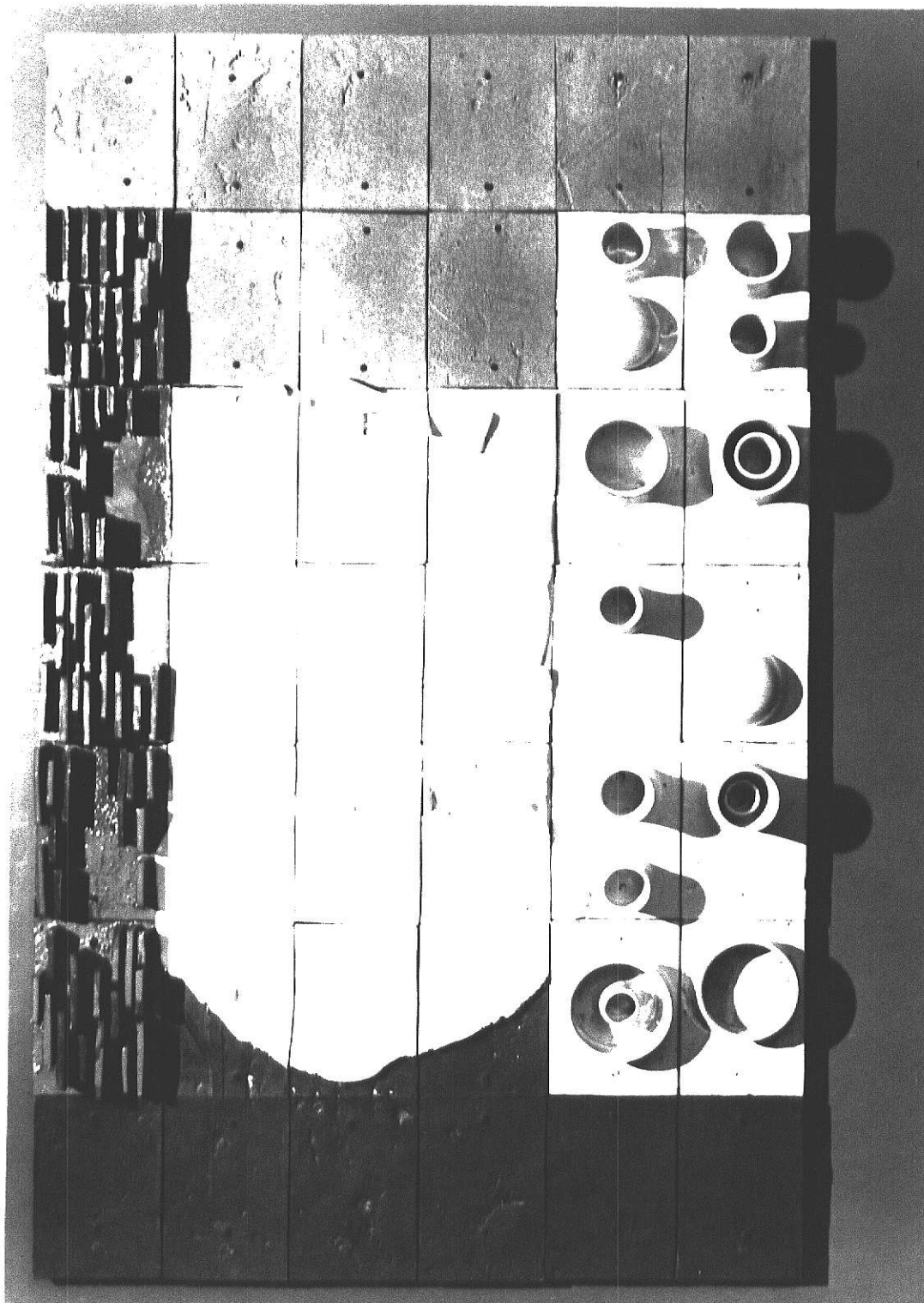
PLATE VIII



EXPLANATION OF PLATE IX

LAND. 5'6" x 3'4 1/2"

