



Ceramics

An Ancient Material

Modified from Dr. Patricia Hill, Millersville University

Development of Ceramics

- Use of dried clays for food storage and cooking vessels
- Discovery that heating improves properties of clay pots
- Experimentation and improvement of heating techniques leads to development of ceramics technology

Early Pyrotechnology

Limestone plaster statues

‘Ain Ghazal Jordan

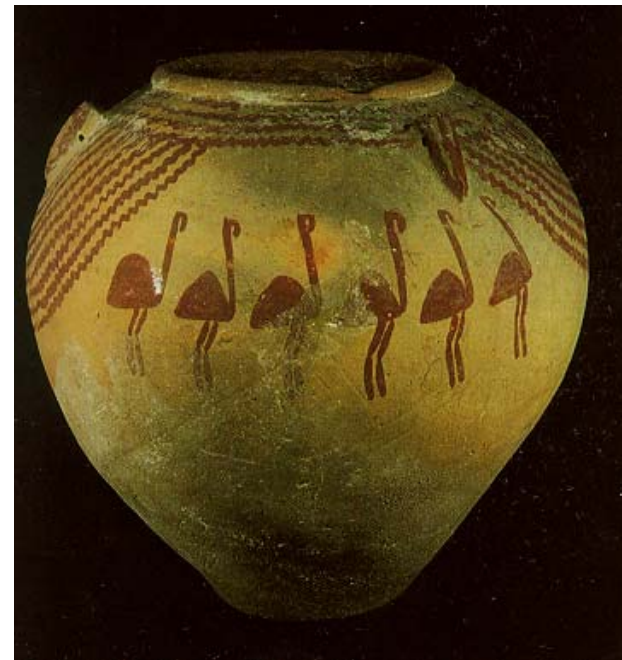
“Pre-pottery” - 8500-5500 BC



Neolithic and Predynastic Pottery



Iranian or Mesopotamian
6th-5th millennium B.C.



Egypt, 4th millennium B.C.

Historical Perspective

- 15,000 - 11,000 BC Burnt ceramics from Nile Valley
- 5000 BC Crude earthenware glazed with alkaline glaze in Egypt and near East
- 3000 BC Chinese pottery, wheels, clay molds
- 1000 BC Chinese porcelain, Greek pottery

Egyptian Faience



Goddess Taweret.



Reign of Akhenaten, 1353-1336 B.C.

