# A multitechnique characterization and quantification of the microstructures of bricks made of different clayey raw materials

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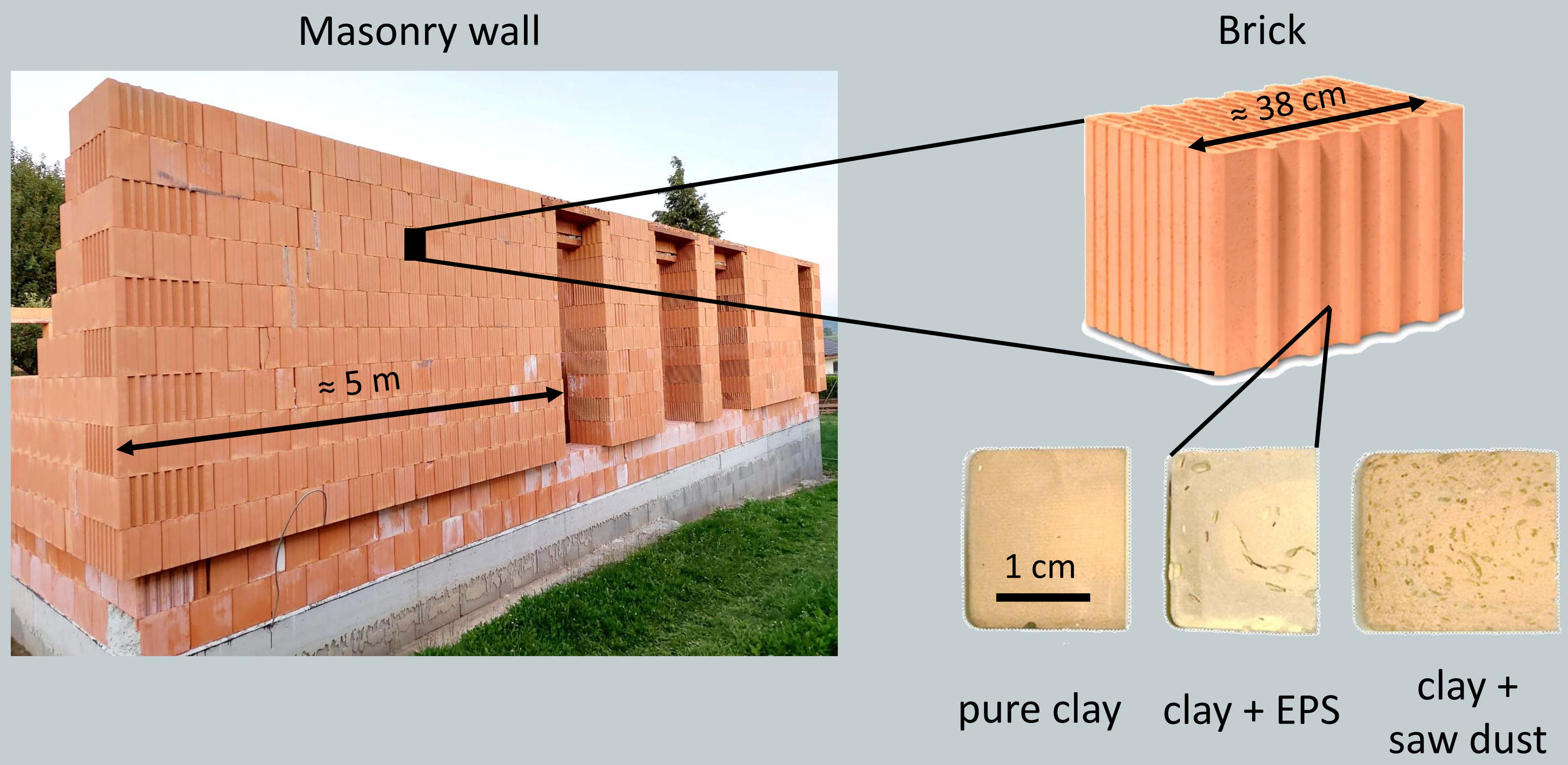
## Motivation

