1. Raw materials and their characterization

1.0 Introduction

- Raw materials for ceramic technology: *natural*, *synthetic*, recycled waste, auxilaries.
- Main parameters and principal characterization techniques: *chemical composition* (X-ray fluorescence analysis), *mineralogical composition* (quantitative XRD phase analysis and thermal analysis), *granulometry* (particle size analysis).

1.1 Fundamentals of systematic and special mineralogy

- *Classification of minerals* (simplified): 1. elements, 2. sulfides etc., 3. halides, 4. oxides and hydroxides, 5. carbonates, 6. borates etc., 7. sulfates etc., 8. phosphates etc., 9. silicates.
- *Classification of silicates*: 9.1 nesosilicates, 9.2 sorosilicates, 9.3 cyclosilicates, 9.4 inosilicates, 9.5 phyllosilicates, 9.6 tectosilicates.
- Composition, structure and properties of *clay minerals* (kaolinite $Al_2Si_2O_5(OH)_4$ = dioctahedral two-layer phyllosilicate, illite, montmorillonite) and *other phyllosilicates* (talc, pyrophyllite, serpentine, micas), *feldspars* (binary phase diagrams leucite-SiO_2, albite-orthoclase, albite-anorthite, feldspar triangle) and *SiO_2 polymorphs*.

1.2 Plastic raw materials for ceramic technology

- *Kaolins*: chemical and mineralogical composition of natural and floated kaolins (kaolinite, quartz, other clay minerals, residues of feldspar and mica), function in silicate ceramics (plasticizer during shaping, high-temperature reactions leading to mullite formation), geochemical origin (weathering of feldspar-containing rocks), dressing procedures to produce floated kaolin and main deposits in the Czech Republic (regions of Karlovy Vary, Plzeň, Podbořany and others).
- *Clays* (including loams etc.): types and qualities, main deposits in the Czech Republic (regions of Cheb, Louny, North Bohemia, Plzeň, Kladno-Rakovník and others).
- Other ceramic raw materials based on phyllosilicates (talc, pyrophyllite, serpentine).

1.3 Non-plastic raw materials for ceramic technology

- *Feldspars* (K-rich alkali feldspars) and feldspathoids (e.g. nepheline): function in silicate ceramics (flux), types (Czech "Ž" classification), main deposits in the Czech Republic (Halámky, Krásno a Mráčnice, Želenický vrch, Otov a Ždánov-Luženičky).
- *Silica raw materials* (sources of SiO_2): *sand*, sandstone, quartzite, massive quartz and others; function in silicate ceramics (grog) and in refractories (tridymite and cristobalite as the main phase of silica bricks).
- *Carbonates*: calcite $CaCO_3$, magnesite $MgCO_3$ and dolomite $CaMg(CO_3)_2$, e.g. for basic refractories.
- *Alumina-rich raw materials* (sources of Al_2O_3): *bauxite* (mixture of gibbsite α-$Al(OH)_3$, boehmite γ-AlO(OH) and diaspor α-AlO(OH) with contents of Fe, Ti, Si etc.; basic raw material for producing Al_2O_3 via the Bayer process, i.e. autoclave leaching with NaOH), Al_2SiO_5 group (kyanite, sillimanite, andalusite).

- Other non-plastic raw materials: *zircon* ($ZrSiO_4$; basic raw material for the production of ZrO_2 via thermal decomposition), *ilmentite* ($FeTiO_3$; basic raw material for the production of TiO_2 via autoclave leaching in H_2SO_4), forsterite Mg_2SiO_4, wollastonite ($CaSiO_3$) and others, including synthetic raw materials (highly pure or mixed oxides with controlled stoichiometry).

1.4 Important characterization techniques for ceramic raw materials

- Thermal analysis (thermogravimetry, dilatometry and DTA) and high-temperature reactions occuring in ceramic raw materials (dehydroxylation and solid state reactions in clay minerals, thermal decomposition of carbonates etc.)
- XRD quantitative phase analysis (especially of clay minerals)
- Particle size analysis (sedimentation and laser diffraction)
- X-ray fluorescence analysis

Complex exercise problem: Use the results of quantitative XRD phase analysis (evaluated by *commercial software* like *X'Pert* ® or *Siroquant* ®) to discuss, for selected floated kaolins the relation between phase composition, chemical composition (from producer's data, determined by RFA) and particle size (determined by sedimentation or laser diffraction). *Additional explicit questions:*

a.) Which minerals contain the alkali oxides ? Compare your XRD-based findings with the calculation of the so-called rational composition.
b.) Which size fractions are enriched in quartz, which in smectites ? Compare your findings with available SEM micrographs.
c.) What can be said about the geological origin and the possible industrial applications of the different kaolins ?