EGU23-3424, updated on 19 Apr 2024
https://doi.org/10.5194/egusphere-egu23-3424
EGU General Assembly 2023

Heitt Mjolnir: an internally heated triaxial rock deformation apparatus for operando experiments at up to 573 K at Synchrotron imaging beamlines

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The 3rd and 4th generation of synchrotron light sources with their high brilliance, fluxes and beam energies allow the development of innovative X-ray translucent rock deformation apparatus that maximise these capabilities. Following on from the development of the *Mjolnir* triaxial deformation rig (Butler et al., 2020), we present an upscaled design: *Heitt Mjolnir*, covering a wider temperature range and larger sample volume while operating at similar pressure, enabling a wide range of time-resolved investigations. This device is designed to characterise coupled hydraulic, chemical and mechanical processes, occurring at various temperatures, from the µm to the centimetre scale in cylindrical samples of 10 mm diameter and 20 mm length. *Heitt Mjolnir* can simultaneously reach confining pressures of ≤30 MPa (hydraulic), 500 MPa of axial stress while the sample's pore fluid pressure is controlled in a dedicated fluid channel and can reach 30 MPa. This apparatus has an internal heating system and is able to reach temperatures of 573 K in the sample with a minimal vertical thermal gradient of <0.5 K/mm. This portable and modular device has been successfully deployed in operando studies at TOMCAT (SLS) and I12 JEEP (DLS) beamlines for 4D X-ray microtomography with scan intervals of a few minutes. *Heitt Mjolnir* allows the 4D characterisation of low-grade metamorphism, fluid-rock interaction and deformation processes. It enables spatially and temporally resolved fluid-rock interaction studies at a wide range of conditions and, by covering most geological reservoirs, will be particularly valuable for geothermal, carbonation or subsurface gas storage research.