TECHNO FILE

clay body building

by Jonathan Kaplan

Developing and building the best clay body for your studio practice requires knowledge of materials, ratios, limits, and of course a whole lot of testing.

Defining the Terms

Clay Body: A combination of component clays, glass formers, fluxes, and other materials formulated for a specific firing temperature, forming process, or function.

DTA Test: A thermophysical measurement of the expansion of a sample material upon heating and cooling that graphically illustrates quartz inversions.

Dunting: Cracking during cooling of ceramic ware due to an excess of crystobalite. Dunting also occurs when ware cools too quickly regardless of cristobalite?

Eutectic: Combination of two or more ceramic materials whose melting point is lower than that of any one of the materials used alone.

PCE: Pyrometric cone equivalent, a measurement of how refractory a material is.

Permeability: The property that allows the flow of liquids through a body, especially in slip casting.

Primary Clay: Clay that is formed but not transported from its parent site.

Refractory: The resistance to heat. Also refers to the ability of a material to withstand a certain temperature without deforming.

Tramp Materials: Non-clay materials that contribute to defects, e.g. lime or coal in fireclays.

Secondary or Sedimentary Clay: Clay moved by geologic processes over time from its parent site.

Vitrification: Firing ware to maturity where a glassy matrix is produced.

Materials, Variable, Ratios, and Limits

Typical clay bodies are built with three main ingredients: clay, feldspar, and silica. Depending on the firing temperature, the ratios between plastic materials (clays) and the non-plastic materials (feldspar, silica) change to produce bodies of excellent workability (1), proper vitrification, and glaze fit. Clay bodies can generally be divided into three groups by temperature ranges: low fire (terra cotta, white talc bodies) firing to maturity between cones 06–04), mid range (white ware, stoneware, porcelain) firing to maturity between cones 4–6, and high fire (stoneware, porcelain) firing to maturity between cones 8–11.

Building or designing a successful clay body is the result of an understanding of how the many materials can be combined in specific proportions to produce a desired result. The types of clays and other materials that comprise the clay body, the firing temperature, the atmosphere, and the forming method need to be considered. In addition, the shrinkage of the materials, their fired absorption, what burns off during the firing (the loss on ignition or LOI), and the thermal expansion of the clay body relative to glaze fit (a most critical criteria) must also be considered.

Plastic Materials

Both primary and secondary (or sedimentary clays) are used to build strong clay bodies at any temperature range. Primary clays are mostly light or white burning kaolins such as Grolleg, EPK Kaolin, 6 Tile , Helmer, Kingsley, McNamee, Albion, and Opticast, among others. Kaolins can lighten the color of a stoneware body and are the building blocks for porcelain clay bodies. When using kaolins as a main source of clay, understand that there are plastic kaolins as well as non-plastic kaolins. Kaolins are refractory and require adjusting the feldspar and silica amounts to achieve a vitrified body.

Secondary clays are ball clays, fireclays, stoneware clays, and red clays. By varying the distribution of materials, there is less of a chance for potential problems. Fireclays are refractory and generally add strength to a mix. Coarse fireclays will contribute some textural elements to the clay while finer mesh fireclays will not. Stoneware clays are generally plastic and smooth and help with vitrification. Ball clays promote plasticity, some can be high in silica and that must be taken into consideration with the total quartz content of the mix. Ball clays fire from buff to dark color.

1 Plastic to Non-Plastic Ratios—Throwing/Handbuilding

Temperature	Plastic	Non-Plastic
Cone 06–04 white talc bodies	40	50
Cone 06–04 terra cotta	60	40
Cone 06–04 white or red casting body	50	50
Cone 4–6 white bodies	60	40
Cone 4–6 non-white bodies	65	35
Cone 4–6 casting bodies	50	50
Cone 9–10 stoneware bodies (white)	70	30
Cone 9–10 stoneware bodies (colored)	80	20
Cone 9–11 porcelains	50	50
Cone 9–10 casting bodies	50	50

Some ball clays that are familiar are Old Mine #4 (OM4), Ti 21, Foundry Hill Creme, Kentucky Stone, FC 340, C & C Ball Clay, Coppen Light, and Champion. Common available fireclays are Hawthorne, Greenstripe, Plainsman Red, Cedar Heights fireclay, Lincoln, Green Ribbon, C Red, and Imco. Familiar stoneware clays include, but are not limited to; Cedar Heights Goldart, and Roseville. Common available red clays are Cedar Heights Redart, and Newman Red.

