Laboratory Study of Mechanical and Transport Properties of Bishop Tuff

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Abstract

Through the application of a range of stress conditions, we aim to document the failure mode of the Bishop Tuff and create a general characterization of its mechanical properties, including bulk and shear moduli, permeability, porosity, and stress-strain curves at varying conditions. By documenting the responses to deformation shown by this rock unit, our data contributes to a general understanding of how this tuff will behave as gradual compaction continues. This in turn will affect the safety of future infrastructure in the fault zone. This project was hosted by the NSF funded RORD REU.

Program Background

- Research Opportunities in Rock Deformation (RORD) Research Experiences for Undergraduates (REU)
- Ten-day field session at Sierra Nevada Aquatic Research Laboratory (SNARL) in the Sierra Nevada Mountain Range studying rock deformation around Bishop CA
- Six-week laboratory session at various host labs across the country
- Program goal of introducing undergraduate students to the field of experimental rock deformation

Background

- The Bishop Tuff is a welded tuff that formed from ashfall and a rhyolitic pyroclastic flow around 764,800 years ago in Owens Valley, California (Andersen et al., 2017)
- The Bishop Tuff is a high-silicate rhyolitic welded tuff, made up of ash and pumice clasts. The main minerals found in the predominate pumice clasts are biotite, plagioclase, quartz, and sanidine. (Anderson 2000)
- Unit is close in proximity to the Owens Valley fault zone

Sources

Anderson, N., Jicha, B., Singer, B., & Hildreth, W. (2017). Incremental heating of Bishop Tuff sanidine reveals preeruptive radiogenic Ar and rapid remobilization from cold storage. *National Library of Medicine*, 114(47):12407-12412. 10.1073/pnas.1709581114

A. T. Anderson, A. M. Davis, & F. Lu, Evolution of Bishop Tuff Rhyolitic Magma Based on Melt and Magnetite Inclusions and Zoned Phenocrysts, *Journal of Petrology*, Volume 41, Issue 3, March 2000, Pages 449–473, https://doi.org/10.1093/petrology/41.3.449

Evans, J., & Bradbury, K. (2004). Faulting and Fracturing of Nonwelded Bishop Tuff, Eastern California: Deformation Mechanisms in Very Porous Materials in the Vadose Zone. *Vadose Zone Journal*, 3 (2): 602–623. https://doi.org/10.2113/3.2.602

