kaolin and color

by Ryan Coppage, PhD and Jenn Wicks

Various clear glaze bases yield different colors from the same pigments with the same amount of pigment. For example, an increase in kaolin content typically results in more scattering of light through your glaze, resulting in various pastel tones of a single color.

Define the Terms:

Coefficient of Expansion (COE): The ratio of geometric expansion (height/width/depth) relative to a change in temperature that is assigned to both clays and glazes. This attributes to and dictates the relative compatibility or fit of a glaze with a clay body.

Color Center: The metal pigment suspended in a medium, with the glaze oriented around and interacting with the metal atom, which absorbs portions of the visible spectrum of light, and ultimately results in glaze color.

Crazing: The development of small cracks on a surface (typically a glaze) as a result of relieving stress from different coefficients of expansion between clay and glaze during cooling.

Saturation: The relative purity (or single-wavelength nature) that a color can possess. High-saturation color is effectively a more narrow color band in terms of reflected light, whereas low saturation is a more broad color band of various or a range of wavelengths.

Scattering: The dispersion of light as it is caught and reflected across and by small particles in any kind of transparent or translucent material. Techno File Terms

Kaolin

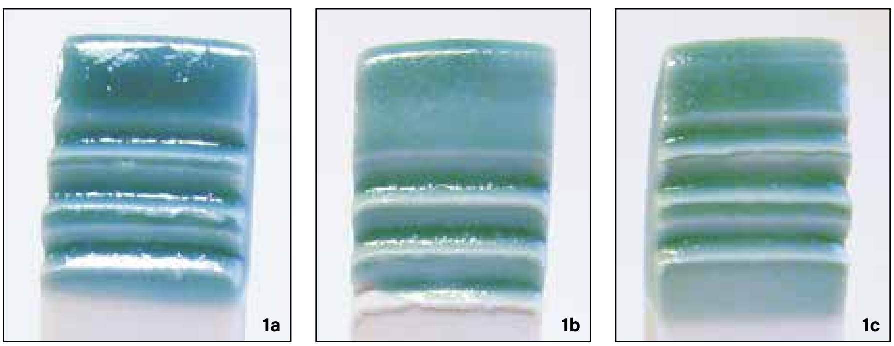
The generically used term for pure "clay," kaolin is everyone's favorite aluminosilicate. It is the weathered derivative of feldspar and comes in many varieties and close cousins—Grolleg, china clay, EPK, Hawthorne bond, Goldart, etc. Mined primarily from its secondary source, it often exists in more pure deposits, is more chemically homogenous throughout its vein, and exists in smaller particle size, which makes it easier to develop. Despite impurities and slight differences in chemical composition, aluminosilicates mostly exist in alumina and silica majorities. Kaolin is the extreme here, as it has often been washed and is just a hydrated aluminosilicate. And, as such, without the use of frits in glaze bases, kaolin content contributes to alumina:silica ratios and ultimately the glassy/clear nature of a glaze (1). Without getting into alumina:silica ratio territory, color space, or a handful of other technical components, there are somewhat easy ways to identify potential color purity or saturation in a glaze by its base recipe.

Pigments

In the simplest of definition, pigments are transition metal oxides, carbonates, and a few sulfates that are responsible for the absolutely brilliant colors in glazes. Despite the vibrant colors that they are responsible for, only a small amount of pigment is needed in a glaze recipe—0.5% for most celadons and up to 12%+ for dark tenmokus. These mechanistically work by creating color centers—effectively coordinating the glaze environment around them, doing some science-type things involving photons and electrons (that you probably don't want to read about), and ultimately absorbing part of the visible light that strikes them. The remainder of the light that isn't absorbed is transmitted through the rest of the glaze, strikes the white surface of clay, and is reflected back out to the eye, which rebuilds it as perceived color. As light goes through more and more color centers on its path through the glaze (and back out), more of those absorbed wavelengths (the parts that are cut out) are subtracted from the light profile. Thus, more pigment results in a deeper, darker color, as less overall light is reflected back to the eye.

Kaolin and Color Quality

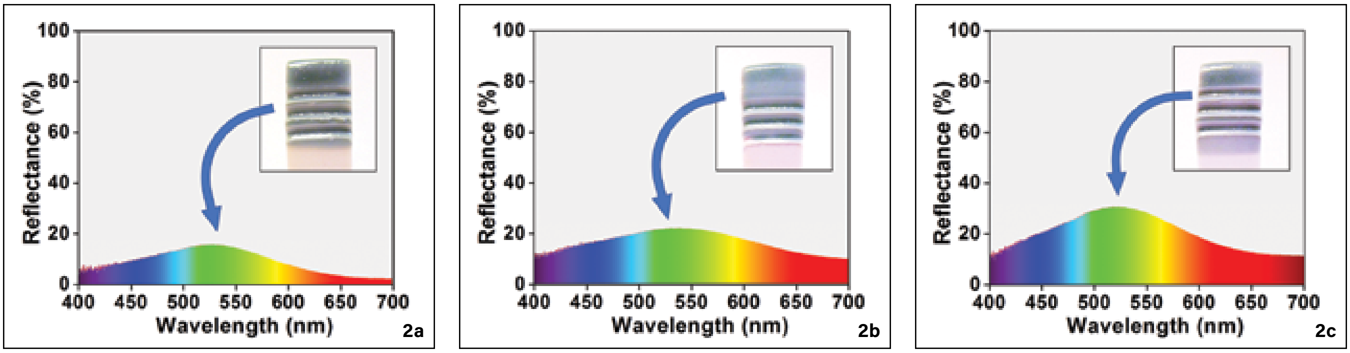
As clay content is increased in each clear base-glaze recipe, an increased amount of light from all wavelengths is reflected back out of the glaze profile, resulting in a higher intensity overall color (2). In addition to the green peak centered at ~520 nm, all other wavelengths are reflected back as well, though smaller in magnitude. Ultimately, this overall increase of reflectance results in more net light of all wavelengths, approaching white light.

