

Ceramic Raw Materials Dictionary:

Alphabetical information on pottery glaze making materials and clay body ingredients:

ADDITIVE A - This clay conditioner gives clay more plasticity, higher green strength and greatly increased workability throughout our range of pre-mixed clays. The most dramatic improvement is in porcelain, white stoneware and sculpture clays. This additive has been thoroughly tested and will not change the color or texture of the fired clays. It can be used in any type of clay mixing. It will reduce mixer or pug mill power requirements by 25%, saving cost and wear in your clay mixing machines.

ALBANY SLIP SUBSTITUTE - Sheffield Pottery Incorporated has developed an Albany slip substitute utilizing a native glacial clay (see Sheffield clay) blended with an assorted amount of fluxing agents. This slip glaze produces a rich brown semi glossy glaze at cone 8-10 which mimics Albany slip glaze in reduction and oxidation firings.

ALUMINA HYDRATE - $\text{Al}(\text{OH})_3$ (m.p. 3722o F/2050o C) is used primarily in glazes as a source of Alumina. It is often favored over the oxide (Calcined Alumina) form due to its promotion of glaze adhesion and its capacity to remain suspended in a glaze. It is also used in salt glaze, bungs, and kiln wash.

ANTIMONY OXIDE - Sb_2O_3 (m.p. 1166o F/630o C) used in glazes as an opacifier and colorant (rarely, due to cost). However, its primary use is as a colorant (cone 06-1). In the presence of Lead or Iron, it will produce yellow. It is slightly soluble and very toxic.

BALL CLAY - is so named because it was first sold in England in the shape of a ball. It is a fine particle size secondary clay containing montmorillonite as its chief clay mineral constituent. It is essentially free of Iron and other impurities, and it fires to a light grey or buff color. It is used in clay bodies (rarely alone due to excessive shrinkage) to promote plasticity and higher firing ranges (cone 5-13). It is also used as a source of Alumina in high temperature glazes (cone 8-13), and it helps to keep a glaze slip in suspension.

BARIUM CARBONATE - BaCO_3 (m.p. 2480o F/1360o C) is used in glazes as the typical source for Barium. It has limited use due to its lack of reactivity and toxicity. In low fire glazes (cone 06-5) it promotes matt (sometimes dull) finishes. However, at high temperatures (cone 8-13), it is a powerful flux. It is used in clay bodies to control scumming by rendering sulfates insoluble.

BENTONITE - $\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2 \cdot 7\text{H}_2\text{O}$ is a decomposition product of Volcanic Ash resulting in a super fine (colloidal) clay. Montmorillonite is the major clay mineral constituent. The combined effect of the particle size and mineral make-up provides the unique quality that promotes plasticity in clay bodies (typically <4%), and enhancement of glaze suspension (typically <2%).

BONE ASH - $3\text{CaO} \cdot \text{P}_2\text{O}_5$ (m.p. 2462o F/1350o C) Natural: Bone Ash is prepared by calcination of selected animal bones (especially cow bones; some CaCO_3 contamination) and then ground to a predetermined particle size. When Phosphate is added to a glaze it tends to cause opacity, too much is likely to cause crawling or blistering. It is used as a flux in higher fired glazes (cone 8-13), and also as flux in porcelain bodies where it is known to enhance translucency. Synthetic: Bone Ash is produced from other non-bone Calcium Phosphate sources such as; the mineral apatite [$\text{Ca}_5(\text{PO}_4)_3(\text{OH},\text{F})$].

BORAX - $\text{Na}_2\text{O} \cdot 2\text{B}_2\text{O}_3 \cdot 10\text{H}_2\text{O}$ (m.p. 1366o F/741oC) this compound is also known as Sodium Tetraborate. Granular: Borax (5 and 10 mol.) has a coarse particle size (99.9% <2.4 mm), and is readily soluble in water and can, therefore, have limited use in an unfritted form. It is used in a glaze as a source of both Sodium and Boron, and it is a rigorous flux in low fire glazes (cone 06-5) due to its decomposition temperature. Used in small amounts (<10%) in high temperature glazes (cone 8-13), it can increase the fluidity of the glaze to help heal over defects (scratches, cracks or pitting) at the maturing temperature. Excess use can cause pinholing and blistering. Powder: (Borax 5 and 10 mol.) behaves the same as the granular form in a glaze. However, when a more rapid solubility (minutes versus hours) is needed the powder is preferred.

BORIC ACID - H_3BO_3 is soluble and has limited use in glazes due to other insoluble sources; i.e. fritted forms. When used as the only flux in an alkaline glaze it is less likely to cause crazing than Sodium fluxes. Boric Acid can be used in a clay body when introducing alkalies, however it is not advantageous, and Boron is a key element.