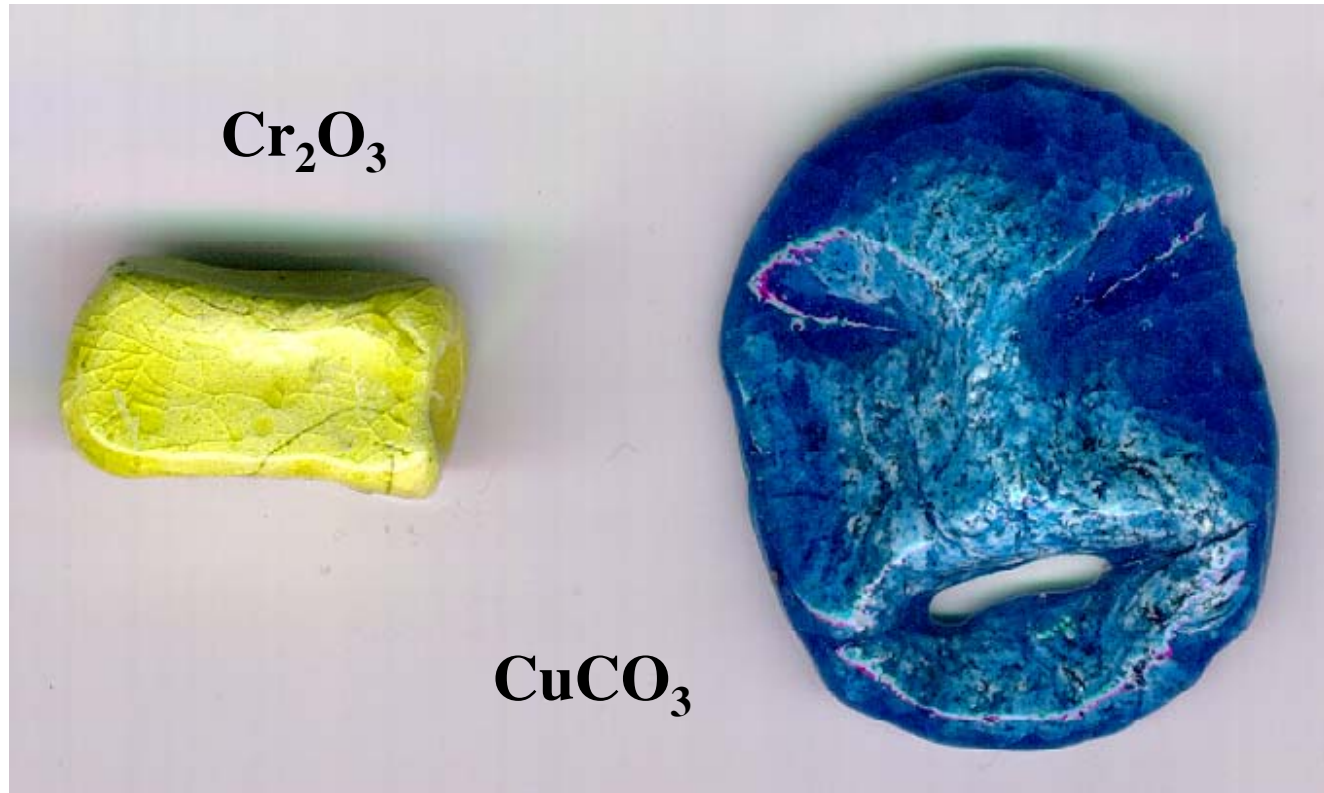
Egyptian Paste

■ Self-glazing ceramic

- Nepheline syenite 39%
- Flint 37%
- Ball clay 6%
- Kaolin 6%
- NaHCO_3 and Na_2CO_3 6%

Low-Fired Ceramic

- Fired to about 900-1000°C (1700-2000°F)



More Faience



Thebes (1070-716 B.C.)

Early Egyptian Glazed Ceramics



Glazed tile (Egypt, 1295-1186 B.C.)

