A Thesis Presented To
The Faculty of Alfred University

CONSTRUCTING ANCIENT KOREAN CELADONS FOR MODERN FIRING CYCLES

by

Grace Dunham

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Under the supervision of:

Chair: **Dr. William Carty**

Committee Members:

Dr. Hyojin Lee

Matt Kelleher

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Honors Introduction

I am passionate about exploring the intersection of art and science in ceramics. As so, I am pursuing a dual degree in Ceramic Engineering and Art & Design. When I began working with clay I was absolutely fascinated by glaze. The color, surface, and texture I could achieve by brushing a pastel-colored paste onto my work seemed truly magical at the time. Throughout my time here at Alfred, knowledge has replaced that magic for better and for worse. Glaze still fascinates me, and my understanding only scratches the surface of what there is to know. As I dig deeper, I find more and more of that magic again and again.

Dr. Carty practically handed me a thesis topic that perfectly combines my interest in glaze and ceramic science. Building from previous research on the firing conditions of ancient Korean celadon pottery, I explored recreating the optical effects present in these glazes using a two-layer glaze system, modern materials, and modern heat treatment methods.

This project was a series of trials and adjustments. The initial hypothesis was to have two different glaze layers with varied concentrations of different fluxes, compounds that assist in melting silica. One glaze high in sodium and potassium and the other high in calcium. The glaze high in sodium and potassium could only be formulated to that concentration using soda ash. Soda ash, however, is a soluble raw material and caused problems with my resulting glaze. The water in the glaze carried the soluble salt through the porous bisqued tile and caused the tiles to stick badly to the kiln shelves. I experimented with changing several variables and fired a lot of tests. I tested different firing processes, temperatures, and kiln atmospheres. This produced an unexpected

benefit of exposing me to the resources around me in Alfred and led to so many wonderful and interesting conversations with so many passionate ceramists.

This research has helped me understand glaze chemistry, the importance of clay body chemistry, and the subtleties of light interaction with ancient glazes. As a result, I have experimented with several different clay bodies in my own work and recognize that clay body contributes to aesthetic as much as glaze. I hope to focus my career researching traditional ceramics and whitewares and furthering my understanding of ceramic materials, processes, and properties, in a context of art. I also hope to continue my artistic practice, something I had the opportunity to dive deep into while working towards my senior show in art and design.

As a kid I saw someone throwing on a wheel at a local community art festival and was mesmerized. I had the opportunity to take a ceramics class in high school and since then it has worked its way into my life. I spent a long time trying to self-teach on a wheel rescued from the trash and succeeded in learning some of the fundamentals of wheel throwing. While my pots were rudimentary, I thought I could express my creativity through my glaze experimentation. At the time I had no knowledge of what glaze even was other than a material that I ordered online and arrived in plastic pints. I systematically would test layering of every new glaze I obtained over every other glaze I had access to. I wanted to build a repository of glaze layering knowledge so I could know exactly how my glazes would look when they came out of the kiln. I wanted to create surfaces that people had not seen before in our community studio. I came to Alfred eager to get on a wheel and learn more about throwing and about glaze.

I took my art and engineering courses, made my pots, made new glazes, and felt some disconnect. I fundamentally love to create, but what do I want to make? I love throwing but do I really like making functional ware? I started feeling like the material I was working with was limited by the constraints of art pottery and of engineering perfection. Perfection isn't very enjoyable. I explored atmospheric firing, but it did not really satisfy my need for something more. I had taken other art classes (printmaking, figure drawing, even foundations) and found my creative brain tweaked in a way that was so much more fulfilling than with pottery. By going to art school, I rediscovered how much I love making art and how fulfilling it can be. I enjoyed every minute of the experimentation I was doing with clay and glaze in the studio, but I didn't feel love for the ceramic work I was making, not until I took Figure Sculpture and Handbuilding with Meghen Smythe. They worked with clay in a way I had never experienced before. I associated hand building clay with a slow and lengthy process of drying and re-wetting and, to me, that is just ultimate torture. Meghen showed me a totally new way of working with the material. I could work quickly and create huge steps in a short amount of time. I worked hard to stop seeing "the right way" of working with ceramic material. Pottery art is full of folklore and "right" and "wrong" ways of making. Ceramic sculpture can be anything. Without the dogma of potters, it can be ultimate freedom from conventional use of material. This was what I needed to see what I am still trying to process as I move forward with creating.

I think once I learned to sketch out forms in clay and feel proud of the results, I was able to find a way of working that allowed me to explore where my artistic interests met my

ceramic interests. I am still struggling with where the two intersect but I no longer feel hopeless as to what ceramic art can be for me.

This exploration culminated in my senior show, affectionately titled, Pareidolia. Pareidolia, the tendency to assign meaning to patterns, is a phenomenon of perception. A common example is seeing faces in everyday objects.

Through ceramic sculpture I explored how elements of the figure can be incorporated into and perceived in abstract compositions, drawing from ideas and imagery from Jeff Vandermeer's book *Annihilation*. In this novel, an alien force has encompassed part of earth and surrounded it with "the Shimmer". Within the borders of "the Shimmer" all waves are refracted, resulting in DNA mutating and transferring across species. The results are strange, beautiful, and terrifying.