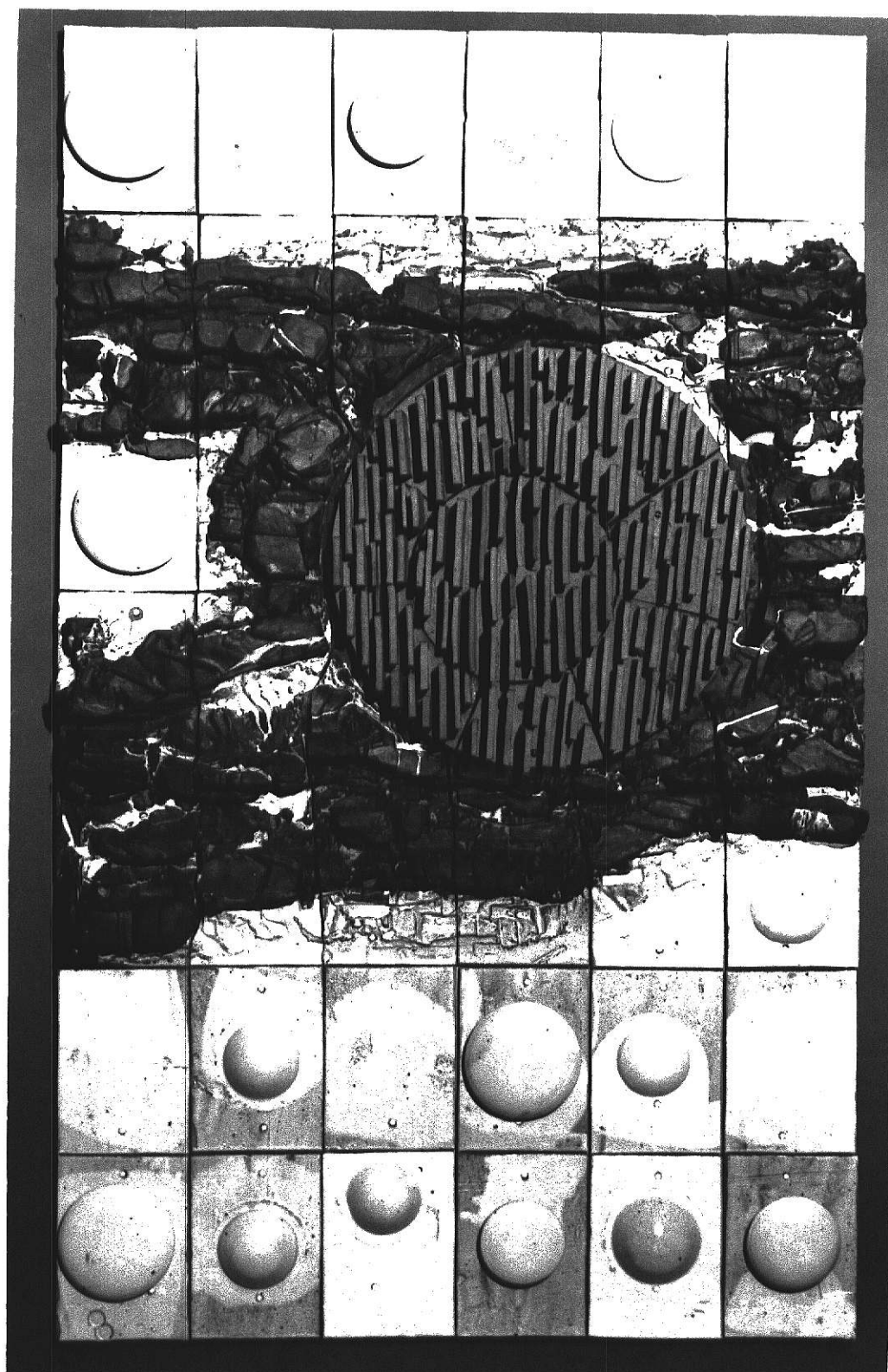
PLATE IX



EXPLANATION OF PLATE X

SNOW. 5'6" x 3'4 1/2"

PLATE X



EXPLANATION OF PLATE XI

SECTION OF SUN PANEL

Light toned cylinders and tiles are sprayed with iron oxide, giving a rich rust-red color; darker cylinders are coated with vitreous black engobe with matt white glazed tile.

PLATE XI



EXPLANATION OF PLATE XII

CENTRAL AREA OF LAND PANEL

Superimposed clay slabs with matt
white glaze.

PLATE XII



EXPLANATION OF PLATE XIII

CLOSE UP OF A TEXTURED AREA, SNOW PANEL

Surface treatment is vitreous black engobe,
matt white glaze, and sprayed iron oxide.