CALCINED ALUMINA - Al_2O_3 (m.p. 3700oF/2040o C) is produced by calcining a hydrated alumina (see alumina hydrate- $\text{Al}(\text{OH})_3$) at temperatures of 1200-1300C to convert it to alpha- Al_2O_3 . Alpha-alumina is the most stable form of aluminum oxide. It is typically substituted for molochite and or silica grogs in porcelain bodies (325 mesh). It reduces shrinkage, increases thixotropy (shear thinning characteristics), minimizes firing warpage, and adds fired strength.

C & C BALL CLAY - is mined in West Tennessee and is produced by H.C. Spinks Clay Company. It is a fine ball clay (69%, <1 micron) used principally in clay bodies to add plasticity and improve strength. In a glaze, it is a source of Alumina and will enhance glaze suspension (see also Ball Clay). CEDAR HEIGHTS BONDING - is a fire clay mined in Ohio and produced by the Cedar Heights Clay Company. It is used primarily in the refractories industry and is not recommended for ceramic use due to potential particle variability from lot to lot (see also Fire Clay).

CHROME OXIDE - Cr_2O_3 (m.p. 4418oF/2270o C) is used (in small amounts <2%; it is very refractory) as a colorant to produce greens. However, this Oxide has a chameleon-like effect on glazes depending on the choice of temperature and flux source, i.e. KNaO , CaO BaO , or MgO . Used in combination with Tin, it will produce pink, and with Zinc Oxide it will produce brown. Bright reds are possible in low-fire lead glazes that are low in Alumina content.

COBALT CARBONATE - CoCO_3 (m.p. 1661o F/905o C) is used as a colorant to produce blues in glazes (also see Cobalt Oxide). This compound is sometimes preferred over the Oxide form due to its particle size, thus eliminating the necessity for ball milling. Cobalt Oxide can substitute for the Carbonate form if used in one-half the given amount. It can also be used with Manganese, Iron Chromate, or Nickel to produce strong blacks.

COBALT OXIDE - Co_3O_4 (m.p. 1661o F/905o C) is the major oxide used for producing blues (also See Cobalt Carbonate). It gives comparable tints of blue in almost all firing ranges and varying firing methods. It's a very strong colorant (typically <2% is used). Glazes employing it as a colorant should be ball milled if mottling in the finished glaze is not desired. When using Cobalt Carbonate the amount should be doubled.

CORNWALL STONE - (Cornish Stone) is produced in Cornwall, England. It is a Feldspathoid used frequently in clay bodies and glazes (feldspathoids are chemically similar to Feldspars, however, they contain only 2/3 the amount of Silica and, therefore, are richer in alkalis). Its unique characteristic is the equal molecular equivalence of CaO K_2O and Na_2O . It can be used in a clay body when lowering the firing temperature of the body is required. In a glaze, it will help to minimize glaze defects such as crawling or crazing (see Feldspar).

COPPER CARBONATE - CuCO_3 (m.p. 2100o F/1149o C) is the most common source for Copper Oxide and is used (2%-5%) as a major colorant to produce greens, turquoise, and copper reds. The carbonate form is preferred over the oxide due to its finer particle size. The finer particle size enhances the production Alkaline glazes: turquoise in oxidation, and copper red in reduction (also see Copper Oxide). It is volatile above cone 8 and may require a sagger to protect other ware and kiln.

COPPER OXIDE BLACK - (CuO) RED (Cu_2O) (m.p. 2100o F/1149o C) are the two stable forms of Copper Oxide. Both forms are coarser in particle size than Copper Carbonate (also see Copper Carbonate). The more common of the two forms (in a glaze) is copper black (2%-5%). It is a strong flux used as a colorant to produce greens in oxidation and reds in reduction. Red Copper Oxide can be precipitated during reduction firings as a component of a copper red glaze finish. Other colors are turquoise in Soda based glazes, yellow-greens in Potash, and blue-greens in Barium. Copper Carbonate can be substituted for Oxide if the amount is doubled.

CRYOLITE - Na_3AlF_6 (m.p. 1828o F/998o C) is found in its natural form in Greenland. It is used in a glaze where Sodium or Aluminum is required. However, the Fluorine content can cause excess boiling of a glaze upon melting. The Fluorine gas driven off during the firing can cause bubble blisters and/or pinholes in the glaze. If the glaze is sufficiently fluid, a soaking period of 1/2 hour can help to eliminate the problem. The Fluorine effect is advantageous in producing crater glazes and crackle effects in other alkaline glazes.