Some clays are specifically processed and blended for a particular forming method. For example, Opticast and FC 340 clays are blended specifically for slip casting. Their particle size is optimized for permeability.

Non-Plastic Materials

Adding silica to a clay body promotes vitrification and glass forming within the ceramic matrix. According to Digitalfire (http://digitalfire.com), the terms "flint, quartz, and silica have come to be used interchangeable in ceramics and you will see them all employed in recipes; they are all the same thing. However, most correctly, the material used in ceramics is silica. Quartz refers to the macro-crystalline mineral we find in nature."

Silica melts at a temperature much higher than we fire to in the studio, 2912–3137°F (1600–1725°C). So in order to lower the meting point to get our clay bodies to vitrify, we need to add melters. Clays contain small amounts of auxiliary fluxes, which can include iron, titanium dioxide, calcium oxide, magnesium oxide, sodium oxide, calcium, magnesium, and lithium, and potassium oxide. When combined with feldspars, which have some of the same fluxes (calcium, magnesium, and lithium), viable eutectics at temperature ranges used by potters and ceramic artists can be achieved. The melting of quartz by these fluxes promotes vitrification. As a result it also lessens the amount of excess quartz, known as free silica, which is highly undesirable because it causes problems and defects as the fired ware cools. Feldspars also contribute alumina and silica.

Feldspars such as Custer, G-200, Nepheline Syenite, and Primas are used in mid-range and high-temperature clay bodies. In low-temperature clay bodies, talc is used. Small amounts of frit can be added at the lower temperature range but particular attention needs to be paid to the upper limit temperature of the bisque firing to avoid beginning to vitrify the ware, making it more difficult to glaze.

Pyrophyllite, a hydrated alumina silicate, increases thermal shock resistance and promotes the fired strength of clay bodies by developing mullite. It can be substituted for an equal amount of silica.

Add grog, which is usually ground up firebrick, to a clay body to provide texture, also known as tooth, to promote even drying and contribute to the fired strength. Refractory calcines such as Mulcoa or Molochite are blended commercial grogs. They are available in many different mesh sizes and are a white-firing alternative to the darker firebrick-type grog, although they are more expensive.

Other materials that can be added to clay bodies are bentonites to increase plasticity and workability in bodies that are short; wollastonite to add calcium and silica, help to lower thermal expansion, and increase fired strength; mullite to promote strength and vitrification; and vinegar or inorganic materials such as Pro Bond, Additive A, and other compositions to increase plasticity.

Limits for Materials
Ratios of Plastics to Non-Plastics

Listed below is a fairly broad range for material limits. These provide a good starting point from which to begin developing a clay body (2). The proportion of plastics to non-plastics at the three major temperature ranges is important in developing clay bodies that have good workability and the necessary vitrification (1). These ratios work very well but can certainly be adjusted to suit specific needs. Note that in all temperature ranges, the casting ratio is the same.

2 Material Limits	
Stoneware Clays	to 100%
Ball Clays	to 50%
Kaolins	to 30%
Fireclays	to 75%
Red Clay	to 25%
Grog	to 30%
Silica	to 25%
Feldspars	to 25%
Pyrophyllite	to 20%
source: *Stoneware and Porcelain* by Daniel Rhodes	

Shrinkage and Absorption

All clays shrink after the physical water evaporates and the body becomes vitreous and dense. The finer the particle size, the greater the shrinkage. Fine particle-sized ball clays shrink the most and the coarser particle-size clays such as fireclays, shrink less (3). Shrinkage and absorption at low-fire temperatures are greater than at higher temperatures. Porcelain clay bodies shrink more than stoneware clay bodies. Proper material selection and making accurate shrinkage test bars of the component clays as well as the clay bodies that use them will provide a great deal of information. The same thinking should also be applied to the absorption or porosity of a clay body. A clay body with a low absorption will be more durable and vitreous. It will be less prone to fail under use, less prone to delayed moisture crazing, and provide lasting use.