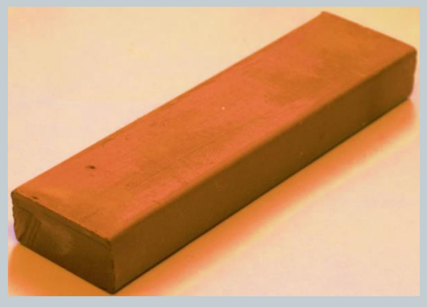
Development and optimizations of clayey brick materials, e.g., regarding thermal insulation, stiffness, and strength properties, are still based on empirical knowledge gained by extensive laboratory test series. It is known that the thermal and mechanical properties of fired clay bricks strongly depend on their microstructures, whose properties are mainly defined by the mineralogical composition, the applied firing temperature and may be influenced by pore-forming additives. We present an extensive series of microstructural characterization tests, see [1] and [2], carried out on five mineralogically different fired brick clays representing a wide range of brick materials used in the European industry. The resulting knowledge enables the development of microstructure-based material models for physically-based predictions of macroscopic brick properties and, subsequently, will allow for innovative development and optimization of modern brick products.




## Materials and Experimental Methods

### Materials

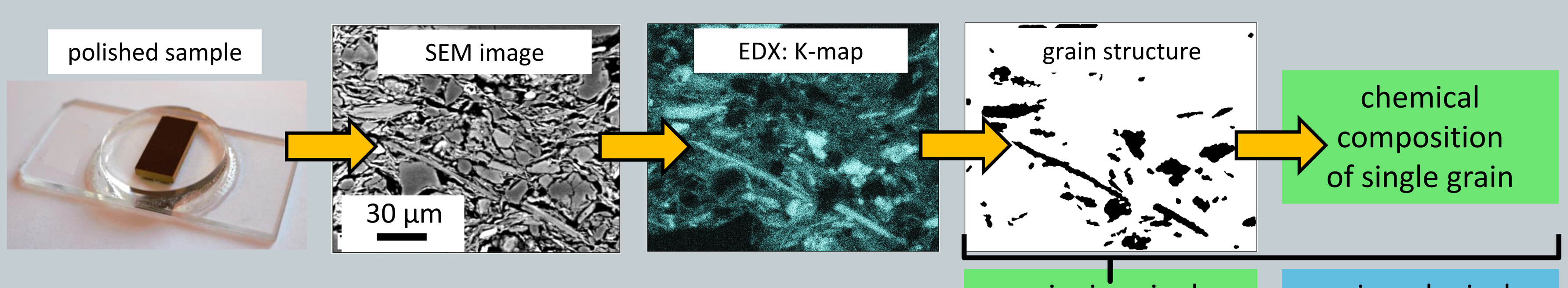
Five brick clays, showing very different mineralogical compositions and grain size distributions, were mined in Germany, Hungary and the Czech Republic. These clays were extruded to specimens measuring 125 x 30 x 15 mm and fired at 880 °C.

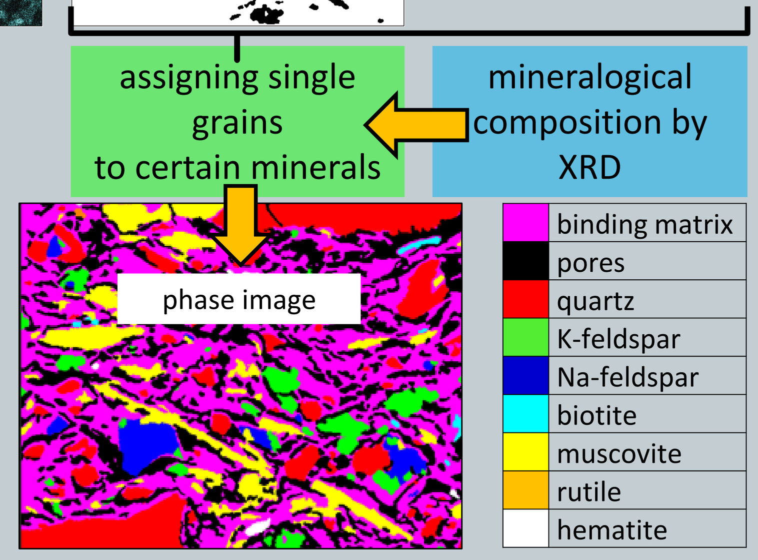


extruded and fired specimen (125 x 30 x 15 mm)


