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Real-time noble gas release signaling rock deformation

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Hypothesis:

- **Noble gas release may be related to deformation state of rock**
- **Natural gases may be used to signal deformation**

Objectives:

- **Discovery of *real-time* gas emission during rock fracture and relate to deformation**
- **Demonstrate new tool in experimental rock deformation**
- **Develop inverse models used to infer fracture characteristics**

Abstract

We present empirical results and relationships of specimen strain, microfracture density, acoustic emissions, and noble gas release from laboratory triaxial experiments performed upon a granite and young basalt. Noble gases are contained in most crustal rock at inter and intra granular sites, their release during natural and man-made stress and strain changes represents a signal of deformation in brittle and semi-brittle conditions. The gas composition depends on lithology, geologic history and age of the rock, fluids present, and uranium, thorium and potassium-40 concentrations in the rocks that affect the production of radiogenic noble gases (4He, Ar). Noble gas emission and its relationship to crustal processes have been studied for many years in the geologic community including correlations to tectonic velocities and qualitative estimates of deep permeability from surface measurements, finger prints of nuclear weapon detonation, and as a potential precursory signals to earthquakes attributed to gas release due to pre-seismic stress, dilatancy and/or fracturing of the rock. Helium emission has been shown as a precursor of volcanic activity. Real-time release of these gases has been demonstrated using a newly developed experimental system utilizing mass spectrometers to measure gases released during triaxial rock deformation. We relate real-time noble gas release to changes of the stress and strain state and acoustic emissions. Noble gas release is shown to represent a sensitive precursor signal of rock deformation. We propose using noble gas release to signal rock deformation/degradation from planned/unplanned circumstances in boreholes, mines and waste repositories. We postulate each rock to exhibit a gas release signature, which will be stress, strain, and or permanent deformation dependent. Such relationships, when calibrated, may be used to sense rock deformation and may be used to develop predictive models.

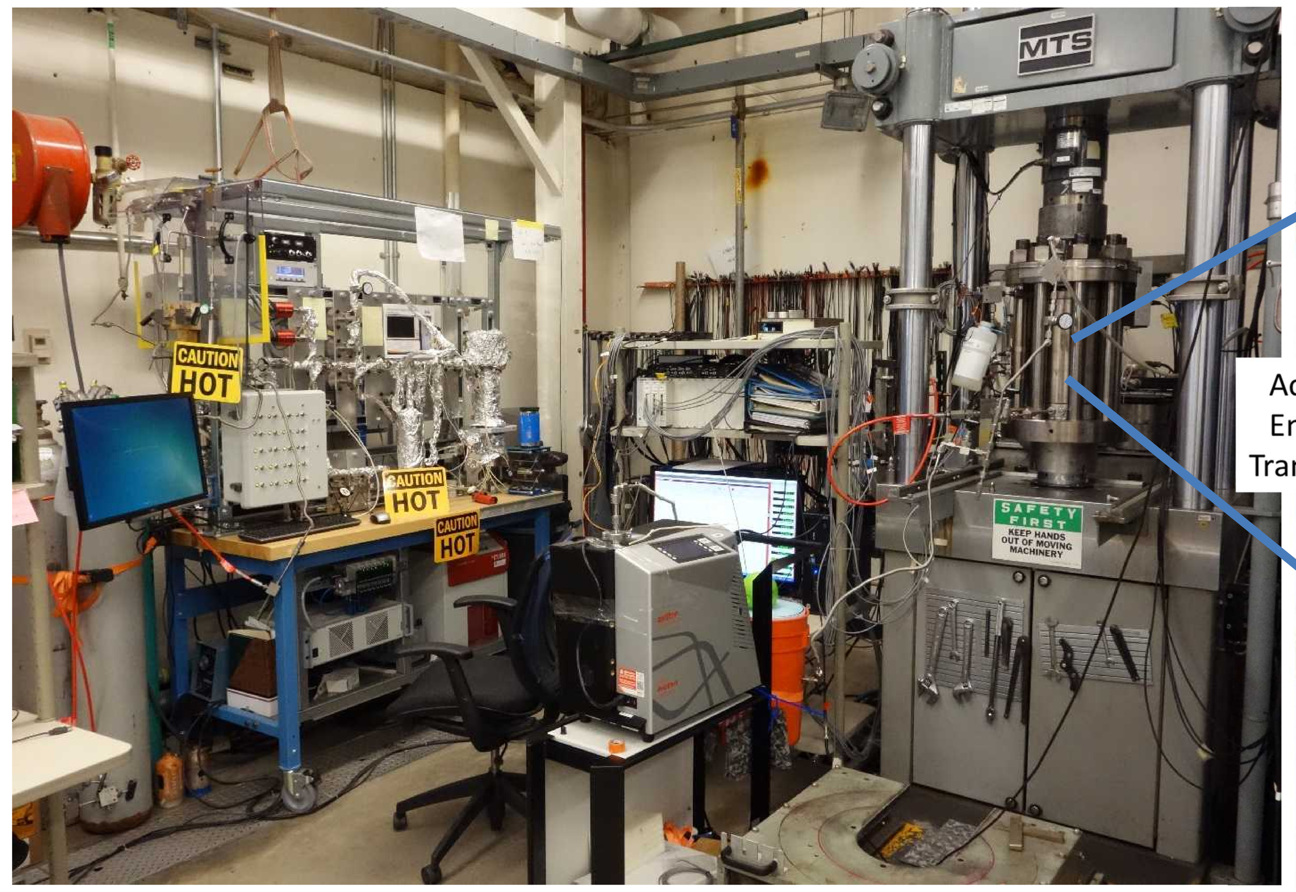
*Immè, G., La Delfa, S., Lo Nigro, S., Morelli D., Patanè, G. (2005). Gas Radon emission related to geodynamic activity of Mt. Etna. *Annals of Geophysics*, 48 N.1, 65-7.