A component of this project was setting up systems within my studio practice to enable a conversation and collaboration between my sculptural work with clay and an open-source AI (Artificial Intelligence) known as Stable Diffusion. Going back and forth in conversation: I prompted the AI with images and key words. The AI fractures, rebuilds and refracts form, color, and content over and over again. This can go on with practically infinite variation. I evaluated and processed these generated images and responded to them in ceramic.

In my perception of AI generated images I experience pareidolia and carry that consciously and subconsciously into my work. What I see in the AI generated images is a reflection of my internal visual database, very much like a Rorschach test. To me, this

collaboration exposed a connection between my human processing of visual patterns and the process by which the AI interprets visual and verbal cues.

With my background, I develop and work with clay bodies and glaze from the perspective of the crystalline and amorphous phases forming within. I continue to work on my understanding and prediction of color in glazes. In the case of transition metal doped glass, I see color as the electronic transitions responsible for the wavelengths of light we perceive. I use this to help understand how I am using glazes in my work to create my desired texture, color, and surface.

To bring my thesis back into focus, this creation of a desired texture, color, and surface is exactly what this thesis is about. This project explores how material research and historical archeological data can be used to create a modern version of a glaze with the desired properties of ancient Korean celadon.

Abstract

Ancient sherds and samples collected from Gangjin and Gimjae celadons (Koryŏ period, 918-1392 CE) were previously analyzed to determine the firing conditions and to evaluate the body and glaze chemistry. Those results show that ancient samples were fired with three- or four-day long soak time at temperatures between 1000°C – 1200°C. The firing conditions of ancient Korean celadons produce a deep glaze-body interaction zone that is responsible for the optical characteristics of the glaze. To mimic the optical effects of ancient Korean celadons in modern firing cycles, the depth of the glaze-body interaction can be obtained using a two-layer glaze system. A two-layer glaze system was created that mimics the microstructure observed in the glaze-body interaction zone of the ancient samples. Color analysis by spectrophotometry, as well as chemical content and distribution mapping via SEM/EDS were used to evaluate the two-layer glaze system. Analysis of these data indicate similar optical effects and chemistry as presented in ancient Korean celadon samples.

Introduction

Carty & Lee demonstrated that ancient Korean celadons were fired for much longer times – 3-4 days compared to 3 hours for modern firings – at a peak temperature of 1200°C, creating a glaze penetration depth that is approximately 10x deeper than in modern ceramics.[1] Crystallites in the glaze also scatter light, further contributing to the appearance of the glaze. To mimic the visual depth of a Korean Celadon glaze, and to allow the incorporation of particulate scattering sites, a 2-layer glaze system that functions in a modern firing cycle was developed.

The chemistry of the ancient celadon clay body was determined. [1] Based on the chemical analysis data of historical celadon, iron oxide levels were measured to be under 2 wt% which is equivalent to Series #2.[1] Insights into celadon body chemistry from Dr. Carty & Dr. Lee were used to create the body used in all glaze testing. [1]

In the ancient Korean celadon, calcium is an indicator of glaze penetration depth. Calcium is a flux in glaze but very rarely present in clay bodies. Migration of calcium indicates the extent of glaze-body interaction.[2]

The original glaze-body interface requires some sort of marker. In Rein's experimental studies to measure the body-glaze interaction, zircon was incorporated into the body. Zircon is an efficient marker because it is readily imaged and does not readily dissolve into the glaze.[2] To determine the glaze application thickness in the ancient Korean celadon samples, another marker needed to be identified, and that marker is proposed to be mullite.

Mullite cannot precipitate from glass because alumina level is too low – i.e., the glaze lies within the glass formation boundary in the alkali aluminosilicate system.[3] Mullite in ancient sample must come from the ceramic body or incorporated body grog.

The original glaze body interface was identified in the ancient sample using mullite particles as a marker.[1]

Therefore, measurements taken from SEM images of a Koryó 12th Century Tea Bowl show a glaze penetration depth into the clay-body of approximately 200μm.[1] The layer of glaze on the surface, up to the original glaze body interface, had a thickness of approximately 100μm.[1] This information was used when considering application thickness of the two-layer glaze system. The bottom glaze layer should have an application twice the thickness of the top glaze layer application.

A top glaze with a chemistry high in calcium and a bottom glaze high in sodium and potassium were proposed to create a gradient of calcium between the layers of top and bottom glaze. When formulating the chemistry for the glazes for use at Δ7[i], Stull and Howat's eutectic glaze compositions, seen in Figure 1, were used as a starting point.[4]

[i] The symbol Δ denotes pyrometric cones, Δ7 indicates "Cone 7". A list of cone temperature values is presented in Appendix A.

