# Real-time Noble Gas Release During Triaxial 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 (Bauer et al 2016)**

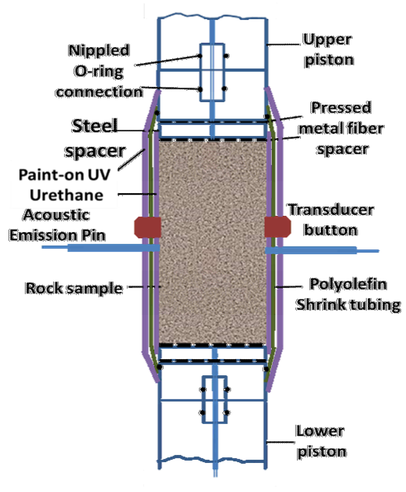
**Develop inverse models used to infer fracture characteristics (Gardner et al 2017)**

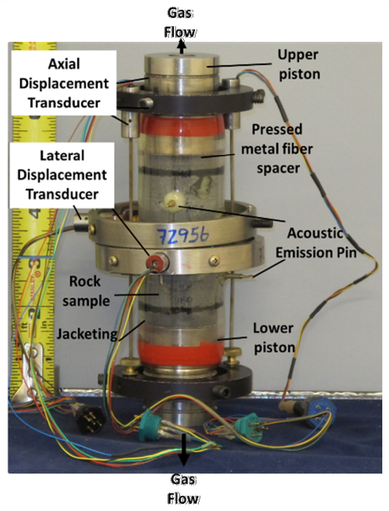
**ABSTRACT**

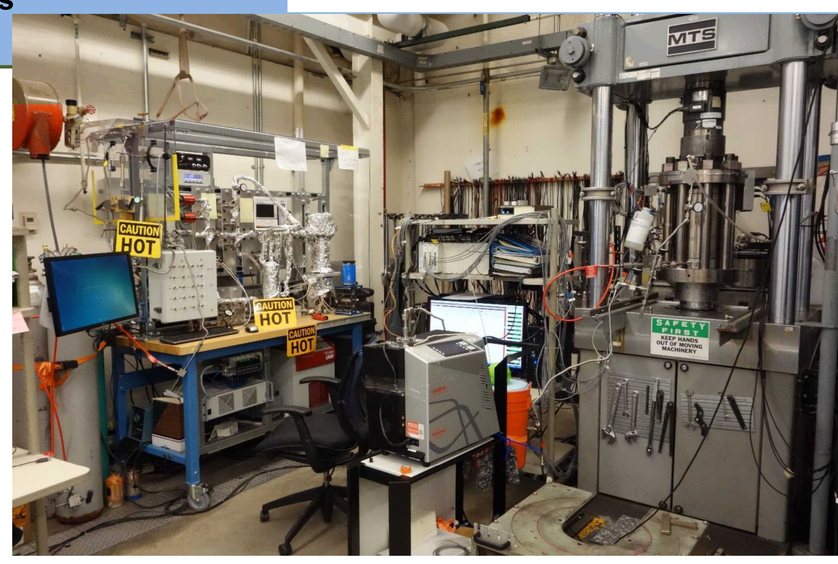
Noble gases are contained in most crustal rock at inter and intra granular sites. Their release during natural and man-made stress and strain changes represents a signal of deformation in brittle and semi-brittle conditions. The noble gas composition depends on lithology, geologic history, age of the rock, and fluids present. Uranium, thorium and potassium-40 concentrations in the rocks also 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.