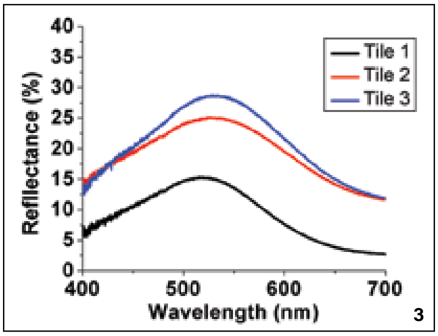


1a-c Cone 6 Laguna Frost tiles with incremental kaolin content in clear bases and colored with 1% copper carbonate, each.

Noticeably, kaolin or clay content will add a certain milkiness to a clear glaze. On the other hand, it adjusts the coefficient of expansion (COE) to be more akin to that of the clay itself and reduces crazing. This exists as a kind of double-edged sword. As an example, the most saturated and pure-color celadons have very little clay content in them at all. At the same time, their COE is not at all similar to the clay body they are on, and thus they craze notoriously like the dickens.

The addition of clay or kaolin to glaze recipes will make the glaze's COE more





2 Reflectance spectra of tiles 1–3, all with 1% copper carbonate pigment, showing increased reflectance profiles centered on the ~520 nm, green portion of the spectrum—as clay content is increased from 6% (a), to 8% (b), to 13.8% (c). **3** Graph with comparative reflective profiles of tiles 1–3. **4** Various clear cone-6 oxidation base recipes, to which 1 % copper carbonate was added for the above reflectance profiles a–c, respectively.

similar to that of the clay it is on, but also introduces a scattering phenomenon to the glaze, such that all wavelengths of light are at least partially reflected back out to the eye—to rebuild the same color in a pastel tone—approaching white light. Overall reflectance is increased as the clay content of the glaze recipe is increased (alumina:silica ratios) (3).

What It All Means

Essentially, as clay content is increased in a glaze body, the color it would normally produce becomes more muted and less saturated—more pastel. Additionally, it will craze far less and be a better fit for a wider range of clays.

On the other side of that coin, those of us who love incredibly vibrant, highly saturated colors are left working with the most aggressively shrinking, finicky porcelains that have COEs similar to that of a pure glass, or a glaze without much alumina content—often to avoid fit/shrinkage and crazing issues. The most purely saturated colors will exist in pure glasses—borosilicates, effectively no alumina content, as just highly alkaline silicates. These have vastly different COE values and would be very crazed/have such a different expansion/contraction nature, that they would chip off with the slightest amount of stress.

To make a glass compatible with a ceramic material, a glaze is effectively designed with alumina content—as an intermediate between a glass and a ceramic. This adjusts the COE to be more similar to that of a ceramic material, such that the expansion/contraction as a function of heat more closely resembles that of clay—or closely enough resembles that of the ceramic body.

Unfortunately, that results in bulk light scattering and some loss of color saturation. Pure colors become pastel as a function of full-spectrum reflectance.

It isn't specifically adding clay, so much as it is increasing the alumina (and borate) content of the glaze itself; however, that happens (and is often practiced) by literally adding clay (or side-stepped by adding silica and borates in conjunction with one another, but this begets more off-gassing and thus pin-holing.)

The mild exception to this would exist in frits, which allow for a little bit of color quality wiggle room, but color saturation is still lost, if even slightly by the presence of alumina. Even Ferro frit 3124 and 3134 have 2% and 10% alumina, respectively.

In conclusion, more frequently than not, more clay in a glaze base = a more pastel, muted color and less clay in a glaze base = a more saturated color, but it is also more likely to craze.

the authors *Ryan Coppage is currently chemistry faculty at the University of Richmond. He teaches a Making Inspired Mugs and Glaze Design class at the Visual Arts Center of Richmond and is starting to make a reasonable number of pots. To see more, visit www.ryancoppage.com. Jenn Wicks is an art major/chemistry minor at the University of Richmond.*

#1 CHUN CLEAR
Cone 6 Oxidation

Whiting	14 %
Zinc Oxide	12
F-4 Feldspar	38
Kentucky Ball Clay	6
Silica	30
	100 %
Add: Copper Carbonate	1 %

Recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment.

#2 FAKE KOREAN CELADON
Cone 6 Oxidation

Whiting	17.89 %
Potash Feldspar	50.53
China Clay	8.42
Silica	23.16
	100.00 %
Add: Copper Carbonate	1.05 %
Zinc Oxide	5.26 %

Recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment.

#3 FISKE 6/10 CLEAR BASE
Cone 6 Oxidation

Whiting	12.8 %
Zinc Oxide	11.0
Minspar 200	34.9
OM 4 Ball Clay	13.8
Silica	27.5
	100.0 %
Add: Copper Carbonate	1.0 %

Recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment recipe comment.

4

Send your technical topic ideas to Ceramics Monthly *at editorial@ceramicsmonthly.org.*