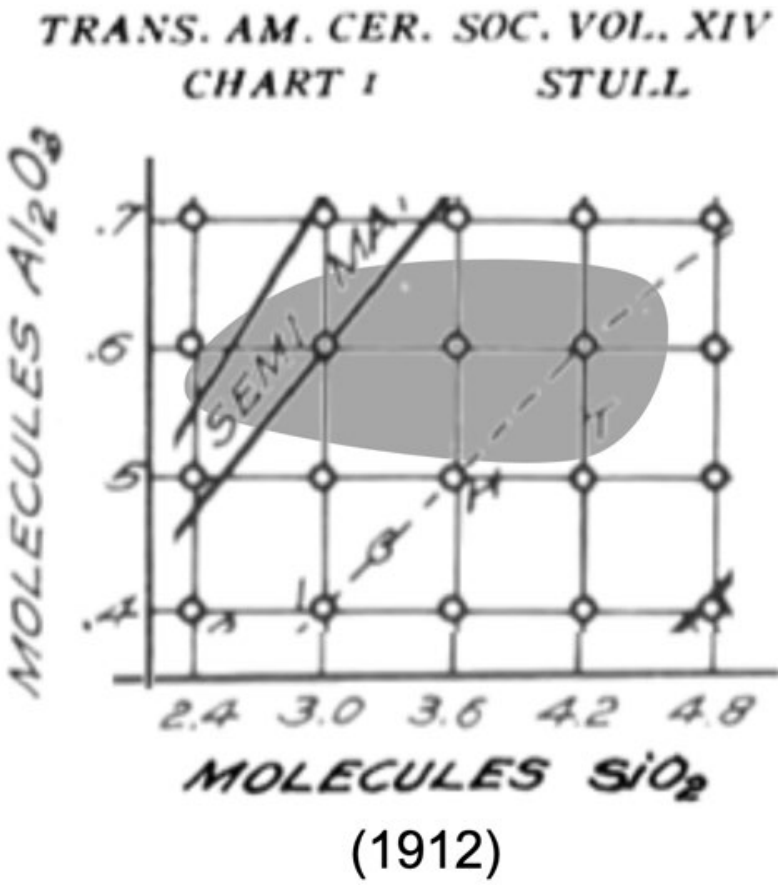

Figure 1. Selection of Stull glaze chart with grey region highlighting the eutectic, adapted from Stull[5] and Stull & Howat[5].

Stull's research focused on simple glazes with a constant flux amount of 1.0 and a constant K_2O:CaO ratio of 0.3:0.7. Their variables were the ratio and amount of SiO_2 and Al_2O_3 in their glaze experiments.[5]

From these studies, Stull and Howat reported deformation temperatures between 1220°C and 1230°C for the "best glazes" within the eutectic.[4] In Figure 1, adapted from Stull (1912)[5], the eutectic[4] is marked using a grey region. To create the two-layer glaze system, silica and alumina levels within this eutectic were selected for glaze

compositions that would melt at similar temperatures to those estimated from the ancient celadon samples.

The highest quality celadons are of a blue-green-grey color.[6] This color is obtained by controlling the ratio of the different oxidation states of iron within the glass structure.[7] Fe^{2+}, reduced iron, results in a blue-colored glass, while Fe^{3+}, oxidized iron, results in a yellow-colored glass.[7] A concentration of Fe^{2+} is needed within the glass to obtain a green celadon color. Historical Korean celadon glazes likely obtain the iron needed for their color from dissolved body iron at the glaze body interface. These pots historically were fired in wood-fueled kilns which had unpredictable atmosphere and results.[6] The highest quality celadons achieved sufficient reduction which resulted in the desired blue-green-grey color.

Experimental Procedure

BATCHING/FORMING BODY

Body recipes were prepared based on previous work.[1] While maintaining chemistry, body raw materials were adjusted to increase workability/plasticity. Table I outlines the raw material body composition on a weight percentage basis. The body materials were batched and added to water with VEEGUM® T (for plasticity), and then mixed (for 30-60 min). The suspension was dewatered on gypsum slabs (about 8 hours) to achieve a plastic body. Test tiles were made using various forming methods including wheel throwing, pressing, extruding, and rolling.

Table I. Body Composition as formulated on a weight percentage basis

Raw Material	**Wt%**
Lizella	15.4
Tile #6	36.6
Red Art	4
Barnard	0.8
G-200	15.6
Magnesium Carbonate	0.6
Wollastonite	0.3
Quartz	27

BATCHING/APPLYING GLAZE

The glaze materials were batched, added to water, dispersed using sodium silicate, and then mixed for 10 minutes. Table II outlines the final glaze compositions on a molar ratio basis. Appendix B contains raw material batches for final glaze chemistries. Table III outlines varying methods and concentrations of iron addition to the bottom glaze composition. The rheology of glazes was adjusted for better application and consistency. To better represent the ancient glaze-body interaction, the bottom glaze needs a thickness twice that of the top. The glaze application process is used to create these layers of glaze. The (high clay content) top glaze was dispersed using sodium silicate so a thinner layer of glaze could be applied while maintaining similar water content/shrinkage to the bottom glaze. The bottom glaze remained undispersed, with the same water content, so a thicker layer of glaze could be applied. The bottom glaze layer was applied with approximately twice the thickness of the top glaze layer application. Almost all glaze applications were dipped, but a switch to brushing resulted in more controlled thickness and consistent results. Glaze was applied to the extruded tiles through dipping in two layers, bottom and top glaze, allowing the tile to dry in between applications. Glaze was applied to the slab tiles through brushing in two layers, bottom and top glaze, allowing the tile to dry in between applications.

