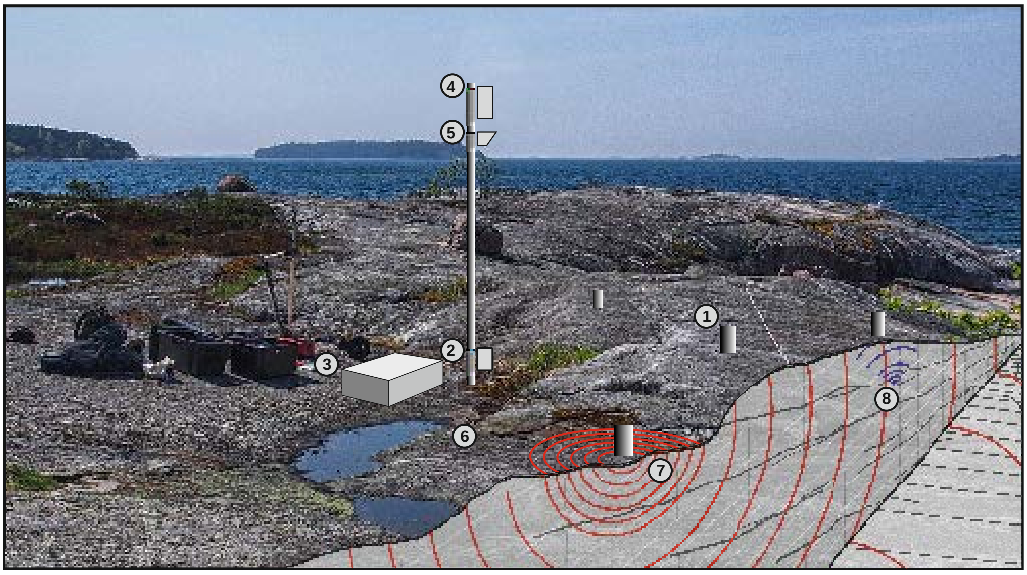
Monitoring progressive fracture propagation in response to environmental stress variations

The installed monitoring system on Långören Island

Project Framework:

The gradual propagation of fractures in critically stressed rock often occurs in response to either local stress variations, or a progressive weakening of fracture tips through a process known as stress corrosion. Also termed static fatigue, this process likely controls the long-term behavior of bedrock in diverse environments ranging from underground excavations to steep rock slopes. In order to better understand such progressive failure in association with natural variations in bedrock stress (for example as a result of thermal cycles), and/or corrosive conditions (for example rainfall, snowmelt, and variations in temperature or humidity), the Engineering Geology Group at ETHZ has installed a portable monitoring system capable of simultaneously recording 'acoustic emissions' from crack propagation, local bedrock temperature fluctuations, and a range of key environmental variables on an island in the Finnish Archipelago.

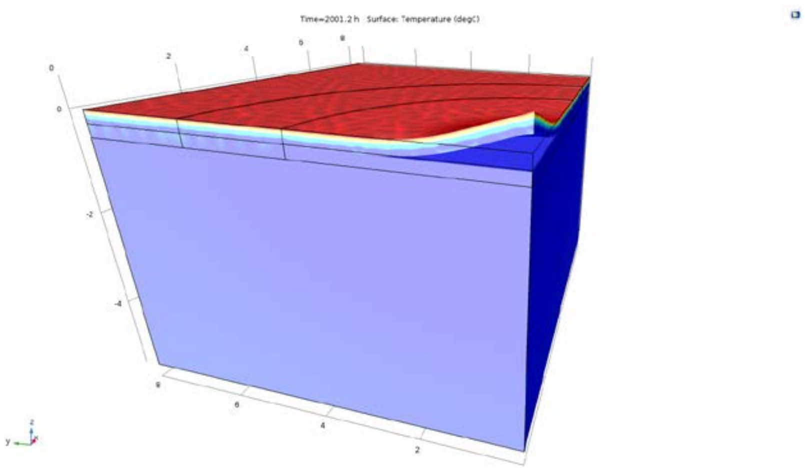
Exfoliation fracturing observed in the hot summer of 2014 was driven by exceptional rock surface temperatures (see: http://www.stressdriven.com/fracturing-of-ancient-bedrock-surfaces-during-an-extremely-hot-summer/). The monitoring system was installed on Långören Island in summer 2016, and data gathered to date has allowed us to identify links between a) environmental conditions and subsurface temperatures, b) peak summer temperatures and an increase in AE events, and c) thermal stress changes modelled buckling of surface bedrock (see below). This has allowed us to extrapolate conditions driving near-surface stress changes back to the 2014 event, and gain new insight into what was an extremely rare event. Results are expected to be directly applicable to fields ranging from nuclear waste disposal, to rockfall hazard assessment, and paleoclimate research.



Schematic of the fracture monitoring installation

1) Combined piezoelectric signal generator and single component micro-acoustic sensors 2) Distribution box 3) Power supply and data logger 4) Temperature, humidity, and solar radiation sensor 5) Rainfall gauge 6) Trace of recent extensional fracture on bedrock surface 7) Actively generated signals allow the monitoring of CODA, which in turn can be related to damage evolution, relative stress changes, and anisotropy 8) Passive acoustic emission recordings provide data on the timing, and direction of fracture events.

Specific goals:
Remote system access is available through a 3G mobile network, although one- to two excursions to the island will be required to undertake system maintenance, and geomorphological and engineering geological mapping of pre-existing and potentially active fractures. The remainder of the project will then involve processing of AE data collected during 2016 and 2017 summers in order to characterize fracturing events, and continue development of the COMSOL model to include high resolution topographic data.



3D model developed in COMSOL Multiphysics correlates hourly bedrock temperature fluctuations with the buckling of a 0.5 m thick bedrock slab.

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