Notes on Clay & Glaze: ***(M. Schmidt - Sp' 2009)***

Origins and Basics of Clay:

Definition of Clay: Clay may be defined as an earthy mineral substance, composed largely of a hydrous silicate of alumina, which becomes plastic when wet and hard and rock-like when fired.

Definition of a Clay Body: A mixture of clay or clays and other earthy mineral substances, which are blended to achieve a specific ceramic purpose.

Clay is plate-like in shape and varies in particle size, texture and color. Because of it's varied particle size most clays shrink at different rates, the more fine the particle the greater the shrinkage. Ball clay, which is very fine, shrinks far more than a fire clay, which is typically more course.

***** 3 Basic Components of a Clay Body:***

1. Plastics (clays) 2. Flux (Feldspar) 3. Fillers (non-clay aggregate such as grog or sand)

***** Primary Clay or Residual Clay:*** Clays that have been formed on the site of their parent rocks and have not been transported, either by water, wind, or glacier. Typically white and pure, free from organic contamination, most ***Kaolins*** are Primary Clays.

Examples of Kaolin *(sometimes called 'China Clay')* **-**

EPK (Edgar Plastic Kaolin or Florida Kaolin, inexpensive & most common Kaolin used in the US)
Tile 6 Kaolin (T-6 Kaolin, good in flashing slips for vapor firing)
Grolleg Kaolin (English Kaolin, very pure white)
Hellmar Kaolin (mined in Montana, good in flashing slips for vapor firing)

**Kaolin is highly refractory, has poor plastic properties - typically white and fairly pure.*

***** Secondary Clay or Transported Clay:*** Clays that have been transported from the site of the original parent rock. Although water is the most common agent of transportation, wind, glaciers and tectonic events are also methods of movement. Secondary clays are typically grey and darker and have plastic properties. ***Ball Clay*** and ***Fire Clay*** are examples of Secondary Clays.

Examples of Ball Clay –

OM4 (Old Mine #4, mined in Kentucky)
Tennessee Ball Clay #1, #5 or #10
Foundry Hill Cream

**Opposite of Kaolin, Ball clay is highly plastic and has excessive shrinkage, which can reach 20+% when fired. Relatively free of impurities.*

Examples of Fire Clay –

Hawthorne Bond (Mined in Missouri & Ohio)
AP Green or Harbison Walker Fireclay (Mined in Missouri)
Lincoln 60 (provides excellent drying properties, has high plasticity)

**Fire Clay is typically course and is added for strength or "tooth" in a clay body. It is highly refractory or resistant to heat.*

Examples of Stoneware Clay and Sagger Clay –

Goldart (mined in Ohio)
Jordan Clay (Mined in New Jersey)
XX Sagger Clay (sometimes considered a ball clay)

**Stoneware/Sagger clays have good plastic properties and are typically grey or dark in color. They are refractory, yet posses desirable working characteristics.*

Examples of Earthenware Clay *(sometimes called 'common clay')* –

Redart (mined in Ohio)
Newman Red Clay
Carbondale Red (or C-Red, similar material as Jasper clay from Gladding - McBean)

**Earthenware clays typically are red or brown in color due to their high iron content. Common clay may be highly plastic, in fact, too plastic, and may feel sticky or greasy to the touch. Typically a low fire clay that matures under 2000 degrees Fahrenheit.*

Ways to alter a clay body to make is more useful – Changes in:

1. Color and Texture 2. Plasticity 3. Shrinkage / Drying Flaws 4. Temperature 5. Glaze "Fit"

5 Basic Stages of Clay:

1. Wet 2. Leather-Hard 3. Bone Dry 4. Bisque 5. Vitrified

Basic Temperature Ranges for Clay Bodies & Glaze *(measured in Pyrometric Cone Equivalent PCE):*

Low Fire: Up to Cone 1 (Cone 022-Cone 1)
Mid Range: Cone 1-Cone 6
High Fire: Cone 7- 12+

Stoneware and Porcelain are typically high fire clay bodies, fired to Cone 9-11.
Earthenware is typically considered a low fire clay body, fired up to Cone 1.

Pyrometric Cone: A pyramid-shaped ceramic device used to quantify the amount of heat delivered by a kiln. These devices (cones) are formulated from different mineral mixtures (clay and flux materials) and numbered accordingly. Cones are chemically formulated to ruse and bend at a predetermined heat. They are placed in a kiln so they can be viewed (or positioned in a Kiln Setter) during firing and when a cone begins to bend it is closely monitored and the firing is terminated when it reaches a specific position (temperature). Or in some electric kilns it shuts off a kiln setter.