Figures

Figure 1

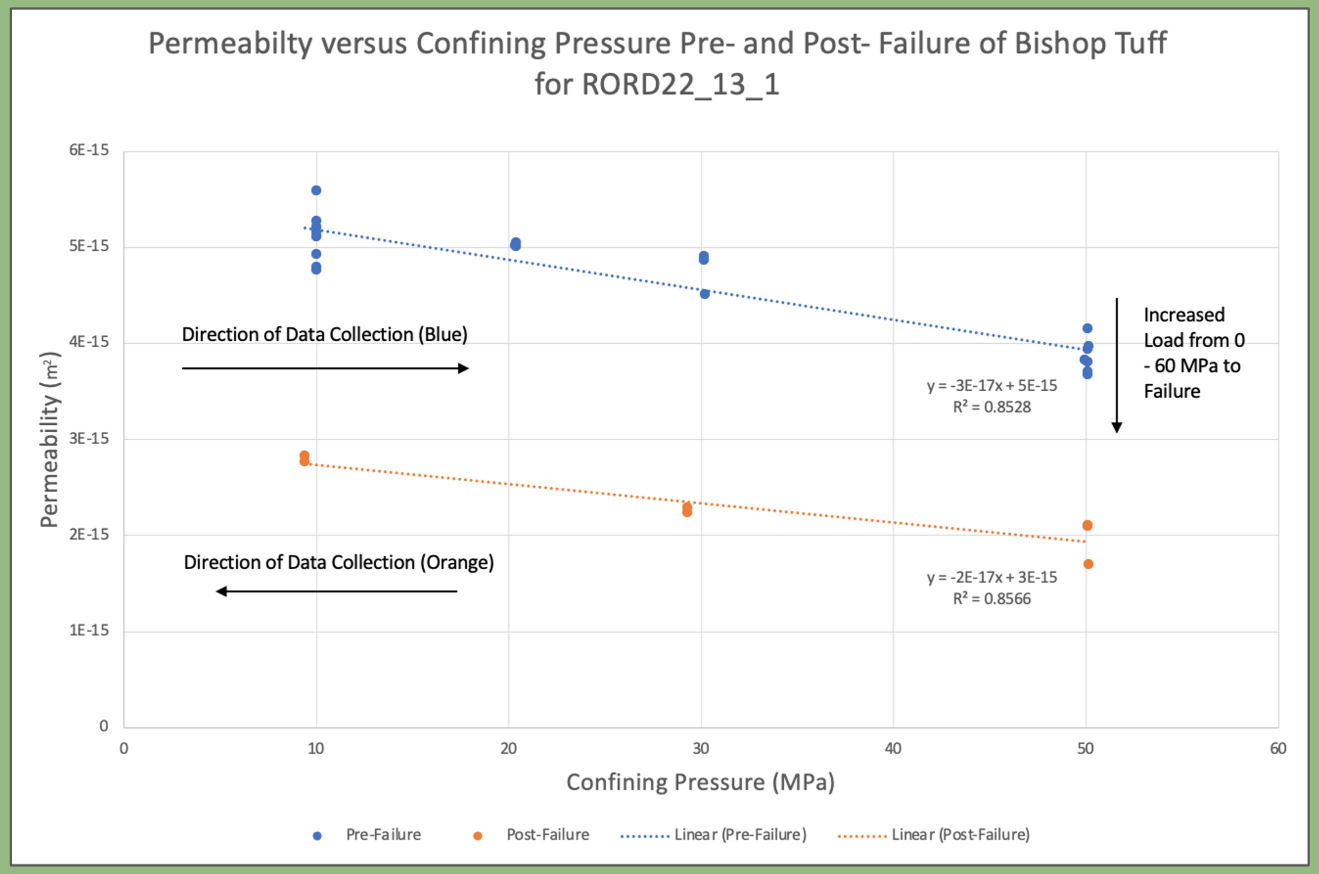


Figure 2

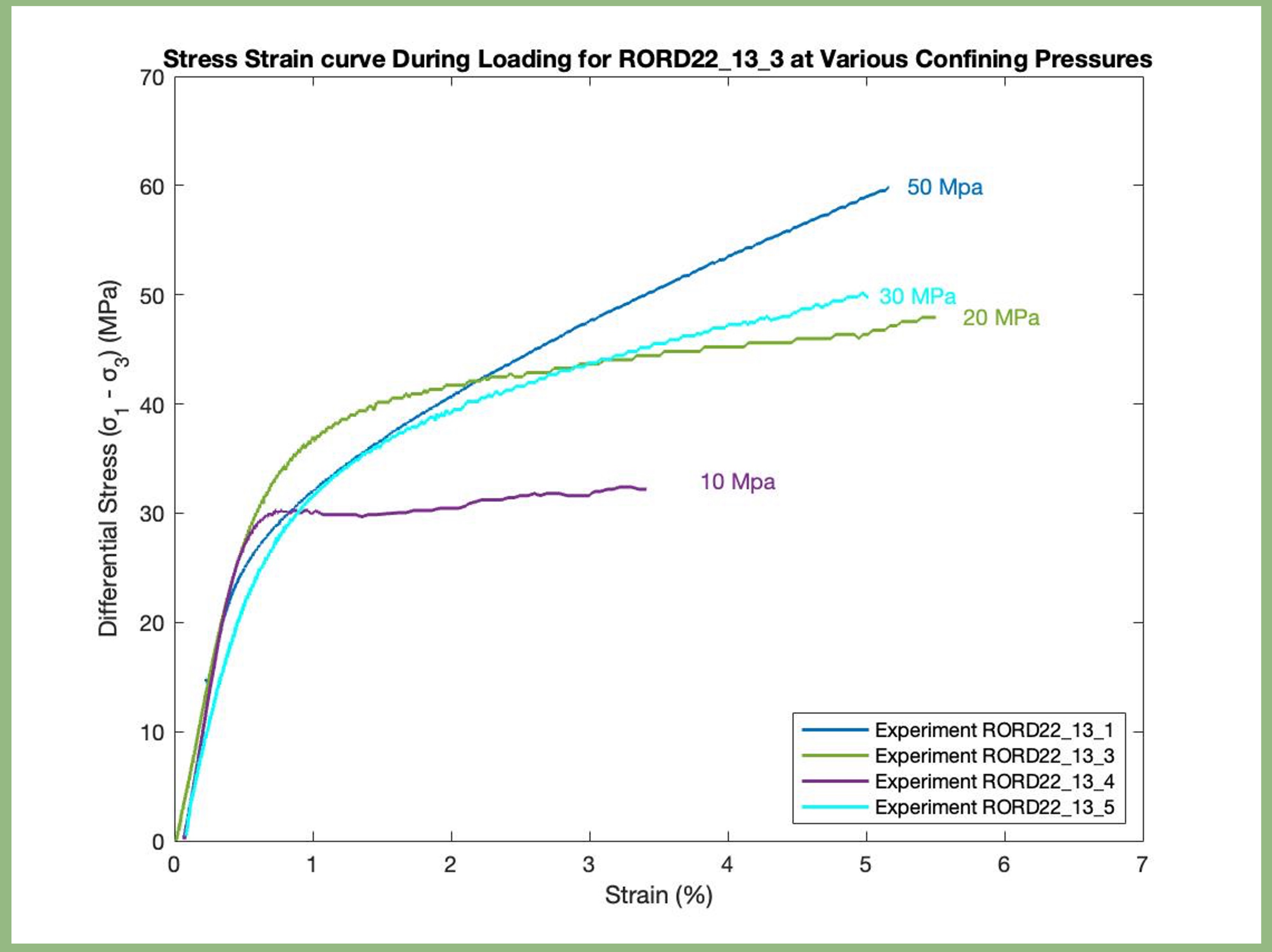


Figure 3

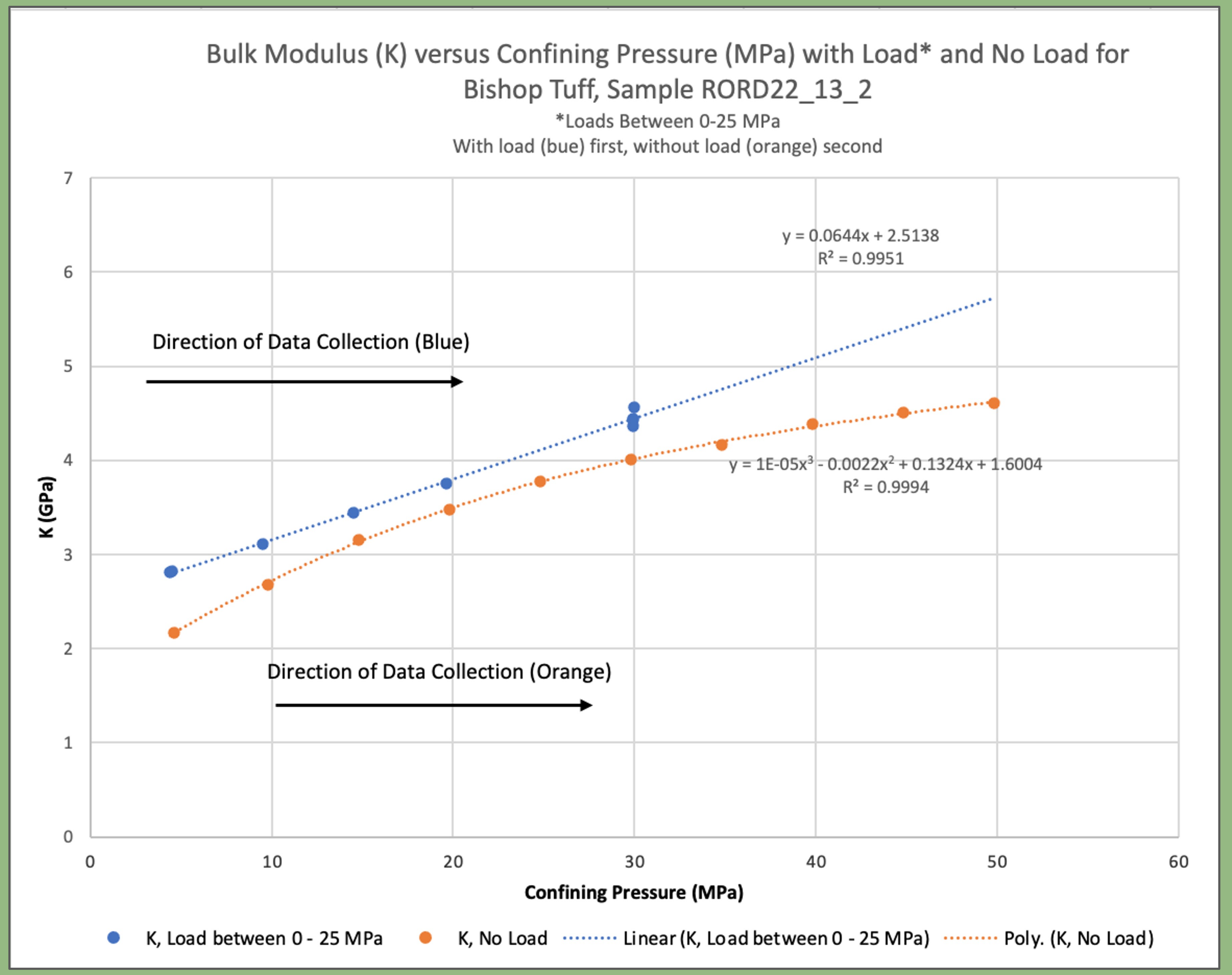


Figure 1

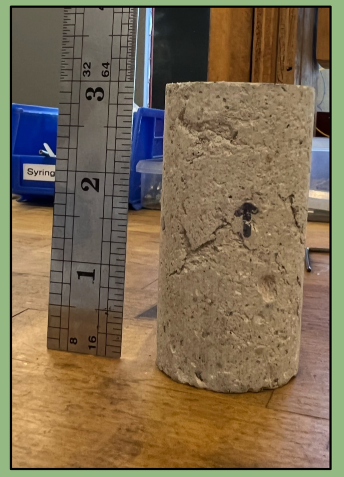
Permeability (m^2) versus confining pressure (MPa) pre- and post- failure of the Bishop Tuff (sample RORD22_13_1). Data was collected with increase confining pressure until failure at 60 MPa, and then the pressure was decreased. Permeability was measured using argon gas. Permeability linearly decreases with increasing confining pressure and decreases after failure.

Figure 2

Differential Stress (MPa) versus Strain (%) show at the confining pressures of 10, 20, 30, and 50 MPa. This data shows that the yield point for the bishop tuff is within 20 - 35 MPa in all experiments. as we increase the confining pressure, the post-yield slope becomes steeper thus showing increase in strain hardening at higher pressures. None of our samples show signs of strain weakening, meaning we had no localized failures which is consistent with our lab observations.