CUSTER POTASH - is mined in Custer, South Dakota and produced (at this writing) by the Pacer Corporation. It is used in glazes and clay bodies as a source of K_2O . It contains 10% Potash and 2-3% Soda, and can be interchanged with G-200 Feldspar with modest adjustments (see also Feldspar).

DARVAN #7 - is a high molecular weight, long chain, Sodium Polyelectrolyte, produced by R.T. Vanderbilt Company. It is used as a general-purpose deflocculant (dispersing agent) in casting and glazing slips.

DARVAN #811 - is similar to Darvan #7 and is recommended for use in red casting slips.

DOLOMITE - $\text{MgCa}(\text{CO}_3)_2$ (m.p. 4800oF/2650o C) is used as an inexpensive source of Magnesia in glazes. It is a double Carbonate of Calcium and Magnesium, and a true Dolomite is typically 56% CaCO_3 and 44% MgCO_3 by weight. Impurities of Alumina, Iron, and Silica are common. It can be used in clay bodies to promote longer and lower firing ranges (below cone 9).

FLINT - (SiO_2) (m.p. 3119o F/1715o C) is the dark porous variety of chert that contains organic matter (chert is a hard, extremely dense, dull to semi-glossy sedimentary rock which is microcrystalline to cryptocrystalline quartz). True flint is very fine (cryptocrystalline) hydrated silica (1% molecular bound water) and is less dense than Quartz Sand due to a fine porous structure. The name flint is a carry over from England and France in which the true flints were prepared by calcination and grinding. Many geologists and archeologists suggest that the term flint be discarded or used only to identify artifacts of prehistoric humans (see also Silica).

FRIT - is commercially prepared by combining water soluble fluxes such as; Alkali Carbonates, Nitrates, Borates, etc., with Silica, which are then fused and ground to a predetermined particle size to render the fluxes insoluble. Harmful compounds such as Lead are also fritted to reduce their toxicity. Frits can be used in both clay bodies and glazes when introduction of water soluble and/or toxic elements is desired.

GLAZE CLAY #1 - is a ball clay mined in Kentucky and is produced by Old Hickory Clay Company. It is a fine ball clay (< 55%, <1 micron) used in clay bodies to add plasticity and improve strength. In a glaze, it is a source of Alumina and will enhance glaze suspension (see also Ball Clay). It is recommended by Ferro for use in fritted glazes.

GERSTLEY BORATE - $2\text{CaO} \cdot \text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ (m.p. 1225o F/660o C) is a hydrated Calcium Borate with Sodium as an impurity (< 5%). Its water solubility is minimal and, therefore, it is one of the only quasi-insoluble sources of Boron other than fritted form. It is widely used as a low-temperature flux and has the advantage of producing low temperature leadless glazes that tend to craze less than other Alkaline varieties. It also tends to advance a milky blue opalescence to a glaze that contains it as flux. ($2\text{CaO} \cdot 3\text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) can be substituted for approximately half the amount of Gerstley Borate in a glaze.

GLOMAX LL - $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ is produced in Dry Branch, Georgia, and is a non-plastic calcined Kaolin (60%, <2 microns) used in clay bodies to control firing cracks and shrinkage. In high temperature glazes (cone 8-13) it is used as a source of Alumina. (See also Kaolin).

GOLDART - is a ceramic grade stoneware clay (95% <74 microns) mined in Ohio and produced by the Cedar Heights Clay Company. It is used in clay bodies to increase refractoriness. Fired at cone 2 cream, and at cone 8 buff. (See also Fire Clay).

GROLLEG - is mined in Cornwall, England, and it is a water-washed primary Kaolin. It is the direct alteration of Granite and, therefore, higher in alkali, e.g. Potassium, than the secondary Kaolins of Georgia. It is a coarse particle size Kaolin, and it is used principally in porcelain bodies to enhance translucency brightness, due to the greater alkali content (see also Kaolin).

HAWTHORN BOND - This is stoneware clay used in clay bodies fired in the range of cone 1-14. It produces an array of colors from cream to brown, depending on the firing temperature.

HELMER KAOLIN - is produced by the Plainsman Clay Ltd. of Alberta, Canada, it contains kaolinite and halloysite (m.p. 3100o F/1700o C) clay minerals producing a white burning fire clay resembling china clay. Halloysite has the same chemical formula as kaolinite $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ however, the crystal structure is different. Halloysite containing clays tend to be more plastic and fire to a denser body than purely kaolinite clays. It enhances flashing (a brown to red surface coloration on unglazed bodies that develops during wood firing - cone 8-14). At the time of this writing Plainsman does not monitor the mineralogy make-up (e.g. halloysite content) and it is produced by a dry grind process of a raw white ore in quarry seams of clay containing some isolated pockets of Goethite (FeOOH) a dark iron mineral. The Goethite is not separated but blended with in the clay.