PLATE XIII



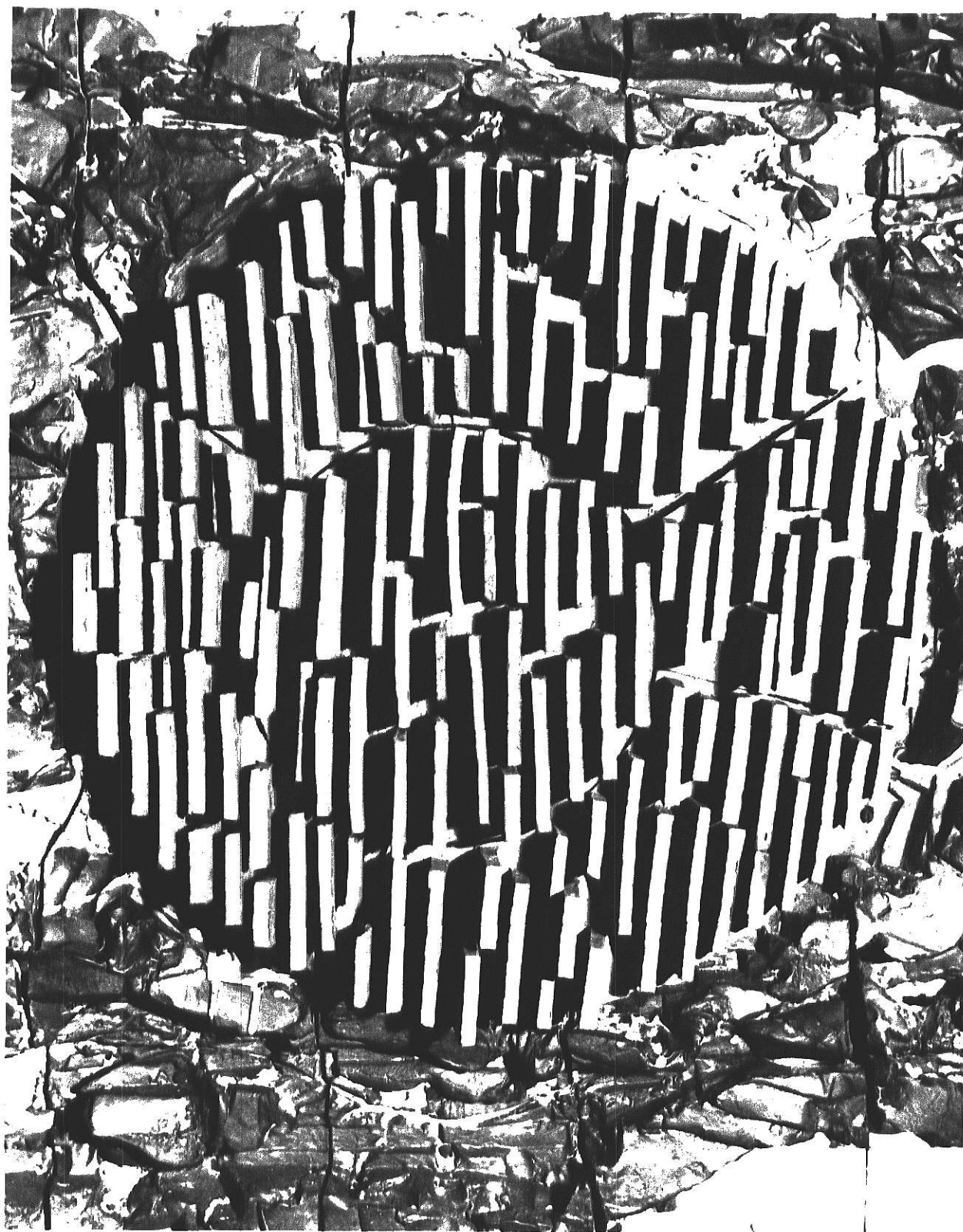
EXPLANATION OF PLATE XIV

SUN MOTIF OF SNOW PANEL

Slab-formed ribs of random height and placement create movement in shifting shadows as the viewer traverses the panel.

This section is formed of a clay body containing 50 percent local ferruginous clay and has no surface treatment.

PLATE XIV



EXPLANATION OF PLATE XV

The installation as seen from inside the Stateroom,
Kansas State Union.

PLATE XV



GLOSSARY OF TERMS

BALL CLAY. A sedimentary kaolinitic clay that fires white to a light buff color and which, because of its very fine particle size, is highly plastic. Ball clays are moderately refractory.

BISQUE. Ware which has been once fired and is unglazed.

CLAY. A natural material characterized by its plasticity when mixed with water. Clay consists of one or more clay minerals together with, in most cases, some free silica and other impurities. The common clay mineral is kaolinite.

CRAZING. A defect of a fired engobe or glaze characterized by hairline cracks which penetrate the surface.

DEFLOCCULATION. The dispersion of a clay slip by the addition of a small amount of suitable electrolyte so that less water is required for fluidity.

ELECTROLYTE. A compound which promotes deflocculation e.g. soda ash.

ENGOBE. A coating of slip, white or colored, applied to a ceramic body to improve its appearance. It was proposed in the text that the term be applied only to a suspension of one or more clays with added materials which are active at the maturing temperature.

EUTECTIC. A mixture whose melting point is lower than that of any of the constituent fluxes.