Figure 3

Bulk modulus, K (GPa), versus confining pressure (MPa) with differential stress and isotropic stress. Data was collected from low to high confining pressure. Bulk modulus with isotropic stress increases non-linearly with increasing confining pressure whereas bulk modulus with differential stress (varying between 0-25 MPa) increases linearly with increasing confining pressure.

Pre-(left) and Post-Failure (right) of sample RORD22_13_1 under 50 MPa confining pressure.

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Methods

- Samples previously defined as Unit C within the Bishop Tuff by Evans and Bradbury (2004) were collected along the Sad Boulders trail in Bishop, California.
- Cored out five cylindrical samples of 38 mm in diameter and 75 mm in length and using a New England Research (NER) Autolab 3000 to take measurements of pore pressure (using Argon gas) as well as bulk, shear, and Young's modulus
- In sample preparation rubber jackets were used to protect samples from oil contamination and then in deformation trials we used Linear Variable Differential Transformers (LVDT) to measure the ongoing compressional deformation during each trial.
- These LVDTs were used to measure displacement which can be used to calculate strain. In order to obtain stress measurements, a load cell was used in experimentation. This load cell measures the load on the sample and can be divided by the area of the sample to calculate stress.

Conclusions

- Preliminary results show that Bishop Tuff has an average porosity of 28.9% and is easily compressible with a Young's modulus of 7.88 GPa.
- The Argon permeability of the intact sample is 4.64x10^{-15} m^2.
- After failure, the permeability decreases to 2.29x10^{-15} m^2 suggesting that the rock compacts.
- Permeability decreases linearly with increasing confining pressure.
- Compaction bands perpendicular to the loading direction suggest pore compaction.
- Yield stress increases from 10-20 MPa then decreases from 30-50 MPa.
- Strain hardening increases with increasing pressure suggests that the sample did not develop a fault.