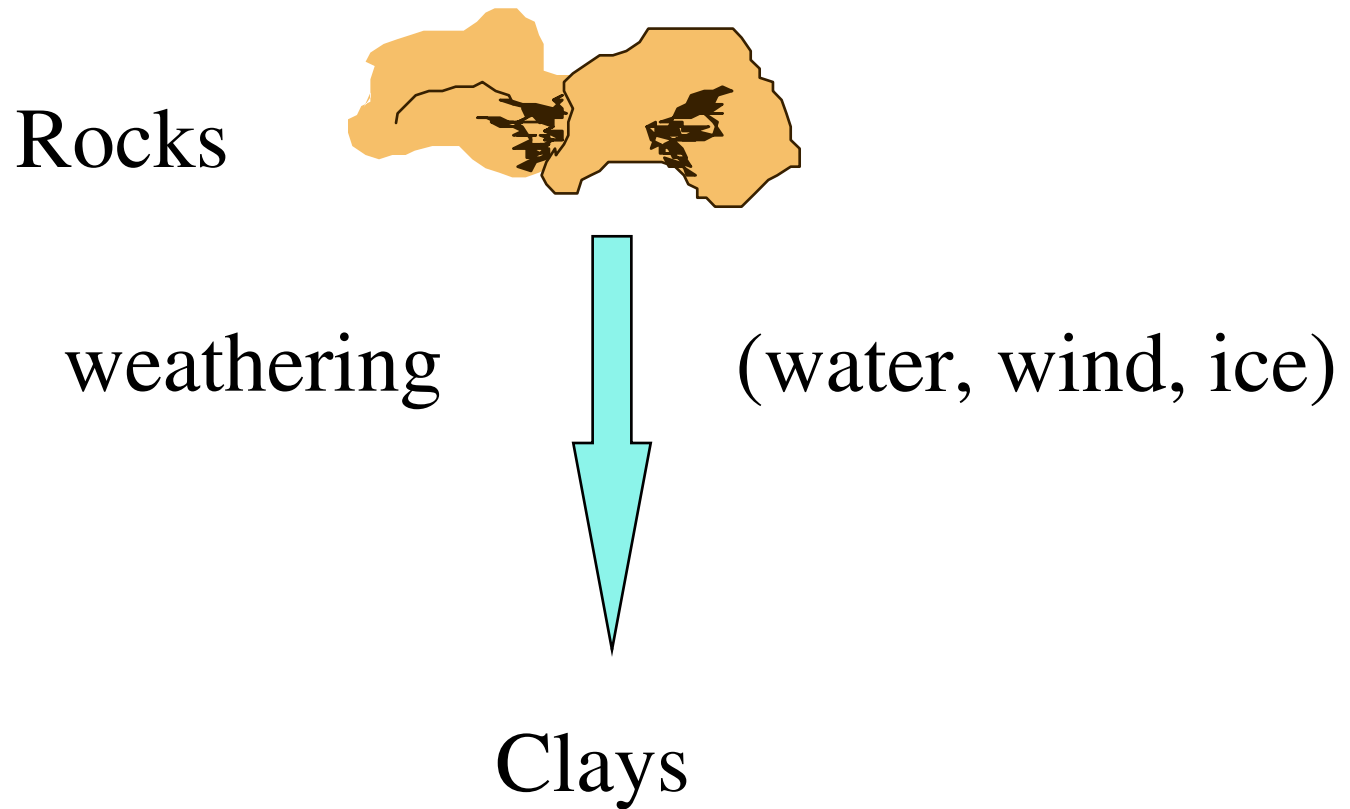


Glazed wig (1295-1186)

Definition of Ceramics

- **Inorganic** material
- made by **heating clay** or other mineral matter **to high temperatures**
- particles **partially melt and fuse** together
- atoms are linked primarily by **ionic bonds**

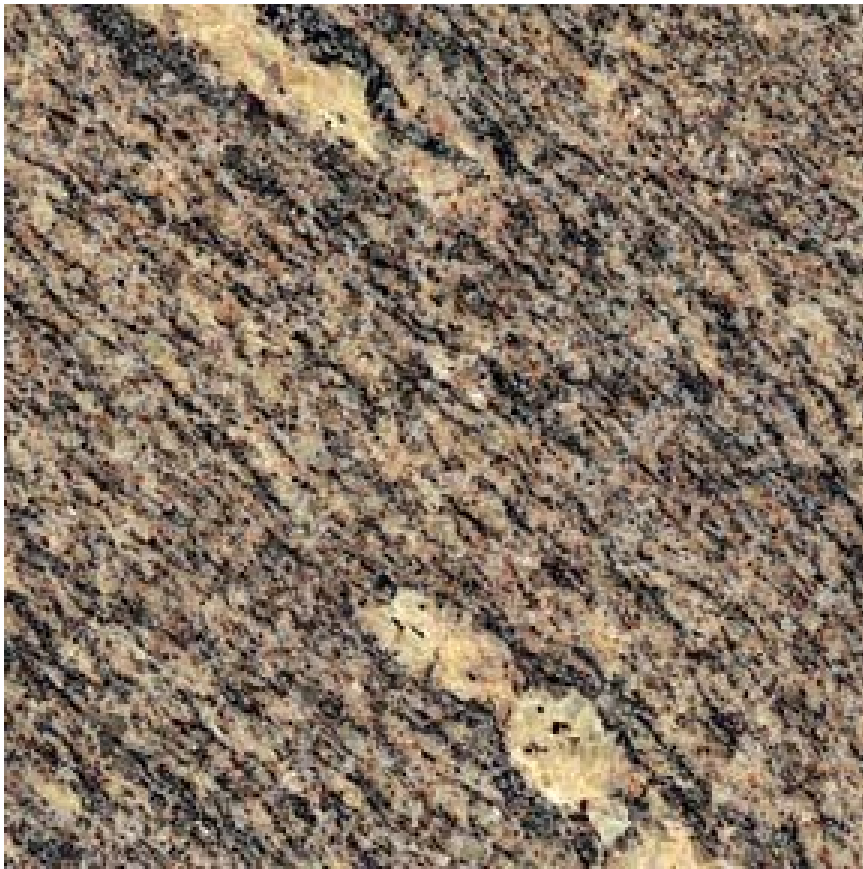
What Is Clay?