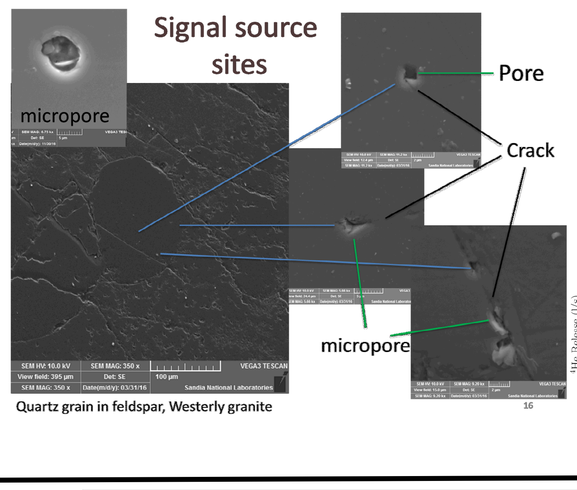
We have been engaged in a laboratory study of real-time noble gas release during experimental rock deformation. The test system developed combines triaxial rock deformation and mass spectrometry to measure noble gas flow before, during, and after rock fracture. We present empirical results and relationships of specimen strain, microstructural evolution, acoustic emissions, and noble gas release for a range of conditions in granite, basalt, shale and bedded rock salt. The data indicate that the gas release signal is precursive to macrofracture. Gas released depends on initial gas content, pore structure and its evolution during deformation, deformation amount, and deformation dependent permeability and conditions of fracture versus intracrystalline flow. Release rate increases as strain and microfracturing increase; gasses are released from intracrystalline sites.

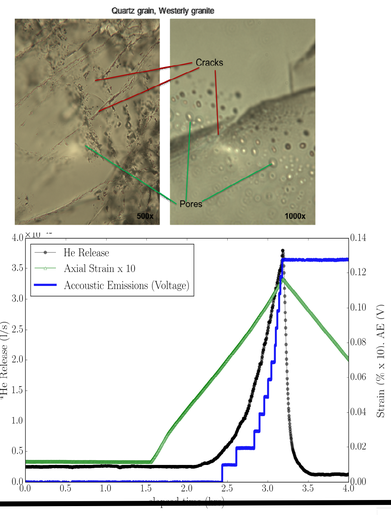
The experimental results show an apparent cause and effect relationship between the accumulation of strain and noble gas release, representing an important signal of deformation.

