The behavior of natural building stones before and after firing experiments

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Damages on historic building materials as consequence of atmospheric influences such as rain, air pollution, freeze-thaw cycles etc. have been intensively investigated over the last 20 years. In contrast, research on the damaging effect of fire on natural building materials has received much less attention. In order to investigate the influence of fires on natural building stones which were extensively used in the area of South- and North-Tyrol during the Middle Ages, changes in the petrophysical parameters and the mineralogical assemblages of selected stones during firing experiments with temperatures up to 1000°C were studied (Allison & Bristow 1999).
This study represents an approach to unravel the reaction behavior of natural building stones during firing, and focuses on the physical and chemical behavior of the stones before and after the firing experiments. From the stone blocks 20 cylindrical cores (50 mm in diameter and 100 mm in height) were drilled and 20 platy samples (50 mm in diameter and 10 mm in height) were cut (normal to the sedimentary bedding at the Gröden Sandstone). Initially, the samples were dried for 48 hours at 40°C. Subsequently the samples were heated in a 1-atmosphere furnace (Carbolite 1100 ELF) at 4 different Temperatures (200, 400, 700, 1000°C) for 6 hours. After the controlled firing the samples cooled slowly in the oven. The cylindric specimens were used in particular for strength- and ultrasonic measurements, the platy samples were used to prepare thinsections for petrographical and microstructural investigations. All specimens were tested before (at 22°C) and after the heat treatments. After firing, the mineralogical changes were investigated with a polarizing microscope, the electron microprobe analyzer (EMPA: JEOL JXA 8100 Superprobe with five wave-length spectrometers and a NORAN energy dispersive analytical system), X-Ray diffraction (XRD: Siemens D500, Siemens D5005 and AXS-Bruker D8). Mineralogical changes, due to changing thermal conditions were monitored with a differential thermal analysis (DTA: Setsys Evolution2400, sample weight 80 mg, T-range 25–1000°C, T-ramping rate 10°C/min). Characterization of the porosity was performed with a mercury intrusion porosimetry (PASCAL140, Porosimeter2000) and BET (Brunauer, Emmett, Teller, 1938) analyses (Quantachrome Nova2200).Ultrasonic measurements and compression- and strength tests were performed to investigate the behavior of the specimens regarding their engineering- and technical parameters (Goudie et. al. 1992).

The experiments and the tests demonstrate the important role of i) the change in the mineralogical assemblage due to pyrometamorphic reactions and of ii) the formation of micro-cracks at temperatures exceeding 600°C in the investigated samples of Gröden Sandstone and Brixen Granite. These preliminary results show that the regionally important Gröden sandstone indeed can be strongly affected by large fires. At low temperatures (200–400°C) changes and hence damages are limited to colour changes (from gray to bright red) due to changes in the oxidation state of the rocks. At higher temperatures (> 700 °C) the change in mineralogical composition and the increase of porosity causes a serious loss of structural integrity and therefore strongly reduces the strength of the investigated sandstone. The Brixen Granite is characterized by a total loss of structural integrity after firing at 700°C for 6 hours due to the increase of porosity and the formation of cracks and micro-cracks.
The results of this study will help to identify historical fire damages, particularly if later restoration campaigns have eliminated the visible effects, and facilitate the restoration of cultural heritage objects damaged by fire.

Allison, R.J. & Bristow, G.E. 1999. The effects of fire on rock weathering: Some further considerations of laboratory experimental simulation. *Earth Surface Processes and Landforms*, 24 (8), 707-713.

Brunauer, S., Emmett, P.H., Teller, E. 1938. Adsorption of gases in multimolecular layers. *Journal of the American Chemical Society*, 60, 309.

Goudie, A.S., Allison, R.J., McLaren, S.J. 1992. The relations between modulus of elasticity and temperature in the context of the experimental simulation of rock weathering by fire. *Earth Surface Processes and Landforms*, 17, 605-615.