What does “clay” mean?

- Clay minerals
 - Hydrated aluminum silicates
- Clay deposits
 - mix of clay minerals and other compounds
- Clay bodies
 - Clay used to make ceramic objects
- Clay slips
 - mix of clay and water

Granite — a Rock!



↗ Feldspar

→ Mica

↘ Quartz

Quartz, Feldspars and Micas



Quartz



Mica



Feldspars

Granite — a Rock!



Feldspar



Mica



Quartz

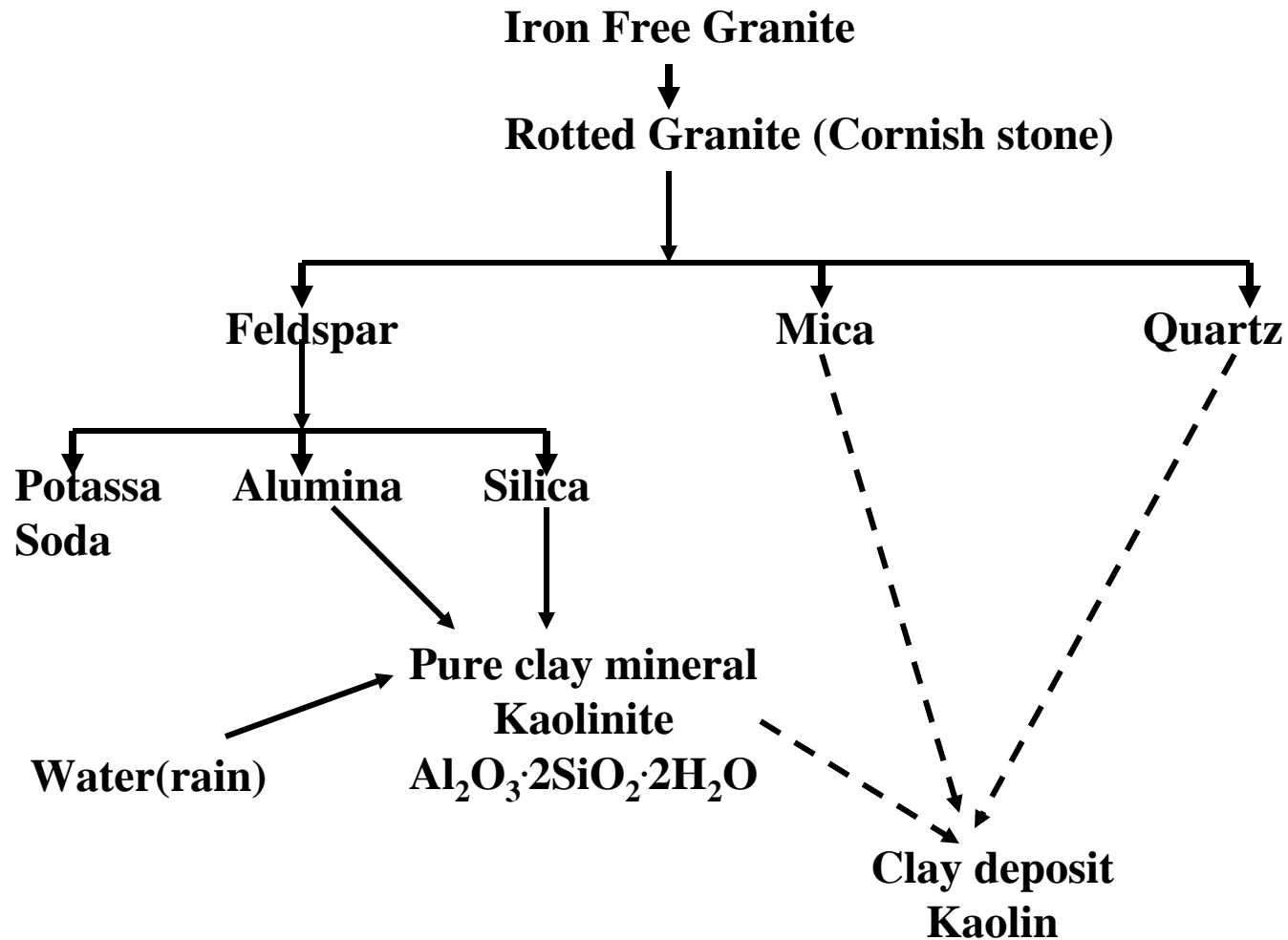


Weathering of Granite

- Granite weathers to produce

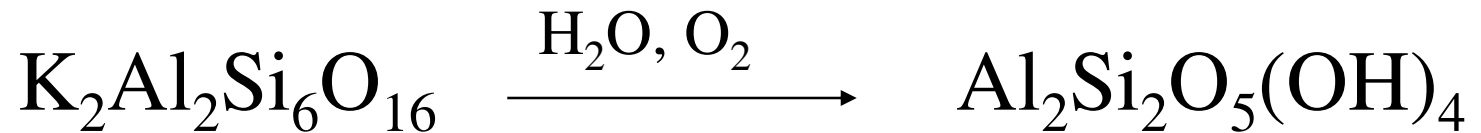
Kaolin or Kaolinite

Formation of Kaolin Clay



Clay Composition

- clay is a **hydrated silicate of aluminum**



Feldspar (granite)

Kaolinite Clay

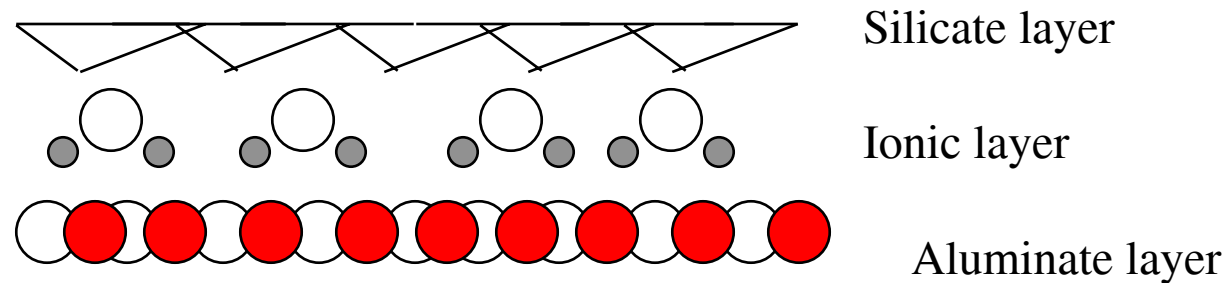
- Other Rocks produce...

Basalt \longrightarrow Montmorillonite Clay

Micas \longrightarrow Illite Clay

Clay Structure

- Layered structure - 2 or 3 layers



- trapped water acts as a lubricant
- makes clay “plastic” when wet
- makes clay shrink as it dries (5-17%)

Micrograph of Clay

EPK

Kaolin

Layered
structure



Clay Deposits

- **Primary** or Residual clays
 - Found at the site of their formation
 - coarse, larger particles , low plasticity
 - usually quite pure
- **Secondary** or Sedimentary clays
 - transported by wind, ice, and water from origin
 - very small particle size, quite plastic
 - contain variety of impurities, various colors

Clay Bodies

Contain a careful balance of...