FELDSPAR. A mineral consisting of alumina and silica in association with potassium, sodium, calcium or lithium.

FERRUGINOUS. Applied to clays having high iron content.

FILLER. A material of little or no plasticity which helps to promote drying and control shrinkage in clay bodies or engobes.

FIRE. To heat ceramic materials in a kiln to the point of fusion or crystal bonding.

FIRECLAY. A clay that is resistant to high temperatures. Such clays are often relatively non-plastic.

FLUX. A substance which promotes fusion and melting.

FUSE. To join by melting.

GLAZE. A thin glassy layer formed on the surface of ceramic ware, usually by firing-on an applied coating of silica and other materials.

GREENWARE. Dry, unfired ceramic ware.

HARDENER. Any material incorporated into an engobe or glaze for the purpose of achieving protection from mechanical damage prior to firing.

KAOLIN. A white firing, refractory clay. Kaolins are usually non-plastic.

LEATHER HARD. Clay which has dried sufficiently to lose its plasticity but which may be joined or carved.

MATURE. Fired to the required degree of vitrification.

MOLECULAR FORMULA. A method of representing a fired glaze in terms of the relative amounts of oxides present. It is proposed in the text that this may also be a useful tool for engobe formulation.

OPACIFIER. Any material added to an engobe or glaze to make it opaque.

OXIDATION. Firing with ample oxygen in the kiln.

PLASTICITY. The property of a material enabling it to be shaped and hold its shape. The greater the plasticity of a material, the greater the shrinkage on drying.

REDUCTION. Firing with a deficiency of oxygen in the kiln.

REFRACTORY. Able to withstand high temperature.

SHIVERING. A defect of a fired engobe or glaze characterized by separation from the ware accompanied by separation of a portion of the clay body.

SINTER. To fire to the point where crystalline cohesion occurs.

SLIP. A suspension of clay or other materials, and water.

VITREOUS. Fired to a point approaching complete fusion and glassification.

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HIGH TEMPERATURE VITREOUS ENGOBES: A STUDY
IN THEIR FORMULATION AND CREATIVE USE

by

PHILIP NEVILLE LEESE

B.F.A., Notre Dame University, British Columbia, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Art

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1971

The purpose of the study was to investigate the formulation of vitreous engobes for reduced stoneware fired to cone 8, suitable for application to leather hard, greenware and bisque clay, and to utilize the results of the study in a creative body of work.

Reference sources included local university and city libraries and the writer's personal collection.

Review of the technical literature showed basic agreement in the qualities desirable in an engobe in terms of fit to a particular clay body, choice of materials and color response, and the means by which these might be achieved.

For a vitreous engobe the clay content should be between 30 and 50 percent, while a feldspathic flux may be present in quantities up to 35 percent. Free silica (flint) above 10 percent may cause crazing of the engobe while too little flint leads to shivering. This is because although engobes have many of the characteristics of a glaze, vitrification is not complete and the materials are subject to stresses similar to those in clay bodies. It was observed that the terms crazing and shivering may in the past have been used anomalously and that the phenomenon as described may have been more a difference of interpretation than descriptive; minimal crazing with separation of engobe from the ware has much the same appearance as shivering. Cracking or peeling after application may be the result of finely divided mineral constituents requiring an excess amount of water in relation to solid material in the engobe. Whiteness in an engobe is achieved primarily by the selection of white burning clays such as kaolin and to a lesser extent, ball clay. These are usually used in combination as they possess complementary traits of plasticity and refractoriness. Color

is attained by the addition of certain metallic oxides; a greater percentage is required than in a glaze and full intensity is not achieved without a transparent cover glaze.

Laboratory investigations were conducted with eleven engobes; there was wide tolerance in fit and composition. Five vitreous engobes with varying clay content were formulated based on the theoretical composition of pyrometric cones within the range cone 6-10; the most successful had a clay content of approximately 20 percent. Advanced work was undertaken with a vitreous engobe containing 70 percent clay, and a range of blue and earth colors was produced. Four of these color variations were adopted in the ceramics department and proved trouble free with normal usage over a period of four months; their value on bisque ware was limited by occasional peeling after drying. It was proposed that engobe formulation by the convention of molecular constituents, as in a glaze, may be a useful tool.

The design, execution and installation of a 74 1/4 square foot ceramic mural in the Kansas State Union was described, supplemented by diagrams and photographs. The mural is in three panels and gives form to the writers concept of WINTER, the title of the work. Surface treatment is by three engobes, two glazes, and sprayed iron oxide over raw clay. A motif area of one panel is constructed of a body containing 50 percent local ferruginous surface clay.

The writers personal philosophy, that meaning in art is related to what is felt emotionally rather than seen, is discussed at some length.