Waste containers in the WIPP

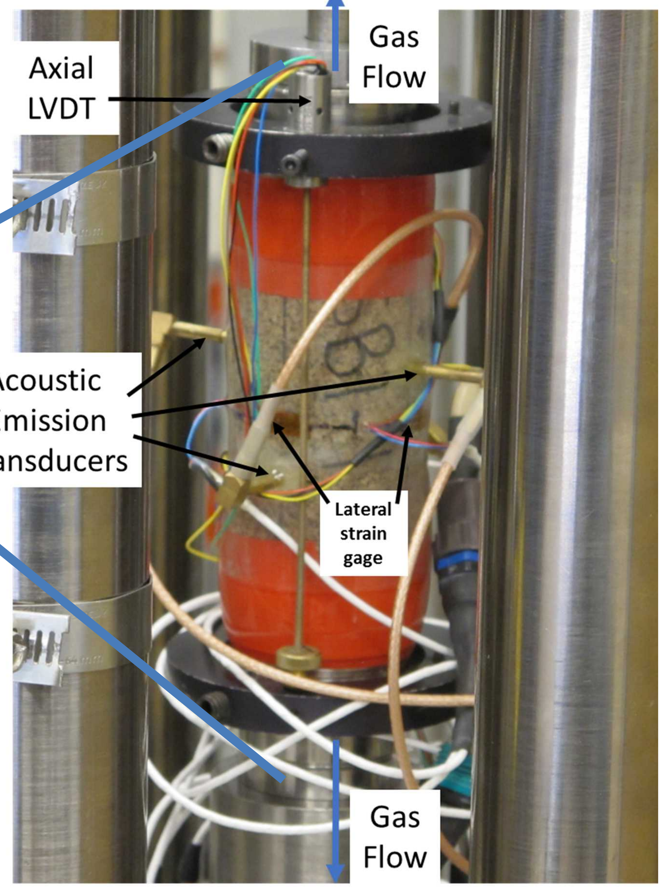
Value Added:

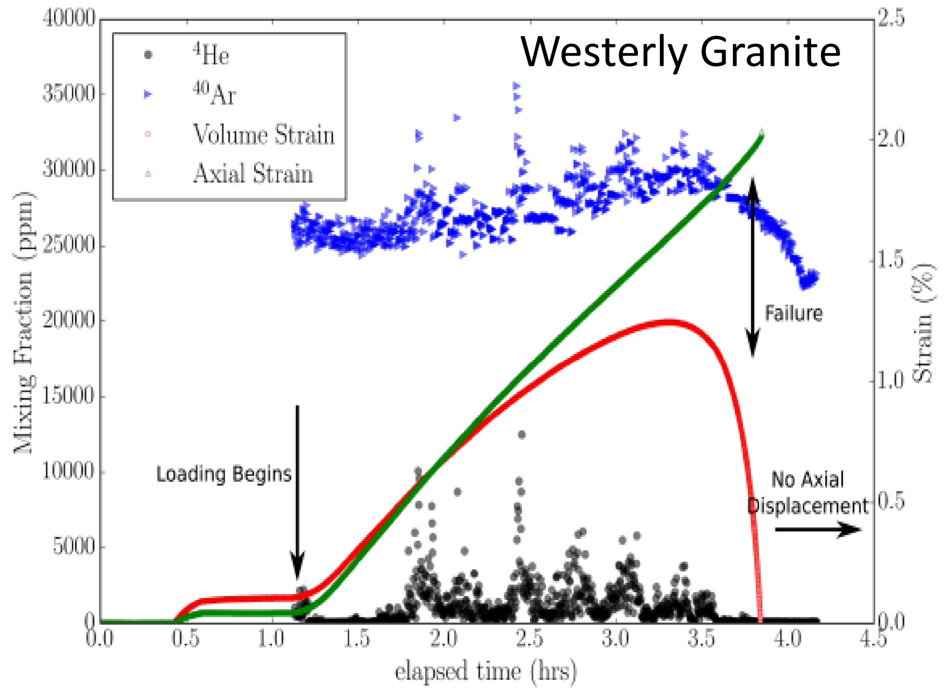
New technique for tracing stress & strain in deforming earth materials

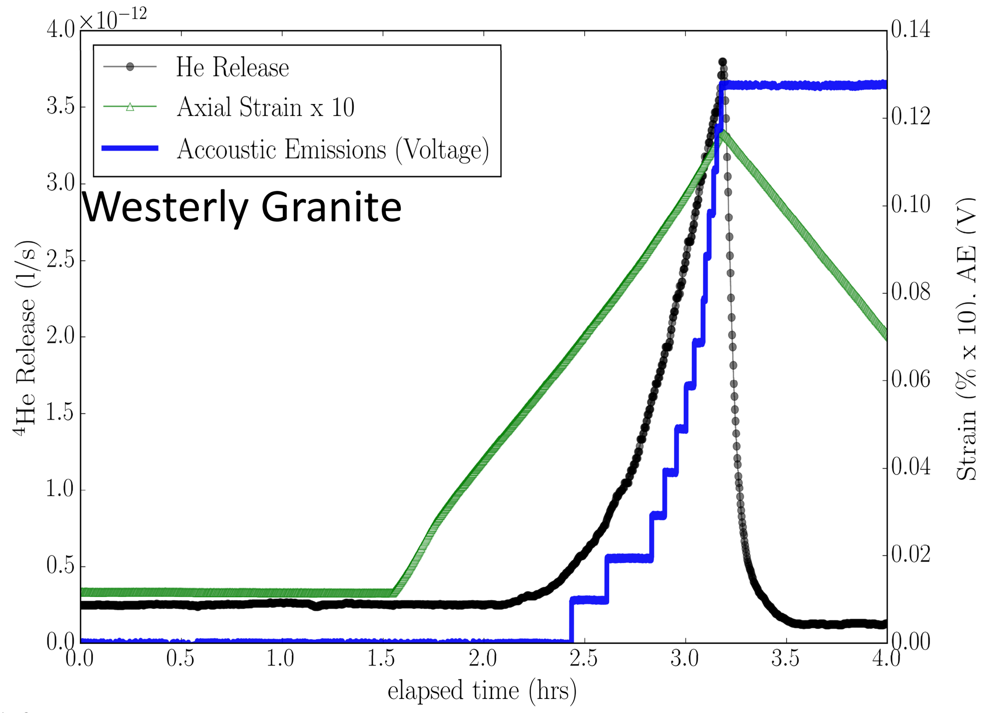
Test System



Sample configuration







Release of Radiogenic Noble Gases as a Signal of Rock Deformation. Geoph. Res. Lett. 2016GL070876 : S. J. Bauer1, W. Payton Gardner2, H. Lee3

The mechanical portion of the test system consists of a triaxial cell(s) in a variety of loading frames, with the capability of triaxial testing of cylindrical samples ranging in diameter from 2.5 cm in diameter (5 cm long) to 10 cm diameter (20-25 cm in length). The triaxial cells are capable of confining pressures to 400 MPa with sufficient axial force (stress) capabilities to fracture rock in compression/extension. The mechanical test system has a pore fluid flow through capability used with high pressure (to simulate pore pressure at depth) and low pressure (in the present application of high vacuum).