- **Clays**

- impart plasticity and workability

- **Fillers**

- aid in shape retention during firing

- **Fluxes**

- control the fusion or hardening point during firing and increase strength of fired product

Classes of Natural Clays

- Common red brick clay
- Natural stoneware clay
- Kaolin (China clay)
- Ball clay
- Fire clay
- Terracotta clay (Earthenware clay)
- Bentonite

Fillers

- High mp materials
- Makes clay body more porous and **controls water absorption of clay**
 - Grog - crushed firebrick or fired pottery
 - Kyanite - $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$
 - Sand - silica and quartz
 - Alumina - Al_2O_3
 - Ground rock
 - Ground shells

Role of Fluxes

- Decrease the firing temperature of clay bodies
- Form viscous liquids at high T
- melt and fuse with other materials to give glass-like materials
- cement clay crystals together
- increases the strength of the fired product

Common Fluxes

- Alkaline Earth Metal Oxides

- CaO, MgO

- Feldspathic materials

- potash feldspar $K_2O \cdot Al_2O_3 \cdot 6SiO_2$

- soda feldspar $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$

- nepheline syenite $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$ + potash
and soda feldspar (high alkali content)

- Calcite or whiting - $CaCO_3$

Typical Porcelain Clay Body

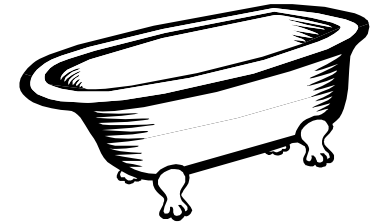
■ Four major ingredients

- **Kaolin** (the clay)
 - » white clay, low shrinkage, mp = 1500°C
- **Feldspar** (the flux)
 - » lowers mp to 1300°C, lowers shrinkage
- **Flint** (the filler)
 - » increases hardness, helps with glaze fit
- **Ball Clay** (another clay)
 - » increases plasticity of clay

Firing Characteristics of Clays

- Fusible

- Deform and melt when heated



- **Vitrifiable**

- Partially melt but do not deform producing dense, nonporous ceramic body

- Refractory

- Resist high temperatures, do not melt or deform

Firing of Clay

The drying and heating of clay above 900°C so that it partially vitrifies and hardens

Steps in firing:

- Increase the temperature over time
- Hold at a peak temperature for a time
- Cool slowly back to room temperature

Types of Ceramic Wares

- Object is air dried — **green ware**
- First firing — **biscuit firing (bisque)**
- Subsequent firings — **glazed ware**

Stages in Firing of Clay Bodies

Stage 1 — Drying

- **rt** \longrightarrow **250°C**
- **residual water** is removed
- **Done at slow rate to prevent explosive vaporization**