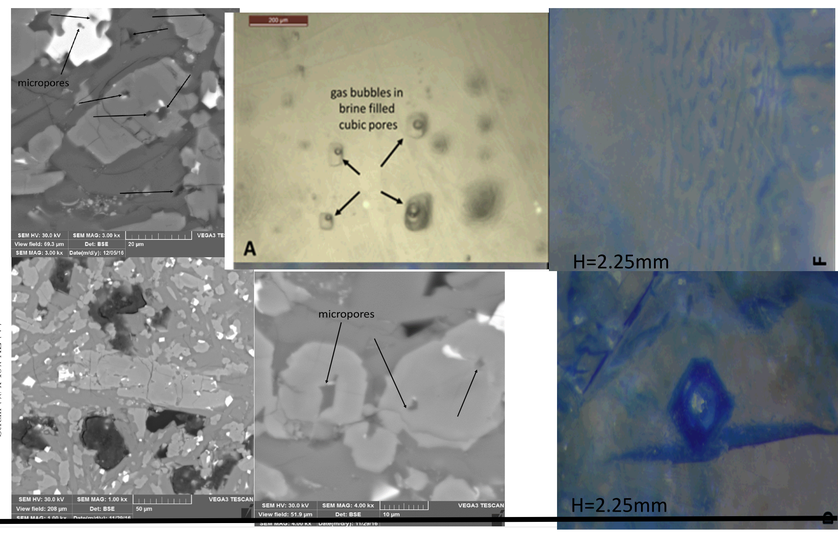


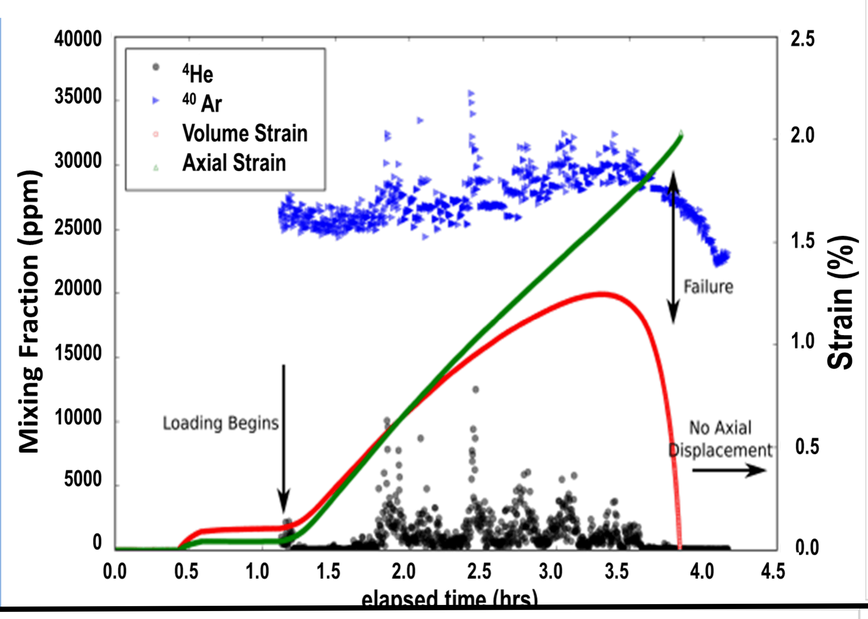



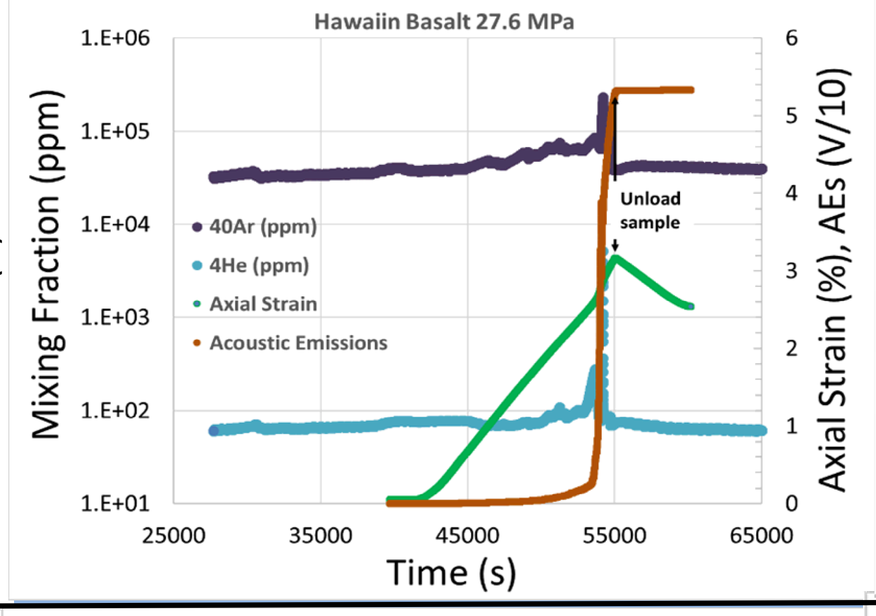



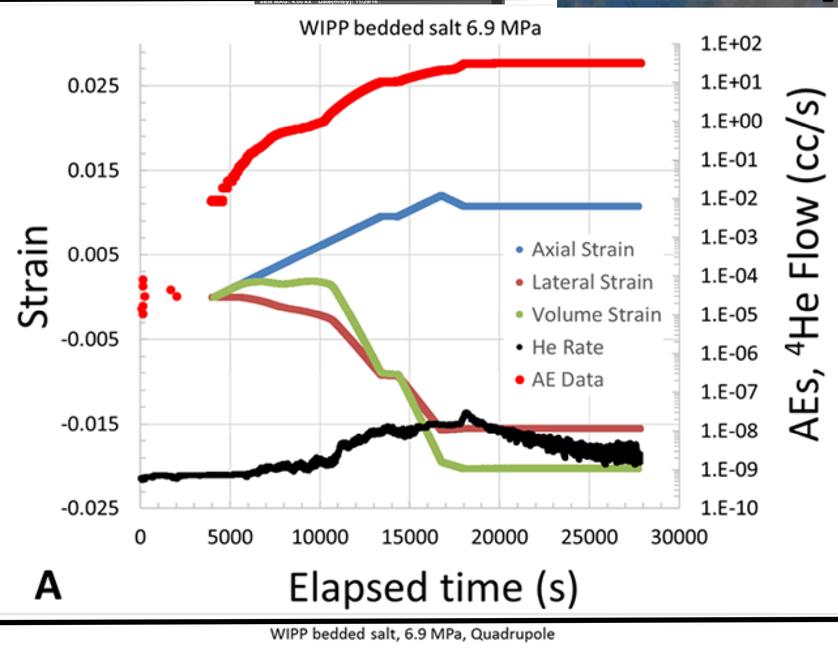



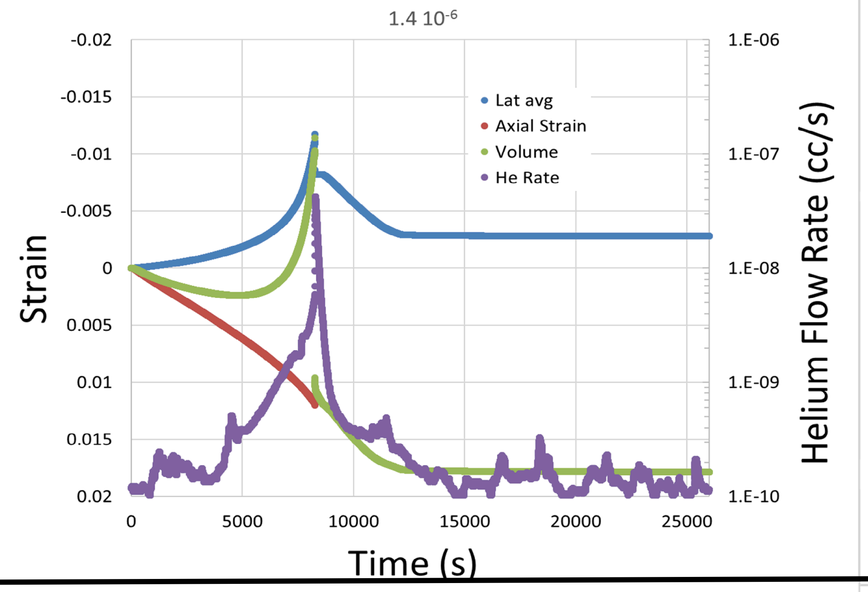



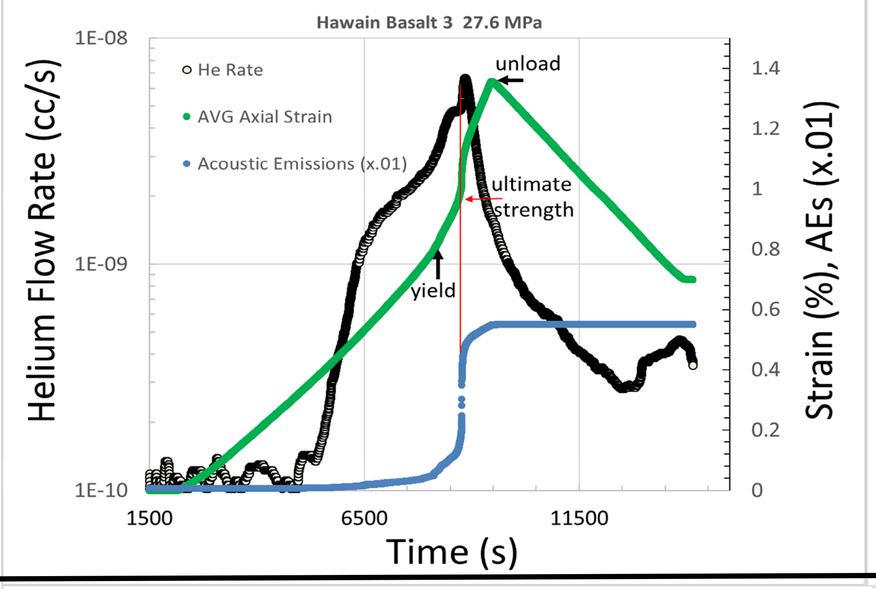



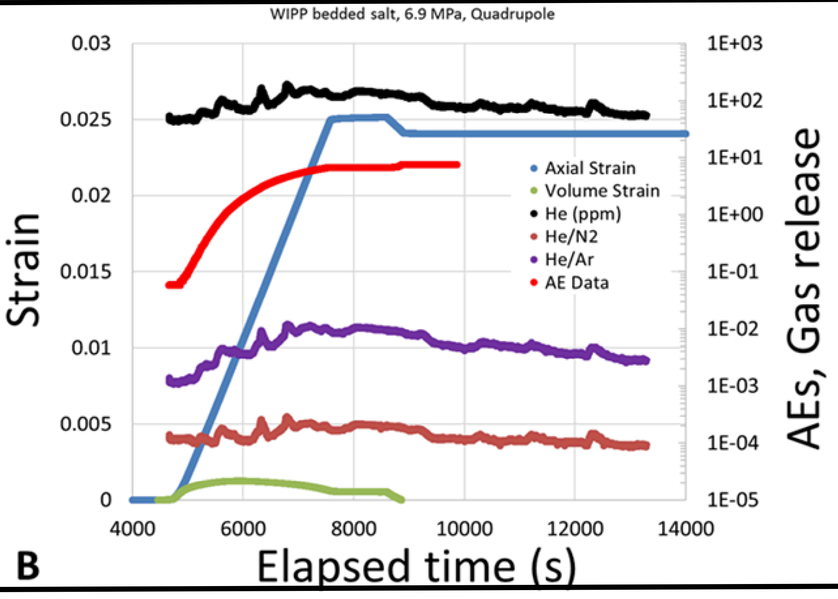



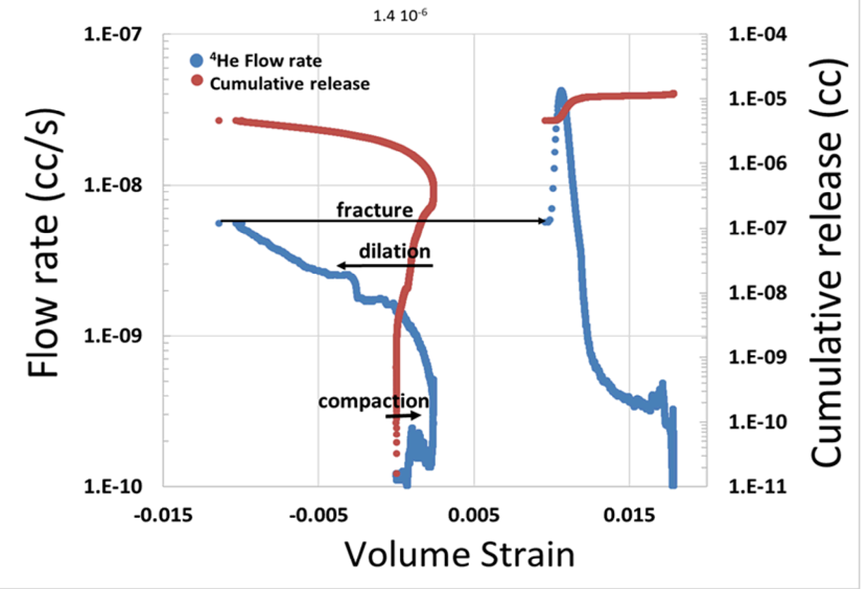