Cone Ranges begin at Cone 022, 020, 019…010, 08…04, 02, 01 – 1, 2, 3…6, 7…8, 9, 10+ etc, *No Cone 0.*
**Thus, Cone 4 is hotter than Cone 08.*

**** 3 Basic Components of a Glaze:**

1. Glass Former (Silica / Flint – use Flint 325m in glaze formulas, Flint 200m in clay body formulas)
2. Flux (Typically a Feldspar or Frit)
3. Refractory (clay, typically Kaolin or Ball clay)

Examples of Feldspar *(sometimes called 'Spar')* –

G200 - "K-Spar." Potassium Feldspar (Mined in Monticello, GA. Inexpensive and commonly used)
Custer - "K-Spar." Potassium Feldspar
Kona F4 – Sodium Feldspar
Nepheline Syenite - Sodium Feldspar
Spodumene – Lithium Feldspar
Lithium Carbonate – Lithium Feldspar/Flux

Examples of Frit *(a man-made engineered "feldspar," used in low fire glazes)* –

Frits are pre-fused, ground "glasses" which are available commercially, in a variety of special compositions. Usually added to low or medium fired glazes, frits are primarily used for safety and reliability when toxic, or unstable compounds are required.
Pemco, Hommel and Ferro are "brand names."

Surface Characteristics of Glaze –

1. Glossy 2. Satin 3. Matte 4. Dry 5. Transparent 6. Translucent
7. Semi-Opaque 8. Opaque 9. Color Intensity 10. Functional 11. Decorative

Interface: The intermediate zone between clay and glaze, which is partly clay, partly glaze.

Reduction and Oxidation Firing, Impact on Color, Clay and Glaze –

Reduction, Reducing Atmosphere: A kiln atmosphere, which is deficient in free oxygen. This condition is accomplished in gas kilns by increasing back-pressure or reducing the amount of primary air available to each burner. The result is an increase in gases like carbon, hydrogen and CO. These are very aggressive in wanting to combine with oxygen. Hydrogen is small and particularly oxygen-hungry and can thus steal it from within clay bodies and glazes. *Reduction firing produces different colors and visual effects because metallic oxides willing to give up oxygen convert to their reduced or more metallic form.* Good examples are copper which burns red (it fires green in oxidation) and iron, which becomes a powerful flux and produces earth-tone browns (it is refractory in oxidation). Because almost all natural clays contain iron, reduction firing normally gives completely different clay surface effects than oxidation.

Reduction firings are not without hazard. Any form of incomplete combustion can generate smoke and deadly gases. CO for example, is deadly and is colorless and odorless. It is important that gas kilns be vented well and if possible that a CO alarm be installed.

Oxidation: A firing where the atmosphere inside the kiln has sufficient supplies of oxygen to satisfy chemical reactions in the glaze and clay, which use it. Typically, electric kilns are synonymous with oxidation firing, however they often have "stagnant" airflow and thus may fire to a more neutral atmosphere (direct-connected kiln vents improve this).

Fuel Sources –

1. Electric 2. Natural Gas 3. Propane. 4. Wood 5. Oil

Vapor Firing –

1. Salt (NaCl which is table salt or rock salt)
2. Soda (Sodium Carbonate/Soda Ash or Sodium Bicarbonate/Baking Soda)
3. Wood (Hard woods such as oak or walnut OR soft woods such as pine or Douglas fur)
4. Raku (Post Fire Reduction – Smoke)

Kiln Architecture & Burners–

1. Updradft
2. Down Draft
3. Cross Draft
4. Natural Draft Burner (Venturi)
5. Forced Air Burner
6. Jack Arch or Flat top
7. Corbelled Arch
8. Sprung Arch
9. Cantenary Arch

Primary and Secondary Air:

Natural Draft (venturi) 10-20 % comes from Primary Air, port on burner
80-90% comes from the Secondary Air, around the burner port.

Forced Air 80-90% comes from Primary Air, port on burner
10-20% comes from the secondary air, around the burner port.

Gas Pressure:

B.T.U. (British Thermal Unit): Amount of heat needed to raise one pint (or pound) of water one degree Fahrenheit.

Pound: Basic unit of measure. PSI = pounds per square inch.
Inches on the Water Column (WC inches): pressure needed to raise a column of water one inch.

1 pound of water is poured into a 1x1 inch glass tube, Therefore one pound per square inch.
At 39 degrees F the water is 27.69 inches tall, therefore 27.69” wc = 1 pound of pressure.
(Propane often is measured in psi, Natural Gas in wc”)

Natural Gas is usually found in low pressure (up to 2 lbs)
Cheaper and cleaner burning, but less BTU’s per cubic foot.
**One cubic foot of Natural Gas yields 1,000 BTU’s*

Propane needs to be stored in a tank…and typically is considered high pressure.
As the tank level decreases or the outside temperature drops; pressure drops.
**One cubic foot of Propane yields 2,500 BTU’s*

Standard Brick Sizes:

4.5x9x2.5 inches
4.5x9x3 inches

Firebrick Grades (hard-brick):

Super duty
High Duty (heavy duty)
Medium Duty
Low Duty

Insulating Fire-Brick (IFB) or "Soft Brick")
*These are common types of IFB -
K26 & K23
K20 & K19

*Alternative Materials include; Industrial/Commercial Castable, Home-made Castable and Ceramic Thermo-Blanket/Fiber (Inslwool).

There are many types of specialty brick, that come in larger sizes, and are made of different materials, such as high alumina brick, which is extremely refractory (heat resistant) and often white-(ish) in color.