Stages in Firing of Clay Bodies

Stage 2 — Dehydroxylation and Oxidation

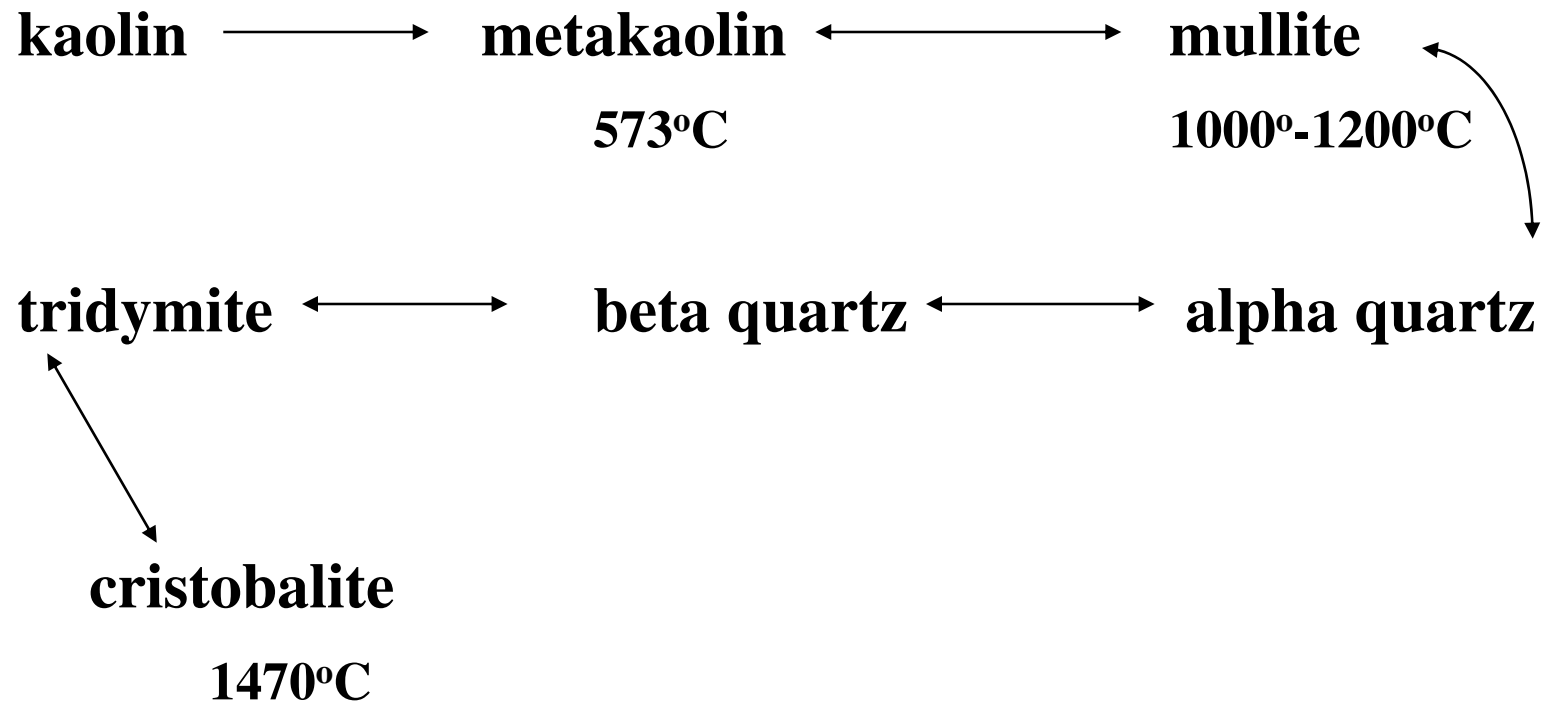
- 250°C \longrightarrow 500°C
- **lattice** or chemically bound water is removed
- organic matter burns off

Stages in Firing of Clay Bodies

Stage 3 — Vitrification

- 850°C → 1450°C
- fluxes melt
- glassy phase develops
- clay undergoes various crystalline phase changes

Vitrification Process



earthenware — 1150°C

bone china — 1250°C

hard porcelain — 1450°C

Stages in Firing of Clay Bodies

Stage 4 — Cooling

- back to room temperature
- crystalline inversions can occur and ceramic can crack

Types of Ceramic Pottery

- Terra-cotta — flower pots
- Earthenware — highly glazed, red body
- Stoneware — dinner dishes
- Bone china — fine china
- Porcelain — toilets and sinks
- Vitrified Pottery

Ceramic versus Glass

Ceramic

- shaped at room temp
- hardens with heat
- silicates, aluminates, salts
- porous
- nonconductor
- microcrystalline

Glass

- shaped at elevated temp
- hardens as cools
- silica and fluxes
- nonporous
- nonconductor
- noncrystalline