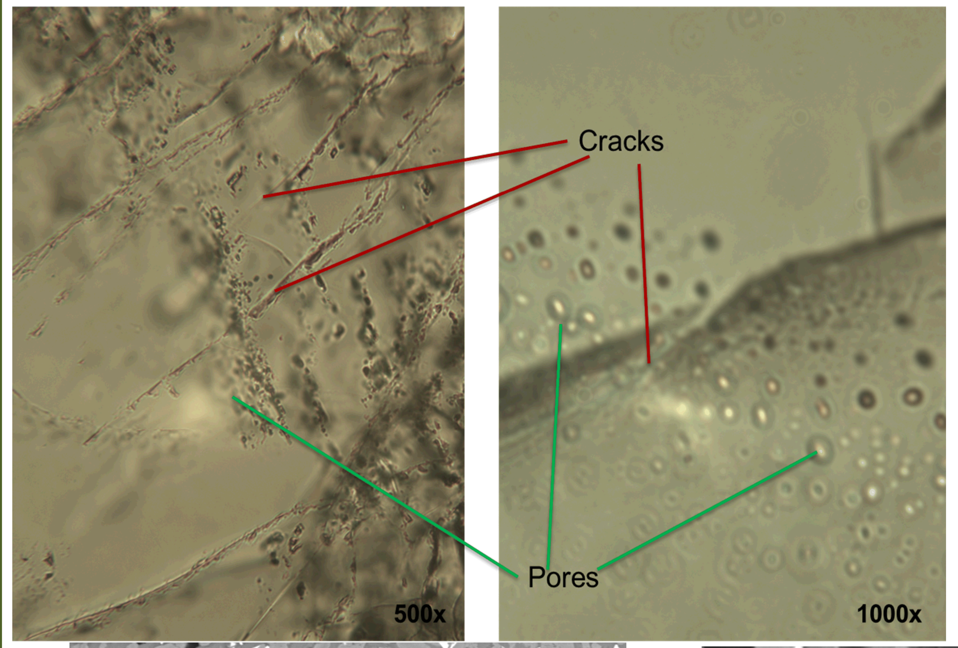
The residual gas analysis portion of the test system utilizes mass spectrometry, which measures the mass-to-charge ratio abundance of gas-phase ions. In our experiments, the mass spectrometer continually scans for gases during the deformation. We use two different mass spectrometers: a helium leak detector which measures the flow rate of mass 4 and a QMS capable of scanning the total abundance of gas over a broad mass range.

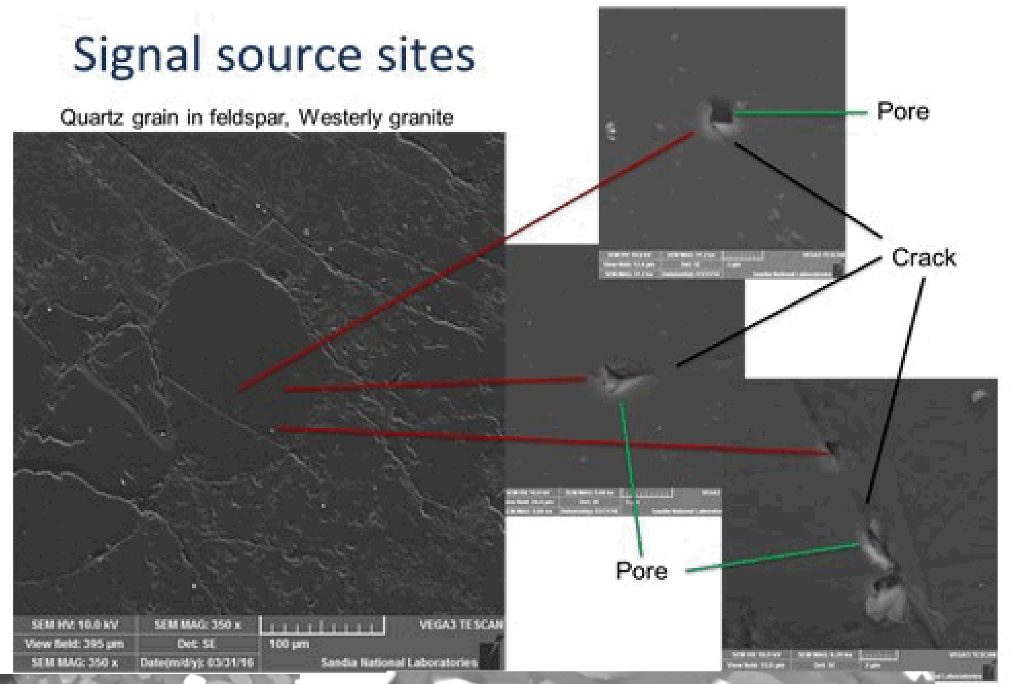
The helium leak detector is an Oerlikon Leibold Phoenix L300i is a specialized mass spectrometer which detects only 4He. It works in the mass range of 2, 3, 4 amu, with a minimum detectable leak rate in vacuum mode is <5x10-12 mbar l/s. Time constant of the leak rate signal is <1 s, and the filament is Iridium/Yttria-oxide. The analytical devices are semi-portable, located on a rolling cart so that all triaxial frames in the lab are accessible.

