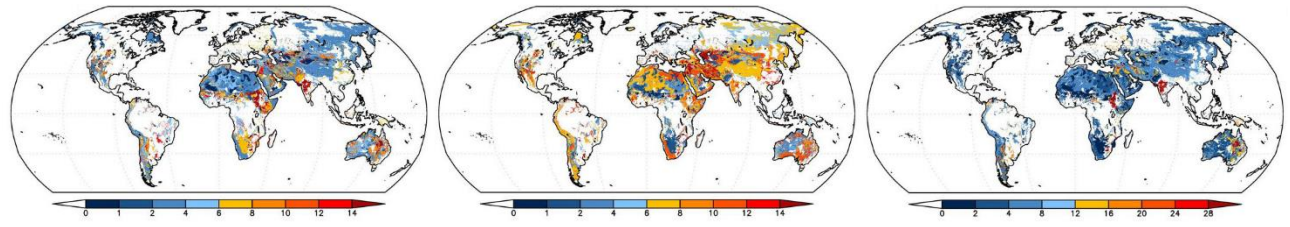
Characterization and modelling of calcined clays for sustainable development

(Proposer: Luca Valentini; Co-proposer: Maria Chiara Dalconi)

With the beginning of the new millennium, society has embraced the idea of "sustainable development" as a key goal for the future generations to inherit a clean and more equitable world. In the field of mineralogical sciences applied to building materials, setting the ambitious goal of sustainable design has boosted research oriented at replacing conventional materials based on ordinary Portland cement (OPC) with a new generation of CO_2-free binders. This is motivated by the fact that the production of OPC clinker accounts for about 6% of the global anthropogenic CO_2 emissions. Among low-CO_2 alternatives to OPC, materials based on the use of clays, which is a relatively cheap and abundant raw material (see figure), have gained consensus over the last few years. This project is focussed specifically on the use of alkali-activated calcined clays for the design of clinker-free binders.



Clay mineral distribution in soils (left to right: kaolinite, illite, smectite)

The main goal of the project is reconciling the observed macroscopic properties of the alkali-activated calcined clay binders (workability, mechanical performance, durability) with the basic physical and chemical processes associated with clay calcination and reaction in alkaline solution. This will be achieved by:

a) determining the structural variations occurring in the clay minerals as a function of calcination temperature, by MAS solid state NMR analysis.

b) performing time-resolved measurements of the aqueous solution concentration, by ICP-OES spectrometry, with the aim of quantitatively testing clay reactivities at different calcination temperatures.

c) investigating in detail the kinetics of clay dissolution and reaction product precipitation by implementing specific numerical simulations, based on the HydratiCA model developed at NIST (National Institute of Standards and Technology).

It is expected that the PhD candidate will:

- Gain familiarity with the concepts of sustainable development (embodied energy and CO_2 etc.) and related instruments (life cycle assessment)
- Become acquainted with the design of cementitious binders and performance of standard mechanical testing of cement-based materials
- Develop skills in advanced experimental and numerical techniques
- Work in an international environment and improve English language skills

Possible collaborations with foreign institutions:

a) NMR measurements: Aarhus University, DK (local contact: Prof. Jørgen Skibsted)

b) ICP-OES aqueous solution analysis: Bauhaus University Weimar, DE (local contact: Dr. Frank Bellman)

c) Numerical modelling: National Institute of Standard and Technology, US (local contact: Dr. Jeffrey Bullard)

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