specimen cross sections show large variety of brick materials

### Automated Identification of Mineral Material Phases



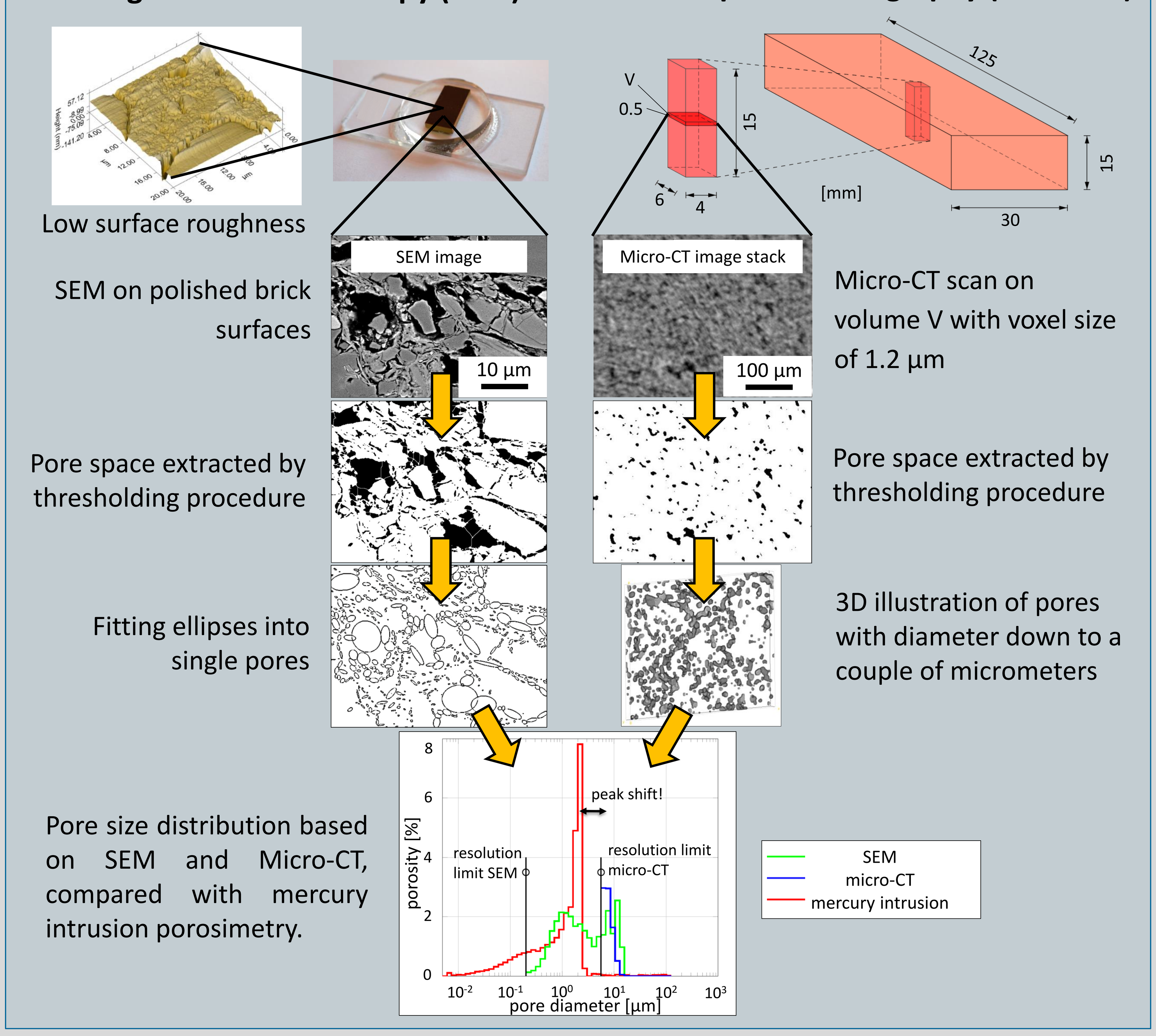




Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscpy (SEM-EDX)

Image analysis to extract grain structure (exemplary figures)

Assignment of grains to minerals with EDX chemistry and XRD mineralogy

### Pore Space Analysis




## Results and Outlook

### Results

- Pore size distributions based on real pore size, not affected by pore throat
- Mineral grain assemblage
- Geometry of mineral phases and pores
- Orientation distribution of mineral phases and pores

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**References:**

[1] T. Buchner, T. Kiefer, L. Zelaya-Lainez, W. Gaggl, T. Konegger, J. Füssl (2021). A multitechnique, quantitative characterization of the pore space of fired bricks made of five clayey raw materials used in European brick industry. Applied Clay Science 200: 105884. doi: 10.1016/j.clay.2020.105884