Table II. Final Glaze Compositions on a Molar Ratio Basis (UMF)

	Top Glaze	**Bottom Glaze**
KNaO (R_2O)	0.0	0.3
CaO (RO)	1.0	0.7
Al_2O_3	0.38	0.55
SiO_2	2.71	4.0

Table III. Sample Identification by Iron Addition to Bottom Glaze

Sample Name	**Source**	**Weight %**	**Glaze Application**	**Atmosphere**
“2-fe0”	NA	0	Brushed	Reduction
“2-fe2”	Red Iron Oxide	0.625	Brushed	Reduction
“2-fe3”	Red Iron Oxide	1.25	Brushed	Reduction
A1	Red Iron Oxide	1.875	Brushed	Reduction
A2	Red Iron Oxide	2.5	Brushed	Reduction
“1-grog”	High Iron Grog (400 mesh)	3	Dipped	Reduction
“1-fe5”	Red Iron Oxide	2.5	Dipped	Reduction
“Elec-0”	NA	0	Brushed	Oxidation
“Elec-50/50”	Red Iron Oxide	1.25	Brushed	Oxidation
A3	Red Iron Oxide	2.5	Brushed	Oxidation

HEAT TREATMENT

Tiles were initially bisqued to Δ04 in either electric or gas kilns. Glazed tiles were fired in an electric kiln (neutral/oxidation atmosphere) or a gas kiln (reduction atmosphere) to Δ7 and held at peak temperature for approximately 1 hr. Samples were allowed to cool to room temperature.

COLLECTING COLOR DATA

The glazed surfaces of the fired samples were analyzed using a portable spectrophotometer (CM-700d, Konica Minolta, Tokyo, Japan). Multiple measurements were taken and averaged L*, a*, and b* values were reported for each sample.

FRACTURE SAMPLES

Fired samples were fractured perpendicular to the glaze-body interface. Fracture surfaces with visible glaze interface were then selected for microscopy.

SEM SAMPLE PREP

The fractured samples were mounted on aluminum mounts and coated in gold in preparation for scanning electron microscopy (SEM) (JEOL 6010LA, Japanese Electron Optics, Ltd., Tokyo, Japan).

SEM

The fracture surface was analyzed using electron dispersive spectroscopy (EDS). Mapping of calcium, silicon, and aluminum was performed.

Calcium was used as an indicator to locate the approximate locations of the interfaces between the top and bottom glaze and the bottom glaze and clay-body. Sample images

were then analyzed using image analysis software ImageJ (ImageJ, V.1.8.0 NIH Image, Bethesda, MD) and the thickness of the layers of glaze was measured using these interfaces as boundaries.

Results

RESULTS OF GLAZE OPTIMIZATION

Results from the initial trial are displayed in Figure 2. In these samples the silica and alumina levels from Stull and Howat's glaze compositions[4] were used to create top and bottom glazes that ideally fall within the eutectic from Figure 1. The flux ratios for the top and bottom glazes were selected to encourage a gradient of high to low calcium concentration from the glaze surface to the glaze body interface. The top glazes had a fixed level of R_2O:RO 0:1 (high calcium). Bottom glazes followed Stull's research[5] and had a fixed level of R_2O:RO 0.3:0.7 (typical calcium).