3 Material Metrics (approximate)		
	shrinkage	absorption
Ball Clays	9–16%	2–6%
Fireclays	5–12%	9–11%
Kaolins	10–17%	8–9%
Stoneware Clays	8–15%	3–4%
source: *Cushing's Handbook* 3rd edition		

Loss on Ignition

The loss on ignition, or LOI, represents the amount of carbonaceous and tramp material that burns off during the initial stages of a firing. By mixing a small amount of ball clay or fireclay with water to form a slurry and passing it through a 60-mesh screen, we can see the residue of sand, small pebbles, bits of coal, limestone, twigs, etc. that need to burn off. As these materials outgas during bisque firing, the importance of a slow bisque firing that reaches a temperature high enough to burn off these materials is critical in preventing glaze defects such as pinholing in glazes or white spots in majolica. Whether one uses commercially prepared clay or mixes their own clay body, a proper bisque firing is an important step to producing defect-free ware.

Thermal Expansion

Every clay company will provide a material analysis of what oxides are present in their clay. Consideration should be paid to the amount of silica. These numbers will play a big role in the expansion of the clay body, which is pivotal in avoiding problems at the major quartz inversions. Clay and glaze calculation software is very useful in providing metrics on the amount of silica present as well as the thermal expansion of the clay body.

Putting It All Together

We can glean a great deal of information from simple testing of component clays for absorption and shrinkage and then develop a series of clay body tests using a spreadsheet (4).

Procedure: Dry mix 10 pounds of each test body in a plastic bag. Mix the dry clay body to slip consistency so that it can be screened through a 60-mesh sieve. Note the screen residue. Dry the slip mixture on a plaster slab to throwing consistency and wedge. Make test bars for shrinkage/absorption, and then use the balance of the clay to throw test-tile rings and small bowls and plates for further glaze testing. Should a suitable clay body be obtained, also run a freeze/thaw test, then put a slice of lemon on a small glazed plate overnight to check for acid attack. Then run a few pieces through a dishwasher cycle to check for alkali attack. Then test again, and again. Finally, send an appropriate sample to a laboratory for a DTA test. These methodological tests of your clay body will insure that your formula has the necessary properties to be successfully used in your studio practice.

A final note: materials change over time and also go out of production. Ongoing testing and modification over time assures that your clay body retains its necessary characteristics.

the author *Jonathan Kaplan's ceramic career has spanned over 40 years. He earned an MFA from Southern Illinois University at Edwardsville and has worked as a production potter, university educator, ceramic artist, professional mold and modelmaker, ceramic designer, and manufacturer. He serves on the board of* Studio Potter *and curates Plinth Gallery in Denver, Colorado.*

References

Clay and Glazes for the Potter by Daniel Rhodes
Stoneware and Porcelain by Daniel Rhodes
Ceramic Science for the Potter by William Lawrence
Cushing's Handbook by Val Cushing
Clay: A Studio Handbook by Vince Pitelka
Ceramic Technology for Potters and Sculptors by Yvonne Cuff
Clay Bodies by Robert Tichane
The Potters' Dictionary of Materials and Techniques by Frank and Janet Hamer
Clay and Glaze Handbook by Jeff Zamek
Ceramics: A Potter's Handbook by Glenn C. Nelson
Out of the Earth and Into the Fire by Mimi Obstler
Chemistry and Physics of Clay by Rex Grimshaw
Digitalfire: *http://digitalfire.com/4sight/education/index.html*

4 **clay body test sheet**

	70% plastics:30% non-plastics					
	Throwing			Casting		
Material	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Plastics						
EPK Kaolin	20		20	10		10
Grolleg		25		5	15	5
McNamee Kaolin	10	10				
Foundry Hill Creme			15			
#6 Tile Kaolin	30	10	5	10		10
Opticast/Velvacast				15	25	10
Greenstripe Fireclay		5	10			
Ti-21 Ball Clay	20	15	15			
FC 340 Ball Clay				10	10	15
Newman Red (screened)		5				
Total Plastics	80	70	65	50	50	50
Non Plastics						
Silica	10	15	15	20	25	15
Nepheline Syenite	10	5	20	30	15	20
Custer Feldspar		5			10	5
Pyrophyllite		5				10
Total Non Plastics	20	30	35	50	50	50
Total Clay Body	100	100	100	100	100	100

The above clay bodies and their component clays are a starting point for investigation. The throwing bodies are meant to be smooth and the casting bodies are set to be a 50/50 ratio. What works for one person may not work for another. Remember to always test and record your results.