Understanding seismic source properties of Magnitude -2 to -6 earthquakes in the Bedretto underground laboratory trough full wavefield modeling

Whether in engineered geothermal systems research, where Earthquakes can be human induced, or in classical earthquake physics, where Earthquakes occur naturally, estimating physics-based quantities such as the magnitude, source size and stress released is fundamental to understanding the impact of each earthquake on its surroundings. Better insight into individual properties are necessary to build physics-based models that can better forecast (and potentially predict) earthquake sequences. A prerequisite for improved efficacy of models are the sensors that are used to precisely measure ground motion produced by an earthquake in physically relevant units.

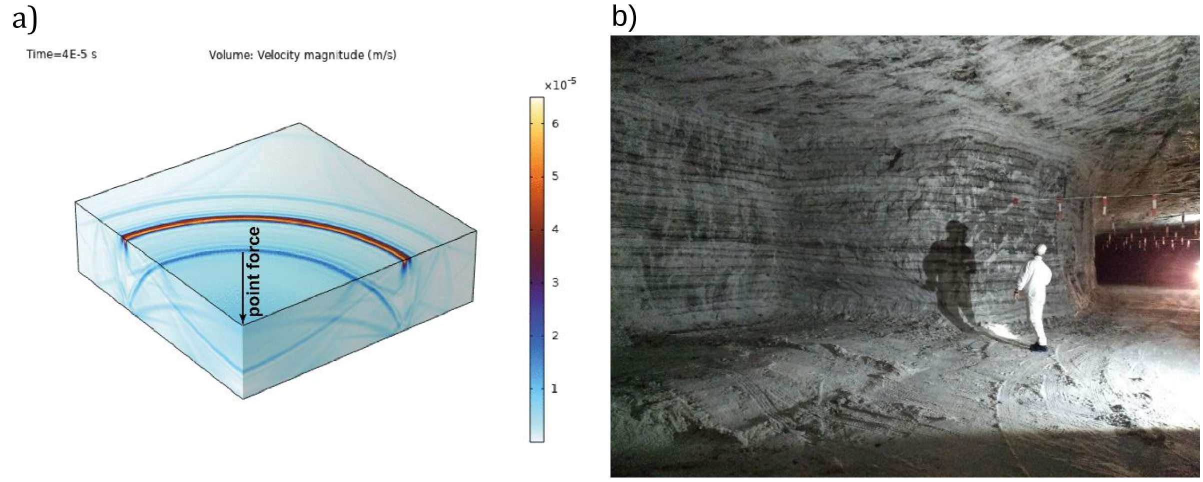

Figure 1: a) Modelled particle velocities of the full wavefield after 40 us, emitted from a point force source on a steel plate (here, only ¼ of the plate is modeled), b) experimental site in salt mine

Estimates of source properties for magnitude -2 to -6 earthquakes are possible and produced in studies in underground laboratories. Studying such events is inherently difficult because of the small magnitudes and the intermediate frequency contents produced by these quakes. Highly sensitive acoustic emission sensors (AE sensors) are typically used to record the seismograms; however, they do not measure physical units directly, are dependent on the coupling to the rock mass and have directional dependency in their sensitivity. To improve our understanding of the behavior of these AE sensors we launched a calibration project embedded within two large research projects at Bedretto (Fault Activation and Earthquake Rupture (FEAR) and Validating of Technologies for Reservoir Engineering (VALTER) http://www.bedrettolab.ethz.ch/en/activities/projects/). The calibration project contains (1) a calibration experiment in the Merkers salt mine in Germany (https://www.erlebnisbergwerk.de/de-de/) as well as (2) the modeling of the full wavefield of the Merkers experiment and (3) the analysis and combination of the experimental and numerical results. The focus of this thesis will lay in the modeling of the full wavefield of the Merkers experiment but participating in the experimental work and in combining the experiment with simulations is very welcome. Aside of the hosts, the project benefits from a collaborative team consisting of several top senior scientists across Europe (Swiss Seismological Service and GFZ Potsdam) and a representative of the sensor supplier in industry.

Keywords: Seismology, full waveform modeling, cluster computing, source properties, sensor calibration, validation of experiment

Label: Master Thesis

Description: The Master student we seek will work on high-frequency full waveform modeling in a viscoelastic medium mimicking the salt rock volume in which the corresponding calibration experiment will take place. The code (Salvus, https://mondaic.com/product/) is fully developed and the project will focus on establishing a suitable mesh (structured or unstructured) to develop a computationally efficient model of the elastic wave propagation induced by known acoustic sources. Combining the modeled ground motion at an AE sensor location with the recorded ground motion of the corresponding AE sensor will result in an absolute understanding of the sensors behavior using transfer function theory.

Goal: The outcome of this thesis will be an appropriate modeling approach of high-frequency viscoelastic wave propagation on the 50 m scale which will lead, in combination with experimental observations, to sensor transfer functions.

Contact Details:
Laura Ermert (laura.ermert@sed.ethz.ch),
Linus Villiger (linus.villiger@sed.ethz.ch),
Paul Selvadurai (paul.selvadurai@sed.ethz.ch)

Published since: November 2022; **Earliest start:** 2022-12-01; **Latest end:** 2023-09-30

Organization: Swiss Seismological Service (SED)

Hosts: Dr. Paul Selvadurai; Dr. Linus Villiger; Dr. Laura Ermert

Field: Earth Sciences