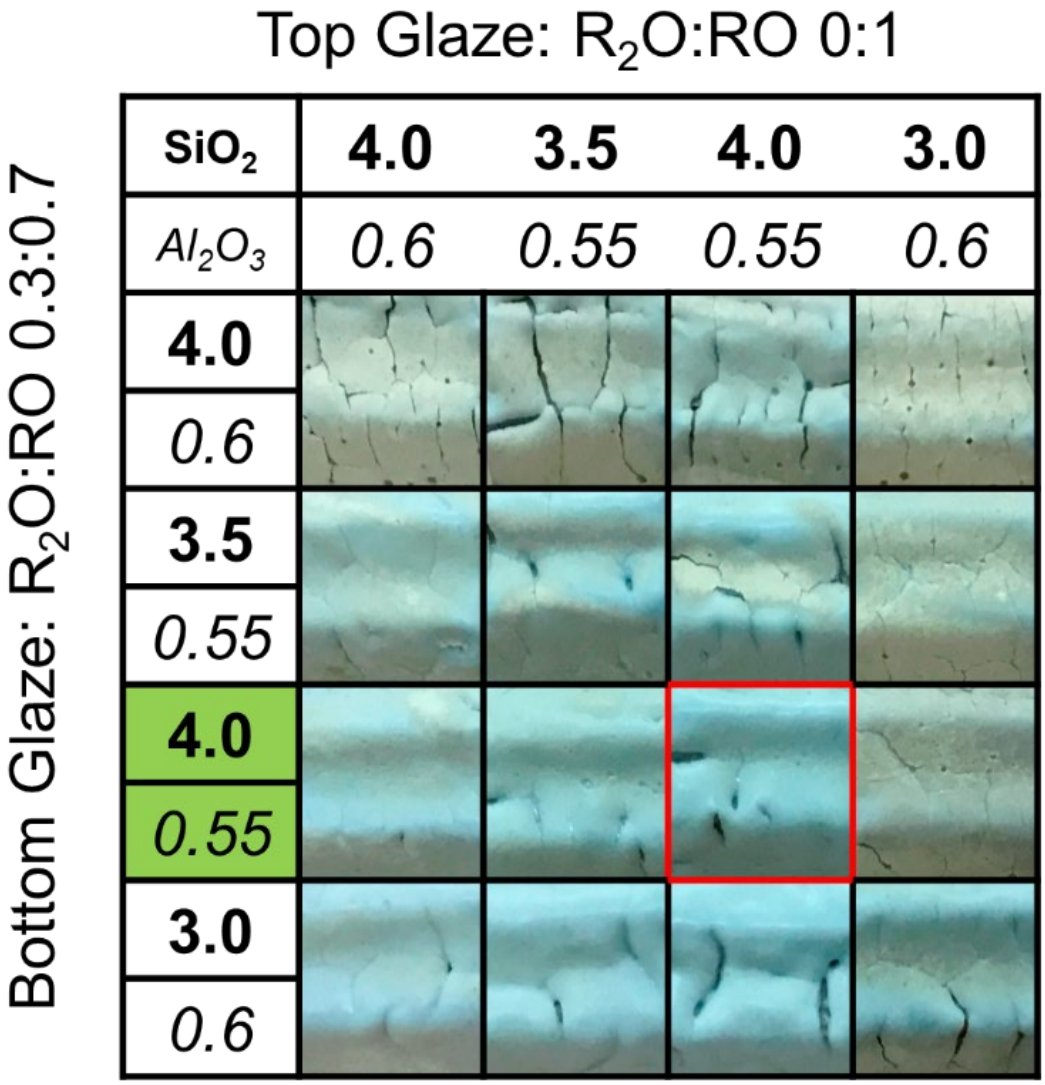

Figure 2. Initial glaze trial results, Bottom: R_2O:RO 0.3:0.7, Top R_2O:RO 0:1. The glaze highlighted in green and outlined in red is the selected "best" bottom glaze for future testing.

As seen in all the images in Figure 2 the top glaze has a dry cracked appearance indicative of difficulty melting. The most promising (glossy) bottom glaze (image outlined in red, composition shaded in green) was selected for further trials. Figures 3 and 4 illustrate experiments to achieve/optimize a glossy top glaze by increasing the ratio of R_2O:RO (Figure 3) and decreasing the level of SiO_2:Al_2O_3 (Figure 4).

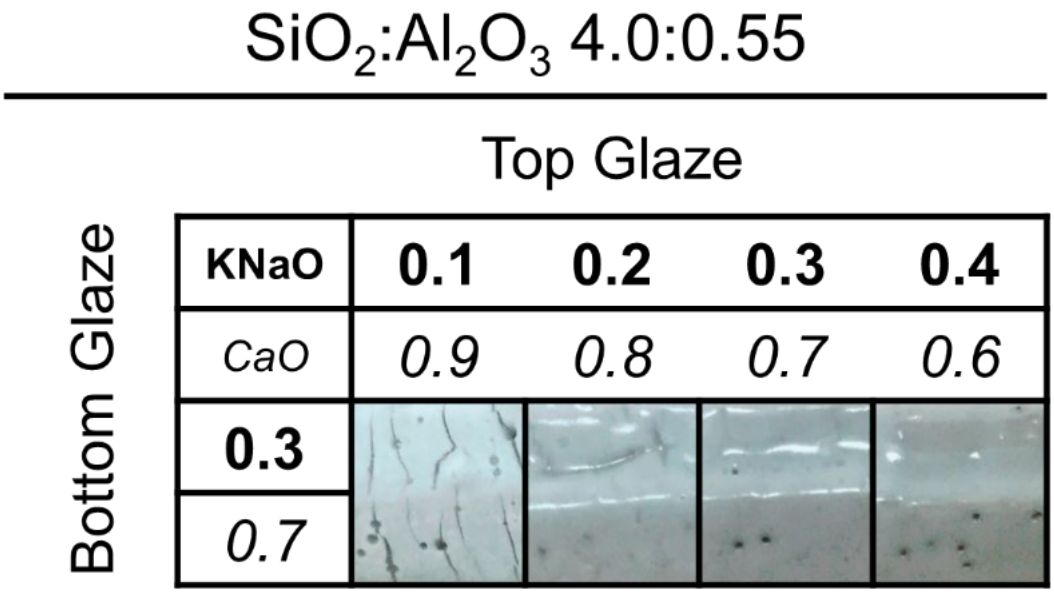

Figure 3. Increasing R_2O top glaze trial results, SiO_2:Al_2O_3 4.0:0.55.

Figure 3 displays the results from a glaze trial where the SiO_2:Al_2O_3 level was fixed for all glazes at 4.0:0.55. As observed in the images of the tested glaze recipes, when R_2O was increased the glaze appeared glossier and displayed less crawling behavior. Another trial, seen in Figure 4, to help improve the melting of the top glaze was to reduce the level of SiO_2 and Al_2O_3.