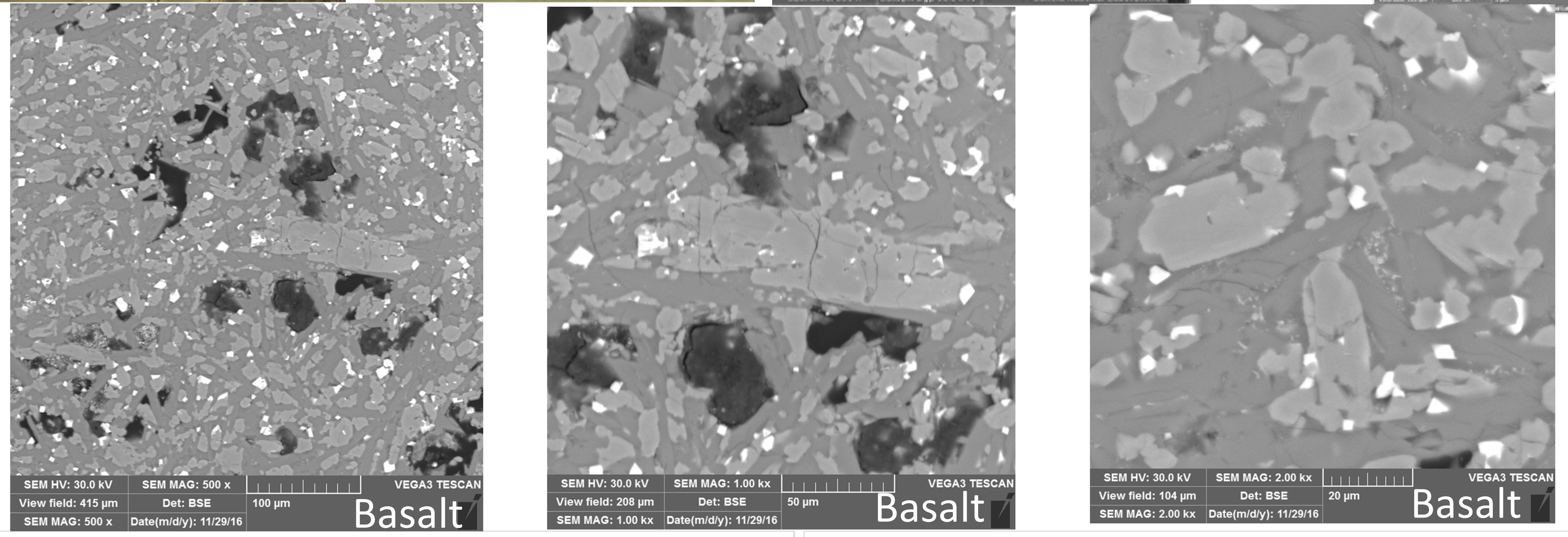
The QMS is a Pfeiffer HiQuadTM , for analysis of neutral particles with a mass range from 1- 340 amu. The scan speed is 0.125 ms- 60 s/amu; typically full scan time for a suite of gases (10 species) is on the order of 1-2 seconds. The analyzer is a QMA 410, with a cross beam ion source and a detection limit at 1 x 10-15 mbar. The detector is SEV 217/Faraday, and the filament is tungsten. The maximum operating pressures are Faraday 10-4 mbar and SEM 10-5 mbar. The software which is used to operate the HiQuadTM is Quadera®, with a LabVIEW® based user interface for data acquisition and control.