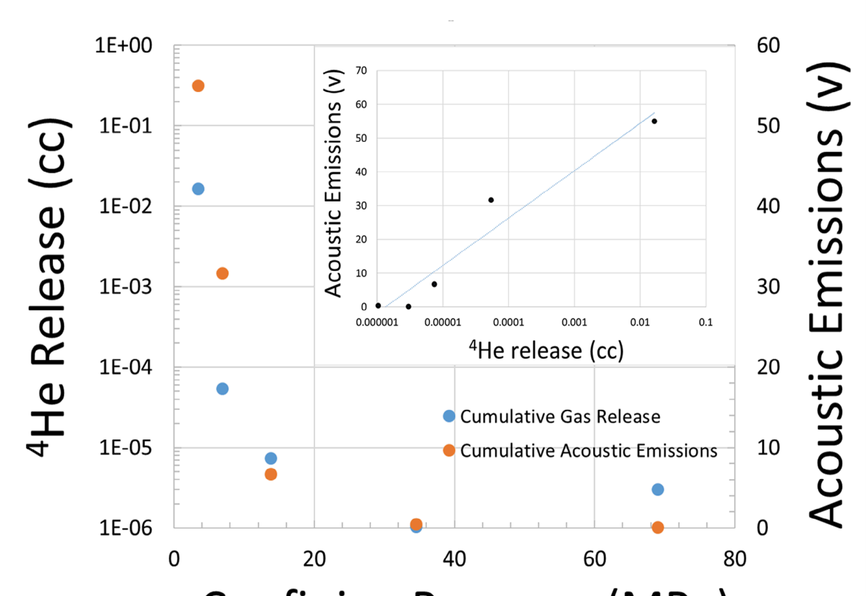



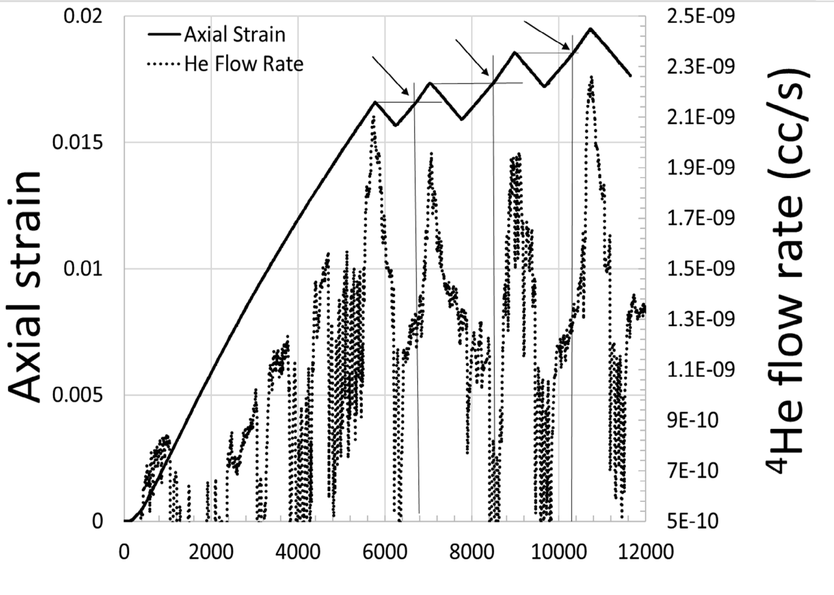




## Results

(1) Noble gases are released and measured real time during deformation

(2) Gases are released from intracrystalline sites.

(3) The noble gas release signal is precursive to macrofracture

(4) Gas released depends on initial gas content, pore structure and its evolution during deformation, deformation amount, and permeability

(5) Release rate increases as strain and microfracturing increase

(6) deformation rate and confining pressure dependent

(7) sensitive to brittle versus ductile conditions

(8) stress history dependent

## Conclusion

Noble gas release measured real-time represents a new tool to track deformation in rock

## Path Forward

Measure gas release in lab, relate to deformation ($\sigma$, $\varepsilon$, AE, cracks)

Develop model……. $\text{Energy Consumed}_{\text{deformation}} \propto f(\text{gas released})$

Measure gas release ……determine: $\text{Energy Consumed}_{\text{deformation}}$

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