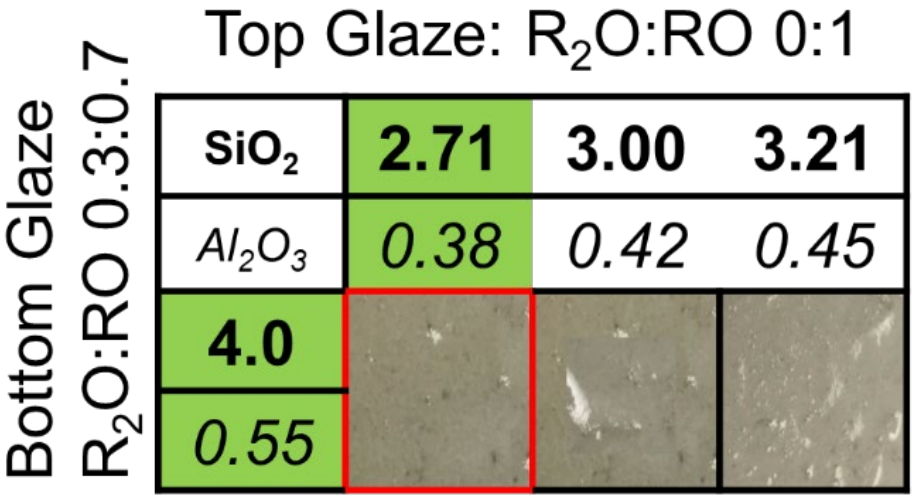

Figure 4. Decreasing SiO_2:Al_2O_3 top glaze trial results, The glazes highlighted in green and outlined in red are the selected "best" bottom and top glazes for future testing.

Figure 4 displays the results of the trial where the level of SiO_2 and Al_2O_3 in the top glaze was decreased at a constant flux ratio of R_2O:RO 0:1. As levels of SiO_2 and Al_2O_3 were decreased the glaze appeared glossier and displayed less crawling behavior.

From the results of this final glaze surface trial, the "best glaze" was selected. The composition is highlighted in Figure 4, in green, and was selected to be used in final color and firing tests for this work. This glaze displayed superior texture (gloss) while maintaining a difference in R_2O:RO ratios between the top and bottom glaze layers that successfully encouraged a calcium gradient, seen in Figure 5.

ANALYSIS OF OPTIMIZED GLAZE

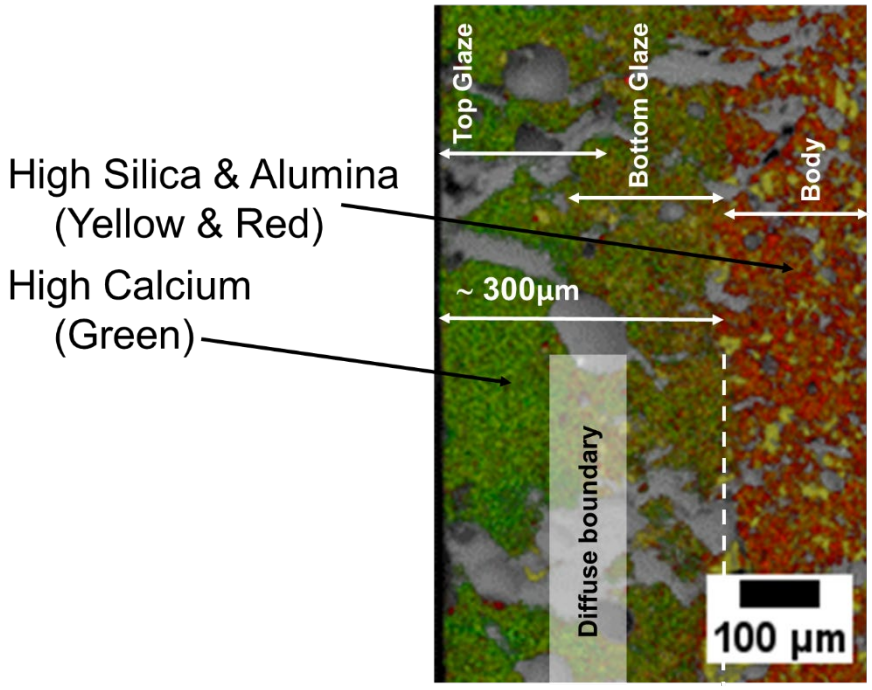

Figure 5. EDS mapping of glazed sample A1, with labelled regions and highlighted boundaries.

Figure 5 displays EDS mapping of glazed Sample A1. The measured glaze layer thickness is equivalent to the sum of the historical glaze layer and historical glaze body interaction depth at 300 µm[1]. The clear gradient in calcium concentration created by the two-layer glaze system is also seen in the mapping of calcium in Figure 5.

Given the firing temperature and approximate dwell time of this sample, the glaze body interaction depth is estimated to be ~ 20 µm.[2] As a result, the dissolved body from this does not significantly contribute to the overall chemistry of the 300 µm glaze layer.

Color is a critical component to defining celadon. The following are the results of color experiments where different iron sources (red iron oxide, high iron grog), iron concentrations, and furnace atmospheres effects on color were tested.