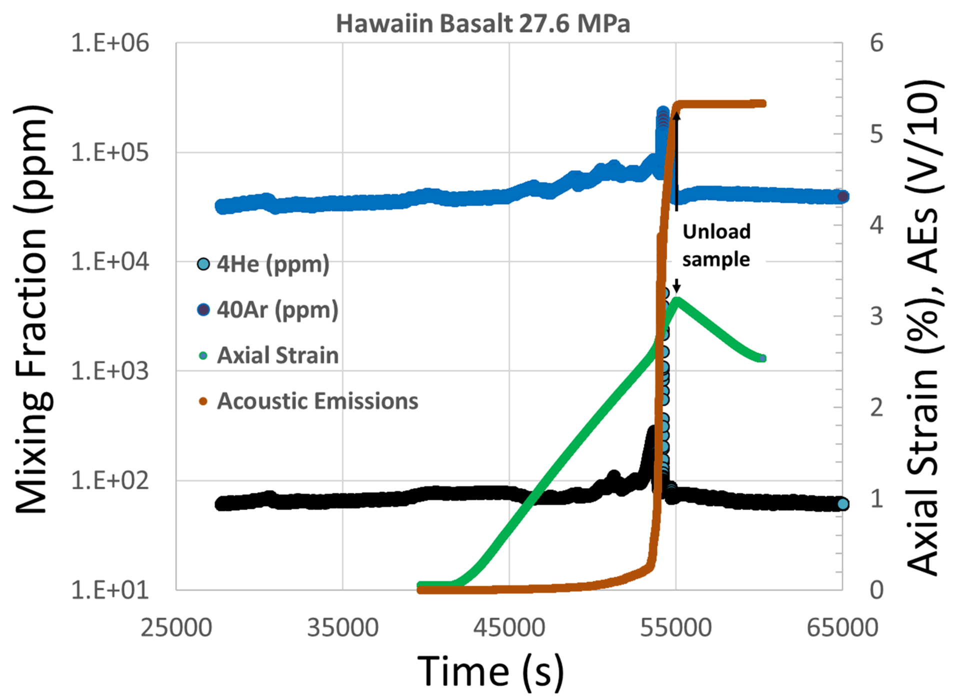
Microstructural Observations

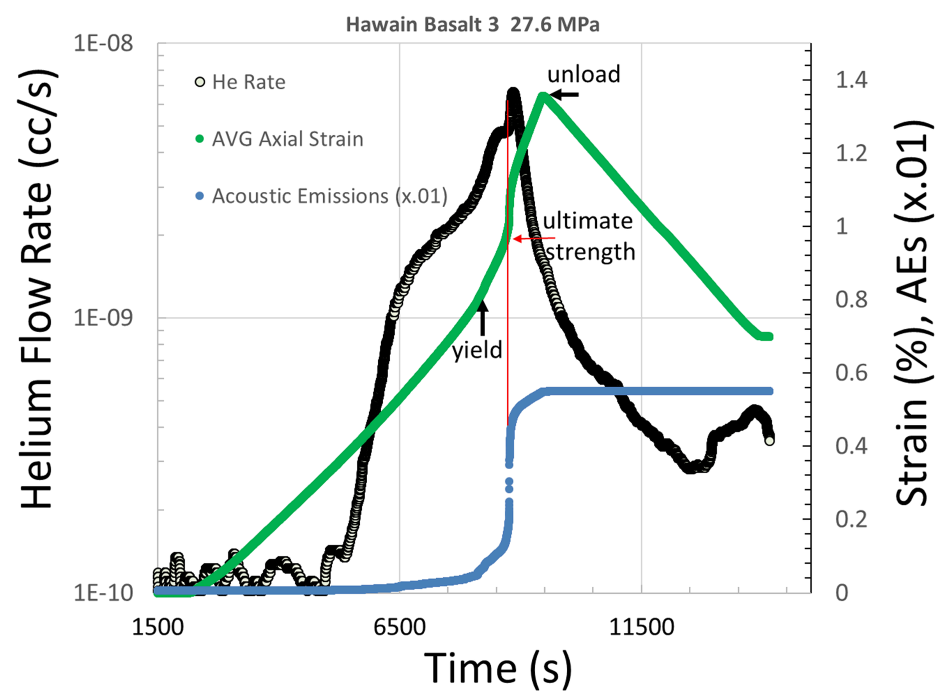
Quartz grain, Westerly granite











Results

1-Gases are released and measured real time during deformation
2-Gas release signal is precursive to macrofracture
3-Gas released depends on initial gas content, pore structure and its evolution during deformation, deformation amount, permeability
4-Release rate increases as strain and microfracturing increase
5-Gases are released from intracrystalline sites

Summary/ Path Forward

Measure gas release in lab, relate to deformation (σ, ε, AE, cracks)
Develop model……. Energy Consumed$_{deformation}$ $\propto$ f(gas released)
Measure gas release …………determine: Energy Consumed$_{deformation}$

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Frank Trusdell , USGS, HVO, collected and provided Basalt samples