INDIANA RED 101 - A glacially derived plastic high iron (~ 6.5 wt. %) red burning earthenware clay similar to Sheffield clay (see Sheffield clay), which naturally fires to a vitreous dense body by cone 02. The product is a high silica and iron (~ 7.0 wt.%) earthenware clay firing to a yellow buff to brown color at cone 05-2. It is produced by the Unimin Corporation, headquartered in New Cannan, CT.

ILMENITE - $\text{FeO} \cdot \text{TiO}_2$ (FeTiO_4) (m.p. 2489o F/1365o C) is used in glazes as a colorant to produce tans and buffs, and it can also be used in granular form to produce mottling. Used in clay bodies or engobes, it promotes Iron spotting in reduction glazes. Rutile can be substituted; however, it contains less Iron and, therefore, its coloring strength is much weaker.

IRON CHROMATE - $\text{FeO} \cdot \text{Cr}_2\text{O}_3$ (m.p. 3000o F/1725o C) is used in glazes (typically <2%) to produce several colors. In combination with Tin, it produces pink/red; with Zinc, brown; in Alkalies, grey; and in Potash and Spodumene glazes (cone 5-12), it can produce mottled greys. In Engobes it also develops grey color.

IRON OXIDE - (m.p. 2818o F/1548o C) Red: Fe_2O_3 Iron Oxide is the most commonly used form of Iron as a colorant in glazes and clay bodies. It is used most often to produce tan to brown colors. When used in amounts greater than 4% it can react as a flux and increase the fluidity of the glaze.

Black: FeO Iron Oxide as a colorant will create a variety of colors depending on the glaze base used. Its effect is most often the same as Red Iron Oxide. However, it is preferred for producing celadon glazes in reduction firing.

Yellow #5060 - is a manufactured product, can be relied on to produce consistent results from year to year.

KAOLIN - Also called China Clay ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) (m.p. 3150o F/1760o C) is found both as primary and secondary clay deposits (Kaolinite is the major mineral constituent), and they are typically coarse in particle size and, as a result, are non-plastic. In glazes it is a major source of Alumina. If used in large amounts in a glaze, it can produce a matt texture. It is the principal component of porcelain bodies, and will produce white stoneware bodies in a wide temperature range (cone 5-16) due to its low Iron content.

Common types of Kaolin include: EPK, Tile #5, Grolleg, Avery and Helmer.

KAOPAQUE 10S - is produced in Dry Branch, Georgia, and is a water washed secondary delaminated Kaolin. The large delaminated clay particles have an average diameter to thickness (aspect) ratio of 11:1, compared to 6:1 for natural Kaolin. Its median particle size is 2 micron, and is used in clay bodies for extrusion when whiteness, brightness, and translucency are desired after firing. (See also Kaolin).

KYANITE - $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ (m.p. 3300o F/1800o C) is a non-plastic aluminosilicate and is typically not found in glazes. It can be added to clay bodies to stabilize shrinkage (due to its tendency to expand in firing) and improve strength. Its principal use is in the manufacturing of high temperature refractories for kiln bricks and furniture (see also Mullite).

LAGUNA BLACKBIRD - is produced as substitute for the Blackbird high manganese and iron earthenware clay (also know as Barnard clay). Blackbird was a naturally occurring clay-like mineral. Laguna Blackbird is produced by the Laguna Clay Company of California, primary use is as a source of iron in dark firing glazes.

LAGUNA BORATE - was developed as a direct substitute for Gerstley Borate (see Gerstley Borate) produced by the Laguna Clay Company. Its main constituent is calcium borate in combination with appropriate blend of additional fluxing agents.

LIZELLA CLAY - 3.9% iron content. A direct substitute for Ocmulgee Clay (which is no longer available). This 16 mesh clay is produced with better quality control than the Ocmulgee Clay, resulting in fewer flaws. Max. temp. is cone 9 with very little reduction. Also available screened to 30 mesh from Sheffield Pottery.

LITHIUM CARBONATE - Li_2CO_3 (m.p. 1330o F/720o C) is the most common form of the alkali Lithium. It is a major flux for higher temperature (Cone 5-13) alkaline glazes. It is less soluble than other alkaline compounds and produces more durable glazes. It can also be used as a supplemental flux to reduce the maturing temperature of stoneware glazes by as much as 2 or 3 cones. The powder and granular forms differ in particle size (the latter being coarser) and reactivity. The granular form can be used at higher temperatures where the reduced reactivity can be overcome.

MACALOID - see Vee Gum T; same as.