Figure 6 is a plot of measured experimental sample color data (white dots) superimposed on historical celadon color data[6] (shaded regions) using the L*a*b* color system. All samples fired in both oxidation and reduction atmosphere are consistent with historical data of Korean Celadon Glazes from 918 C.E. to present.[6]

In the reduction fired samples, as iron concentration increased, a* decreased, the samples appeared more green (eg. A1 and A2). The measured colors of these reduction-fired samples are consistent with historical data from the highest quality 12th century Celadon wares of Kanjin (I) and Puan (III).[6]

In the oxidation fired samples, as iron concentration increased, b* increased, the samples appear more brown in color (eg. A3) but are still consistent with historical celadon color data.[6]

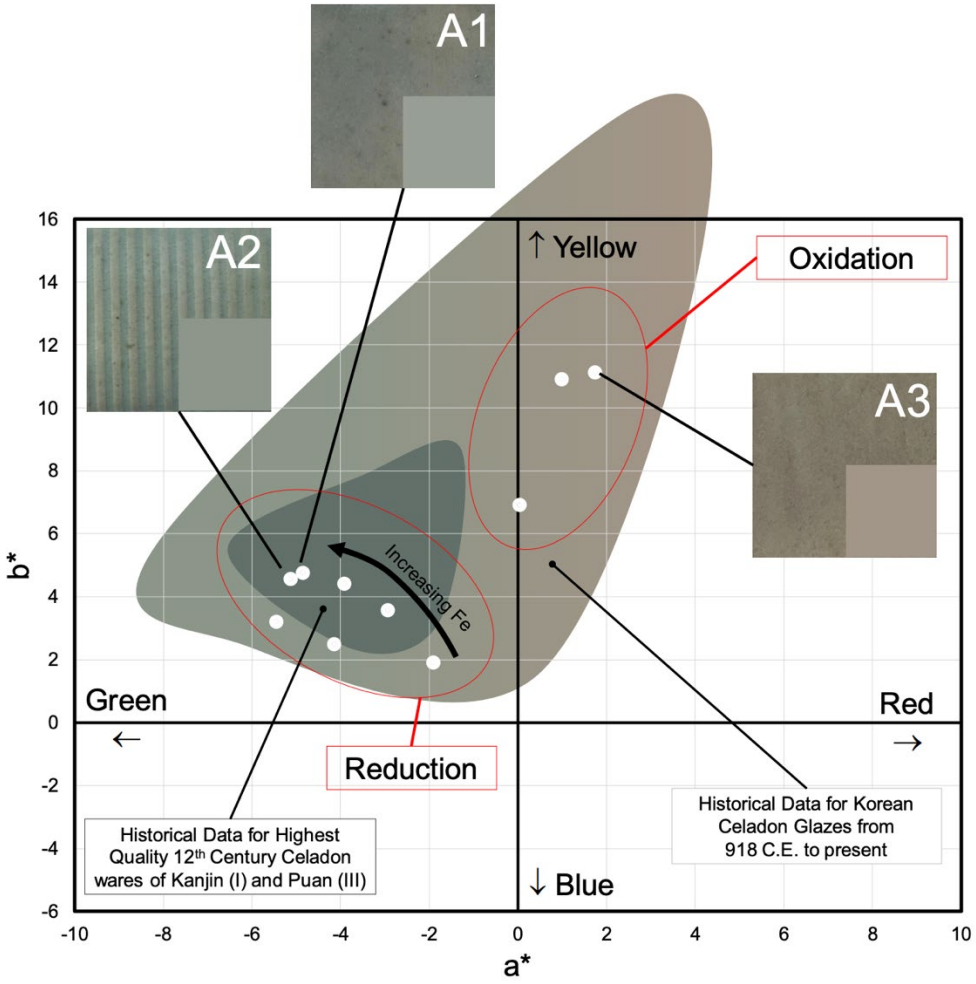

Figure 6. Visualization and plot of sample colors compared to historical color data [6]

Discussion

GLAZE OPTIMIZATION

Different trials and adjustments were completed to obtain a glaze that recreates the optical effects present in ancient Korean celadon pottery. This glaze should have similar chemistry, texture, and color. The glaze must maintain a difference in R_2O:RO ratios between the top and bottom glaze layers and create the appropriate calcium gradient with the correct thicknesses of each layer. A two-layer glaze system was explored, initially with glaze layers containing very different flux ratios. The starting top glaze was very high in calcium (R_2O:RO 0:1) and the base glaze was very high in sodium/potassium (R_2O:RO 0.9:0.1). This starting point, however, did not result in successful samples. This is likely due to the use of soda ash in high quantities as raw material in the bottom glaze. Soda ash, a soluble source of flux, migrated through the porous tiles during application and caused them to stick to the kiln shelves during firing.

FIRING TEMPERATURE

The initial glazes did not produce acceptable results. These glazes also displayed severe overfiring at Δ10. So, a switch to Δ7 was made by adjusting the silica and alumina ratios to more accurately represent the temperatures at which the ancient pieces are believed to have been fired.[1]

SILICA ALUMINA RATIOS

A change in silica and alumina ratios was made to the glaze chemistry that was directed by reviewing Stull and Howat's deformation temperatures.[4] The silica and alumina ratios within the eutectic were used to build two glaze layers that would melt without boron around Δ7. The fluxes were adjusted and remained the biggest difference between the glaze layers. The top glaze remained R_2O:RO 0:1 (high calcium). The bottom glaze followed Stull and Howat's research and had a fixed level of R_2O:RO 0.3:0.7 (typical calcium). However, the top glazes of these trials did not melt sufficiently, as seen in Figure 2. This is likely due to the silica and alumina levels being too high for the calcium-aluminum-silicate eutectic[8]. Using the approximate silica and alumina level and ratio from the calcium-aluminum-silicate eutectic[8], additional top glazes were created with lower amounts of silica and alumina.

WOLLASTONITE VS. WHITING

To address a glaze texture uniformity issue, wollastonite ($CaSiO_3$, a raw material source of calcium) was used instead of whiting ($CaCO_3$ raw material source of calcium) at the suggestion of an online source[9]. The resulting glazes did not melt as much as their counterparts that contained whiting. It is possible that less calcium is available in wollastonite to dissolve into the glass than is available in whiting. This could be due to the calcium silicate structure of wollastonite vs. the calcium carbonate structure of whiting. A switch back to whiting resulted in better (glossier) glazes.

COLOR OPTIMIZATION

Glaze chemistry, iron concentration, and kiln atmosphere all impact final glaze color. Historical Korean celadon glazes likely obtain the iron needed for their color from

dissolved body iron at the glaze body interface. An iron source was added to the bottom layer of the two-layer glaze system to mimic the historical source of dissolved body iron. Incorporation of mullite was proposed as an additive in the bottom glaze to scatter light and supply a source of iron. High iron body grog was sieved down to 400 mesh to mimic the size of mullite particles measured in ancient samples (measured 30μm) using ImageJ (ImageJ, V.1.8.0 NIH Image, Bethesda, MD) (ref. KICET paper/mullite image). Incorporating 400 mesh grog from an iron-body into the bottom glaze was tested as a source of iron for color and mullite for light scattering. Additional tests incorporated red iron oxide directly into the bottom glaze. Defining a difference in the light scattering between the samples with incorporated grog and those with red iron oxide was not conclusive. For fine tuning glaze color experiments, red iron oxide was chosen.

ATMOSPHERE – NEED FOR REDUCTION

Reduction is necessary to achieve the characteristic colors of high-quality celadon glazes. In a modern firing, abundance of natural gas fuel is used to create a reducing atmosphere by forming CO as the oxygen scavenger.

Reproducing a gas kiln firing is difficult, if not impossible, because all gas and air adjustments are made by hand at the discretion of the operator. This firing requires practice and artistry to use the equipment dependably. Therefore, local reducing methods in an electric kiln were used in an attempt to be more reproducible. One possible way to create a local reducing environment in an electric kiln would is use oxygen scavengers like aluminum or carbon. This was first attempted in a saggar: a ceramic container used inside a kiln to create a local atmosphere. Firing a saggar containing aluminum foil to

scavenge oxygen (create reduction) did not result in samples with any desired color response or noticeable change from a glaze fired outside of a saggar (data not shown). Incorporation of powdered sugar into the glaze was also tested for creating a reducing environment in an electric kiln. As the sugar burns it scavenges oxygen from its surroundings, however, this also did not result in samples with the desired color and resulted in noticeable glaze bubbles (data not shown). Since all the attempts at local reduction in an electric kiln were unsuccessful in developing desired glaze color, in the end, a gas reduction firing was used.

GAS REDUCTION.

After attempts at local reduction were unsuccessful, a gas kiln was used to do a traditional reduction firing, sacrificing computer-controlled reproducibility. In the first trial, gas firing glazes were applied by dipping and pouring. Glazes flaked and came out thick and crawled (data not shown). In areas where the top glaze was very thick, the glaze did not melt much at all. An adjustment was then made to the application procedure where dispersant was added to thin the top glaze. Brushing and spraying were also chosen as application methods. In addition, slab-rolled tiles were used for brushing tests. Glaze was brushed allowing for drying in-between coats. First, two coats of bottom glaze were applied by brushing, then an even thin top glaze was applied by brushing. In this second trial there were uniform color responses and optimal surface texture (satin and glossy finish). These tests are seen in Figure 6 along with the color data collected from them.

Conclusions

Incorporating the glaze-body interaction, to assess chemistry shift, allowed for the development of a closer chemistry match in the trial glazes that closely mimicked the historical celadon samples. A bottom glaze with R_2O:RO 0.3:0.7 and SiO_2:Al_2O_3 4.0:0.55 was selected as the best bottom glaze. This glaze needs to be applied twice as thick as the top glaze for best results. A top glaze with R_2O:RO 0:1 and SiO_2:Al_2O_3 2.71:0.38 was selected as the best top glaze. It is necessary to apply this glaze in a thin and even layer for best results. The presence of mullite particles, imbedded deep in the glaze, scatter light and change the perception of the glaze, suggesting a need for the two-layer system approach, further improving closeness of the trial glazes to the visual appearance of the historical Celadons. The two-layer approach is an effective method for simulating the deep glaze-body interaction that results from ancient firing cycles and is proposed to be a necessary inclusion for the replication of ancient Korean Celadons using contemporary ceramic materials.

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Appendix A

Table IV. Pyrometric Cone Equivalent Temperatures (Seger and Orton)

Cone	Seger (°C)	Orton (°C)
04	1020	1060
03	1040	1101
02	1060	1120
01	1080	1137
1*	1100	1154
2	1120	1162
3	1140	1168
4**	1160	1186
5	1180	1196
6	1200	1222
7	1230	1240
8	1250	1263
9	1280	1280
10	1300	1305

Appendix B

Table V. Final Glaze Batch Recipes, weight % basis

Glaze	**Nepheline Syenite**	**Whiting**	**EPK**	**Flint**
Final Top	0	33.22	32.57	34.21
Final Bottom	36.53	17.21	16.02	30.23