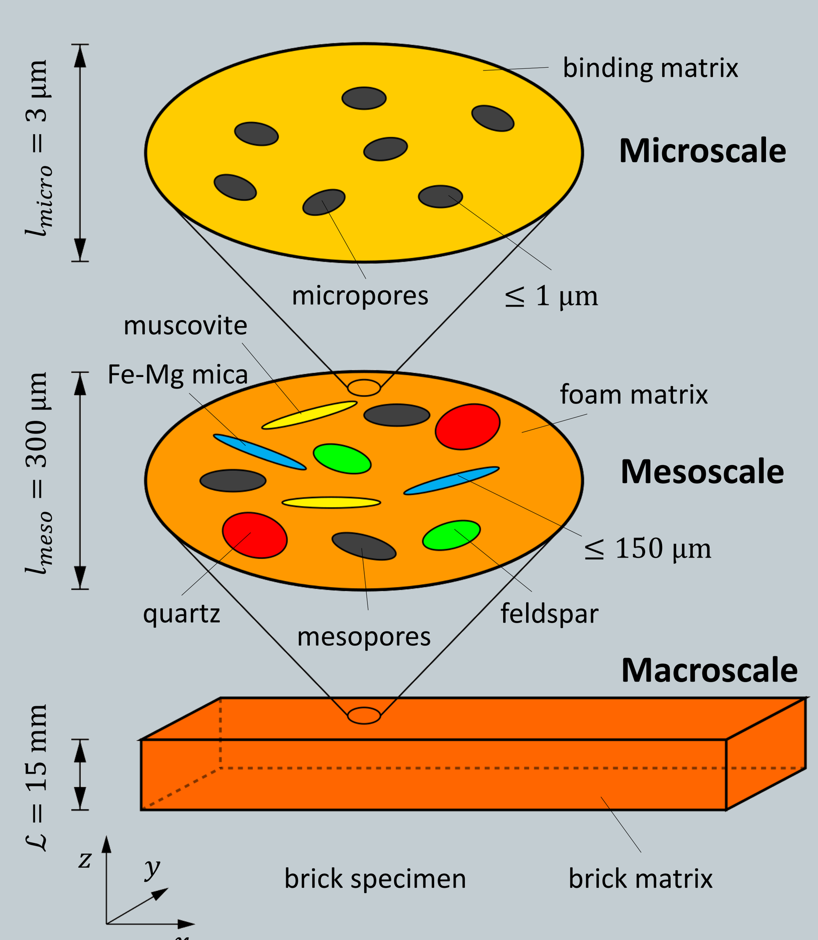
[2] T. Buchner, T. Kiefer, L. Zelaya-Lainez, W. Gaggl, J. Füssl (2021). Automated morphometrical characterization of material phases of fired clay bricks based on Scanning Electron Microscopy, Energy Dispersive X-ray Spectroscopy and Powder X-ray Diffraction. Construction and Building Materials 288: 122909. doi: 10.1016/j.conbuildmat.2021.122909

[3] T. Kiefer, J. Füssl, H. Kariem, J. Konnerth, W. Gaggl, C. Hellmich (2020). A multi-scale material model for the estimation of the transversely isotropic thermal conductivity tensor of fired clay bricks. *J. Eur. Ceram. Soc.* 40(15):6200-6217. doi: 10.1016/j.jeurceramsoc.2020.05.018

[4] T. Buchner, T. Kiefer, M. Königsberger, A. Jäger, J. Füssl (2021). Continuum micromechanics model for fired clay bricks: upscaling of experimentally identified microstructural features to macroscopic elastic stiffness and thermal conductivity. Submitted to Mater. Des.

### Outlook

**Multiscale Material Model for thermal conductivity and elastic stiffness [3,4]**




Mori-Tanaka homogenization on each scale:

$$\mathbb{C}^{hom,s} = \sum_r f_r^s \int_0^{\pi} \int_0^{2\pi} W_r(\theta)\mathbb{C}_r : \mathbb{A}_r(\varphi,\theta;X_p)\frac{\sin(\theta)}{4\pi}\mathrm{d}\varphi\mathrm{d}\theta$$

$$\boldsymbol{\lambda}^{hom,s} = \sum_r f_r^s \int_0^{\pi} \int_0^{2\pi} W_r(\theta)\boldsymbol{\lambda}_r \cdot \mathbf{A}_r(\varphi,\theta;X_r)\frac{\sin(\theta)}{4\pi}\mathrm{d}\varphi\mathrm{d}\theta$$

Experimental model validation: