Geophysical Research Abstracts
Vol. 17, EGU2015-12027, 2015
EGU General Assembly 2015

Isotopic tracing (D, 18O and 29Si) to understand the alteration on historic glass

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In order to better preserve historic glasses, e.g. stained glass windows, the understanding of their alteration mechanisms and of what controls the kinetics corresponding to each process is required. The ancient stained glasses are characterized by thick alteration layers, continuous or as pits, that are cracked or lost. Therefore, if a passivating role of the alteration layer has been proved on some other kinds of glass (such as basaltic or nuclear glass) in aqueous medium, the issue can be addressed for low durable stained glass weathered in varying atmospheric conditions.
The mechanism of alteration layer formation was first investigated by performing dynamic and static experiments on model medieval glasses altered with a solution doped in 29Si at different concentrations (or saturation degrees). Solid analyses were carried out by SIMS and solution by HR-ICP-MS. Medieval stained glass has mainly a potash-lime-silica composition with a low content in alumina. The alkaline and alkaline-earth elements have thus a modifier role in the glassy network. This structural difference compared to boro- or alumino-silicate glasses could induce differences in the alteration mechanisms. However, the analysis of the Si isotopic signature of the gel layer highlighted that diffusion, but also hydrolysis/condensation reactions, are also involved in the gel layer formation process, leading to a structural and textural reorganization. The second objective was to determine the kinetic role of the alteration layer, and especially to trace the circulation of water once the altered layer is formed. For that, ancient glasses were exposed to simulated rainfall events / drying periods cycles during 3 months by using a solution doped in D and 18O. NanoSIMS analyses have shown that the transport in the alteration layer is mainly driven by diffusion in the porosity despite the presence of cracks that could have been preferential ways of circulation. This demonstrates also a potential protective role of the alteration layer formed on stained glasses in atmospheric medium. All these results will contribute to improve the knowledge of glass alteration processes and to develop appropriate conservation / restoration strategies of these historical artefacts.