MAGNESIUM CARBONATE - MgCO_3 (m.p. 5072o F/2800o C) is used as a source of MgO in glazes. In glazes (cone 5-10), it can develop a butterfly surface favored for utility ware. At high temperatures (cone 9-16) it has a similar effect as Alumina; it will increase the viscosity of a glaze and hence reduce the fluidity; e.g. crystalline variety, in which Alumina is not desired.

MANGANESE CARBONATE - MnCO_3 (m.p. 3000oF/1650oC) see Manganese Dioxide.

MANGANESE DIOXIDE - MnO_2 (m.p. 3000oF/1650oF) is a source of MnO in glazes or clay bodies, and is used to develop reds, blues, purples, and black (MnCO_3 is considered a weaker colorant per unit weight of MnO than MnO_2 , at a minimum, two times the amount is needed). It is a vigorous flux (cone 5-10) in glaze and clay bodies (in a clay body use <5%), and it is also a strong oxidizing agent in glazes. The powder and granular forms differ by particle size and reactivity. The granular form can be used at higher temperatures where the reduced reactivity will develop dark speckles in both clay bodies and glazes.

MISSISSIPPI M & D - is a ball clay, mined in Sledge, Mississippi, and is produced by the Kentucky & Tennessee (KT) Ball Clay Company. It is a super fine ball clay (85%, <1 Micron), used principally in clay bodies (<10%) to improve strength and plasticity. However, used in excess it can cause extensive shrinkage and warpage (see also Ball Clay).

MOLOCHITE - $3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ (m.p. 3150o F/1760o C) is a high temperature calcination of high purity kaolin to maximize the conversion of kaolinite to mullite. It is available in a wide range of sizes (from 8 to 325 mesh) from Hammill & Gillespie, Christy Mineral Co, English China Clay, and NARCO. It is typically used as a low impurity grog in porcelain and white clay bodies grog improving drying shrinkage and thermal shock resistance.

MULLITE - $3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ (m.p. 3300o F/1800o C) is calcined Kyanite. Naturally occurring Mullite is not very common. It is named after one of the only known deposits on the Isle of Mull, off the West Coast of Scotland. Like Kyanite, it is non-plastic aluminosilicate and is typically not found in glazes. It can be added to clay bodies to stabilize shrinkage, improve strength, and modify thermal expansion.

NEPHELINE SYENITE - $\text{K}_2\text{O}\cdot 3\text{Na}_2\text{O}\cdot 4\text{Al}_2\text{O}_3\cdot 9\text{SiO}_2$ (m.p. 2200o F/1200o C) is a Feldspathoid used frequently in clay bodies and glazes (Feldspathoids are chemically similar to feldspars, however they contain only 2/3 the amount of Silica and are therefore, richer in Alkalies). Its unique characteristic is: the molecular equivalence of K_2O and Na_2O is greater than a typical Soda or Potash feldspar in relation to the Silica content. It can be used in a clay body when lowering the maturing temperature of the body is required. In a glaze, it can reduce glaze defects such as crazing and extend the working range of a glaze in the cone 011-5 vicinity (see also Feldspar).

NICKEL CARBONATE - NiCO_3 (m.p. 742o F/400o C) ; see Green Nickel Oxide.

NICKEL OXIDE - (m.p. 742o F/400o C) Green: NiO Green Nickel Oxide (typically <3%) is used in glazes (most commonly porcelain enamels) to produce blues, greys, browns, and yellows, depending on the molecular equivalence of the Alkalies, Alkaline earths chosen. It can also be used to soften the effect of Cobalt and Copper colorants.
Black: Ni_2O_3 in a glaze Black Nickel Oxide will reduce to Green Nickel Oxide at 600o C and produces similar results as NiO . Greater amounts may need to be added to a glaze to achieve the same effects.

G-200 POTASH FELDSPAR - is mined in Kingsmont, Georgia, and is produced (at this writing) by the Feldspar Corporation. It is used in glazes and clay bodies as a source of K_2O . It contains 10% Potash and 2-3% Soda and can be interchanged with Custer feldspar with modest adjustments (see also Feldspar).

PEARL ASH - K_2CO_3 (m.p. 1000oF/540oC) is Potassium Carbonate. It has a tendency to absorb atmospheric moisture, and is extremely soluble. When it is necessary to use in a glaze, its principal effect is in softening other colorants, i.e. Copper and Cobalt, when used as a low temperature flux (cone 011-3).

PETALITE - $\text{Li}_2\text{O}\cdot \text{Al}_2\text{O}_3\cdot 8\text{SiO}_2$ (m.p. 2550o F/1400o C) is a Lithium source used primarily in ceramic clay bodies (particularly for flame-proof ware, and refractoriness) to reduce thermal expansion and increase thermal shock resistance.

PYROPHYLLITE - $\text{Al}_2\text{O}_3\cdot 4\text{SiO}_2\cdot 2\text{H}_2\text{O}$ (m.p. $>3300^\circ\text{F}/1800^\circ\text{C}$) is used mainly in wall and floor tile clay bodies. It can also be used to produce ovenware bodies, control shrinkage and firing cracks, but should be kept under 15% of the body weight due to its non-plastic make-up. Rarely used in glazes; however, it can be substituted for Kaolin to reduce thermal expansion and improve crazing.

PYRAX HS - (m.p. $2790^\circ\text{F}/1530^\circ\text{C}$) is a high Sericite (a fine grained muscovite mica; $\text{K}_2\text{O}\cdot 3\text{Al}_2\text{O}_3\cdot 6\text{SiO}_2\cdot 2\text{H}_2\text{O}$) pyrophyllite blend produced (at this writing) by the R.T. Vanderbilt Company, Inc. It is made up of 35% foliated (platy) Pyrophyllite, 35% Quartz, 25% Sericite, and 5% Kaolinite. Rarely used in glazes, it is used primarily in wall tile bodies to reduce abrasive wear on molds and dies. However, it will lower maturing temperature, moisture expansion (increasing crazing resistance), and enhance strength in vitreous bodies.

PYRAX RG - (m.p. $2970^\circ\text{F}/1635^\circ\text{C}$) is a refractory grade, high pyrophyllite blend produced (at this writing) by the R.T. Vanderbilt Company, Inc. It is made up of 45% foliated (platy) pyrophyllite, 45% Quartz, and 5% Kaolinite. Rarely used in glazes, it is used primarily in insulating firebrick bodies. It can be substituted for feldspar and a portion of Quartz to reduce thermal expansion in clay bodies (cone 5-14). In addition, it will help to stabilize shrinkage due to its tendency to expand during firing. The expansion is particle size dependent.

PYROTROL W-200 - (m.p. $2970^\circ\text{F}/1635^\circ\text{C}$) is a 200 mesh refractory grade andalusite (Al_2SiO_5) pyrophyllite blend produced (at this writing) by the Resco Company. It is made up of 25% massive (blocky) pyrophyllite, 25% Andalusite, and 50% Quartz. Rarely used in glazes, it is used primarily in controlling shrinkage in stoneware clay bodies (cone 5-14) due to its tendency to expand during firing. The expansion is particle size dependent. Pyrotrol is not recommended as a direct substitute for Pyrax RG due to their different mineral make-up and particle shape. Alkatrol(s): the Alkatrol series of products are produced by adding, sericite (a fine-grained variety of muscovite - $\text{KAl}_2(\text{Al},\text{Si}_3\text{O}_{10})(\text{OH})_2$) to blends of andalusite and pyrophyllite to help broaden firing temperature range. Typically added to whiteware ceramics, to assist whiteness, improve warping (reduces fired shrinkage), and thermal shock resistance. Individual alkatrol variations are blended to various chemistries by altering the andalusite:pyrophyllite:sericite ratios during blending. Piedmont Minerals and the Resco Company produce these products by dry crushing & screening.

PIONEER - is produced in Dry Branch, Georgia, and is an air-floated plastic secondary Kaolin (60% <2 micron) noted for high green strength and white firing properties. It can be used in slip casting, ram pressing, and extruded clay bodies. In glazes, it is used as a source of Alumina.

REDART - is mined in Ohio, and produced by the Cedar Heights Clay Company. It is a fine particle size earthenware clay with a firing range of cone 06-1. It is used in earthenware clay bodies for its noted intense red color produced after firing.

RUTILE - TiO_2 (m.p. $3452^\circ\text{F}/1900^\circ\text{C}$) is an economical source of TiO_2 when pure white is not required. It is used in clay bodies and glazes (typically 1-3%) to produce ivory through yellow to dark tans in oxidation, and purples and blues in reduction. Its most frequent use is to modify the action of other colorants and to produce special effects such as mottling and streaking. Such effects are particularly striking in Gerstley Borate/Colemanite glazes.

Dark Milled: is a grade between Ilmenite and Rutile (greater amount of Iron). Light Ceramic: is a fine size true Rutile with some Iron contamination. Granular: is a coarse particle size true Rutile with some Iron contamination. The granular form is less reactive than the Light Ceramic grade and therefore, is used to promote mottling at higher temperatures (cone 8-13).

SHEFFIELD CLAY - is mined and beneficiated by Sheffield Pottery, Inc. in Sheffield, MA. It is a glacially derived high iron (~ 8.5 wt. %) narrow particle size red burning earthenware clay containing biotite [$\text{K}(\text{Mg},\text{Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH},\text{F})_2$], hornblende [$\text{Ca},\text{Na},\text{K})_{23}(\text{Mg},\text{Fe},\text{Al})_5(\text{SiAl})_8\text{O}_{22}(\text{OH})_2$], chlorite [$(\text{Fe}, \text{Mg}, \text{Al})_6(\text{Si}, \text{Al})_4\text{O}_{10}(\text{OH})_8$], quartz [SiO_2]. It can be used in both clay bodies and glazes (dense body at cone 5) and it is a stoneware glaze at cone 11-12.

SILICA - SiO_2 (m.p. $3119^\circ\text{F}/1715^\circ\text{C}$) is second only to clay in significance as a ceramic material, and it is the most abundant mineral in the earth's crust. The principal siliceous materials are: Crystalline Quartz, Quartzite, Sandstone, Silica Sand, "Organic" and Amorphous Silica: including Flint and Diatomaceous Earth. Silica is frequently referred to as "Potter's Flint" and is often just ground sandstone. It is used interchangeably with Quartz. Silica or Quartz is used in clay bodies to modify shrinkage, porosity, and strength (these modifications are affected by particle size and crystallinity). Quartz has a phase transition at $1063^\circ\text{F}/573^\circ\text{C}$, i.e. the Quartz inversion. Upon firing, this inversion occurs rapidly and results in volume expansion, which can lead to firing cracks in clay bodies high in Free Quartz. In glazes, Silica is the most common glass former. It serves to control the fusibility and viscosity, which are dependent on the amount of Silica in the glaze. Typical mesh size of 200 (>74 microns), 325 (>45 microns), and 400 (>30 microns) are offered for varying applications in clay bodies and glazes. The coarser 200 mesh helps to control shrinkage while the finer 325 and 400 mesh are useful in glazes for their reactivity and ease of going into solution.

SILICON CARBIDE, BLACK - SiC (m.p. $5100^\circ\text{F}/2800^\circ\text{C}$) contains up to 10% Free Silica and is highly refractory. It is used mainly in high temperature kiln furniture (cones 5-16), and has been experimented with in Alkaline glazes in amounts of 0.5 to 1.0% to produce artificial copper reds.

SODA ASH - (a.k.a. soda ash light) - Na_2CO_3 (m.p. 900o F/490o C) anhydrous sodium carbonate is a very active flux for low temperature glazes (below cone 5). However, it is water soluble and is generally used in fritted form to prevent recrystallization in the glaze suspension. Glazes which use raw Soda Ash should be well-ground and used immediately, or dry-ground and only the amount needed mixed with water. Soda Ash is also used in small amounts as a deflocculant (see Darvan #7) in clay slips to reduce the amount of water needed to make the slip fluid. Sodium bicarbonate (NaHCO_3) can be substituted as a deflocculant for Soda Ash, however, the amount should be doubled.

TIN OXIDE - SnO_2 (m.p. 2066o F/1130oC) is found in nature as the mineral Cassiterite. It is the most effective opacifier at all temperature ranges from terra cotta to porcelain. Amounts of 4-5% are typical, however, as little as 2%, and as much as 8%, are used in a glaze. If quantities above 8% are used it should be calcined to red heat (850o F/450o C) to prevent crawling of the fired glazes. Any of the Zircon opacifiers such as Zircopax, or Superpax will substitute, although greater percentages of each will be necessary (up to 10%) for similar results.

TITANIUM DIOXIDE - TiO_2 (m.p. 3360o F/1850o C) is produced by digesting Ilmenite (FeTiO_4) in Sulfuric Acid and then purifying to TiO_2 . It is used in a glaze as an opacifier, and it tends to produce cream colors versus the white color of Tin Oxide. It promotes acid resistance and texture to a glaze (such as the mottling effect similar to Rutile, but without the Iron contamination.) The Light Ceramic Rutile grade can be substituted if the Iron content is not a concern.

UMBER (Burnt) - is a ferruginous clay raw material consisting of Limonite ($\text{FeO}\cdot\text{H}_2\text{O}$) and Manganese Dioxide. It is used in engobes and clay bodies to promote red/brown color (see also Iron Oxide).

VELVACAST - is produced in Dry Branch, Georgia, and is a water-washed, coarse particle size secondary Kaolin (39% <2 micron) used principally for rapid casting of slips (controlling the heat rate of water removal for reduced warping) and ease of mold release (see also Kaolin).

VANADIUM PENTOXIDE - V_2O_5 (m.p. 1270o F/690o C) is derived from Vanadium ores in Denver, Peru, Namibia, and Zambia. It is used in a glaze as a colorant to yield yellow, greenish yellow and reddish brown. It can be used in 5% to 10% amounts to produce yellow. In combination with Titanium or Tin various shades of yellow can be obtained.

VEE GUM T - is produced by the Vanderbilt Company, Inc. It is a super fine (colloidal) purified Bentonite (hydrated Magnesium Aluminosilicate). Like Bentonite, it is used as a plasticizer (in white clay bodies due to its iron-free make-up) and as a suspension agent in glazes (typically <2%; see also Bentonite).

VEE GUM CER - is produced by Vanderbilt Company, Inc. It is a mixture of Vee Gum T and a medium viscosity Sodium Carboxymethylcellulose (SCMS). It is used in glazes to optimize the surface hardness of un-fired glazes, to stabilize viscosity, and to enhance glaze suspension.

VOLCANIC ASH - is pulverized pumicite (Volcanic Dust, i.e. minute fragments of volcanic glass). In a glaze, it can be considered as a Silica rich Potash Feldspar (70% Feldspar/30% Flint). Its use in clay bodies is limited to buff or dark stoneware due to its high Iron content. Stoneware bodies containing Volcanic Ash produce vitreous bodies with reduced shrinkage, stabilizing warping over a long firing range (cone 5-9).

WAX RESIST - is a wax emulsion, available in an oil or water base, and is used to resist glaze water penetration during the application of glaze. NOTE: As oil base wax resist ages, thinning may be required: Use a very small amount of water added gradually (no more than 1/2 cup as it is possible to add too much). Suggested removal of oil base wax resist from brush is as follows - boiling water, steam, or kerosene. Due to the aging of oil based wax a water base emulsion is more stable and much easier to use and clean up after.

WHITING - CaCO_3 (m.p. 4650o F/2570o C) is defined as a finely ground powder composed essentially of pure Calcium Carbonate derived from Limestone, Chalk, or Marble. It is the most common source of Calcium in a glaze and clay body. In stoneware glazes (cone 7-12), it promotes a matt finish and enhances chemical durability by producing harder and more chemically resistant glaze. In stoneware bodies (cone 7-12) it acts as a flux (typically >3%), and it will increase shrinkage and strength by lowering the point of vitrification while decreasing porosity. Snowcal 40 is a popular whiting from Hammill & Gillespie derived from the famous chalk deposit originating in Yorkshire England. Vircon 2511 produced by Specialty Minerals, from several North America limestone sources as a grounded product designed for narrow particle size distribution.

WOLLASTONITE - CaSiO_3 (m.p. 2804o F/1540o C) is a naturally occurring Calcium Silicate, and is mined principally in Willsboro, New York. It can be used to replace Silica and Whiting in clay bodies and glazes. In stoneware bodies (cone 5-13) it will promote low moisture expansion, and improved shrinkage, strength, and thermal shock resistance. When used in a glaze it acts as a Frit of CaCO_3 and SiO_2 to produce smoother and brighter glazes than Whiting.

YELLOWBANKS BUFF CLAY 401 - is produced by the Unimin Corporation, headquartered in New Cannan, CT. This product is a plastic high alumina stoneware clay (ball clay like plasticity) firing to a white to yellow buff at cone 8 - 12.

YELLOW OCHRE - $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$ Limonite (m.p. 2415o F/1325o C) is common in earthenware clay sources (rarely used in glazes as a colorant) and is one of the primary yellow or buff colorants in raw clay. When fired, the molecular bound water evolves off and forms Red Iron Oxide (Fe_2O_3). It is a significant source of red color in earthenware clay bodies. Used in Engobes as a colorant to produce ochre yellow, tans, and browns. Naturally occurring Yellow Ochre is less expensive than manufactured Yellow Iron Oxide.

ZINC OXIDE - ZnO (m.p. 3272o F/1800o C) is derived from Zinc Sulfide ores. It is an important component of many glaze types (cone 5-13) and is used as a flux, opacifier, and color modifier. It reduces the expansion of a glaze (second only to Magnesia), improves craze resistance, gloss, whiteness, and increases maturing range. In crystalline glazes, low in Alumina, it promotes crystal growth.

ZIRCOPAX - ZrSiO_4 (m.p. >3600o F/2000o C) is a Zircon opacifier used in glazes and slips, produced by Tamm Ceramics. It is produced (when compared to Superpax) with a coarse particle size, decreasing reactivity. It is less expensive than Superpax, however, greater amounts are necessary because of the reduced reactivity. ZIRCOPAX PLUS gives higher purity and a brighter white opacity. ZIRCOPAX is no longer available (see Superpax, Tin Oxide, and RZME Zirconium Silicate).

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