**Temporal evolution of seismic b-value and fractal dimension: analyzing precursory signatures of brittle deformation**

**Objective:** To analyze the temporal variation in b-values and D-values during biaxial compression tests; analyze if there is a correlation of these dimensionless with microfracturing mode.

**Background:**

1. Confined biaxial experiments can be classified into 4 different stages:
   1. Stage 1: Linear and increasing stress-strain curve, distributed tensile microfracturing
   2. Stage 2: Non-linear and increasing stress-strain curve, spatially clustered shear and tensile microfracturing; initiation of fracture formation
   3. Stage 3: Non-linear and decreasing stress-strain curve, spatially clustered shear and tensile microfracturing, decline in shear microfractures; fracture formation complete
   4. Stage 4: Frictional sliding; rock is at residual strength, spatially
2. Confined compression experiments show statistically similar signatures to earthquakes (b-values, D-values)

**Methods**: (These are largely similar to the methods in the manuscript)

* Biaxial compressional tests on calibrated samples of sandstone and granite, with 0 – 30 MPa confining pressures
* Fractal dimension (D-value)
* Seismic b-value
* Microfracturing mode and predicted Acoustic Emission energy

**Preliminary Results:**

Stage 1: Tensile microfracturing and low AE energy is associated with high b-values and D-values

Stage 2: Tensile+Shear microfracturing and high AE energy due to initiation of shear fracture formation is associated with suppressed b-values and D-values.

Stage 3: Tensile+Shear microfracturing and high AE energy due to coalescence of shear fracture is associated with even lower b-values and D-values.

Stage 4: Tensile microfracturing and low AE activity associated with frictional sliding are associated with rebound of b-values and D-values to slightly higher values than Stage 2 and 3

**Effect of Confining Pressure:** Confining pressure has the opposite effect on b-value and D-value. The increase in confining pressure results in larger D-values (increased distribution of damage), and lower b-values. However, the temporal patterns during biaxial experiments for b-values and D-values remain consistent for all tested confining pressures.

These results are seen in calibrated samples of both sandstone and granite.

**What does this mean?**

* The depression of seismic b-values and fractal D-values are precursors to nucleation of fracture.
* The depression of seismic b-values has been suggested as an earthquake precursor, with foreshocks exhibiting significantly lower b-values than mainshocks/aftershocks.
* Our methodology allows us to study the distribution of microfractures and quantify it through D-values. We observe that damage goes from distributed (Stage 1) to localized (Stage 2 and 3) to distributed again (Stage 4). We now have micromechanical models for this.
* Several studies have proposed b vs D relationships – some show direct correlation while others show inverse correlation - between the two dimensionless parameters. Our study shows that b and D vary significantly within a single experiment itself, and thus the relationship between b and D is a function of when the quantities are measured in the experiment/stress cycle.

**Why does this happen?**

(Currently reading on this)

* Our data shows that the depression of b-values and D-values coincides with the onset of shear microfracturing in our experiment (shear microfractures are very significant in sandstone, but are also present in granite).
* Theory presented by Horii and Nemat-Nasser, 1985 suggests that shear cracks cannot propagate by themselves and need tensile microfractures to connect them. Thus, application of boundary stresses results in localization of stress along tips of shear microfractures.
* Thus, formation of tensile microfractures occurs around the formed shear microfractures due to localization of stresses. This results in depression of D-values.
* The localization of stresses in the crust has also been correlated with a decline in seismic b-values (also observed in lab experiments).

Future work:

* Analyze stress concentrations in samples – are they concentrated around shear microfractures? Do tensile microfractures form as wing cracks to the existing shear microfractures during nucleation of a shear macrofracture?
* Calculate b-values and D-values for tensile and shear microfractures separately – will do this only if there is value to it
* Analyze effect of confining pressure – maybe develop a mechanistic model