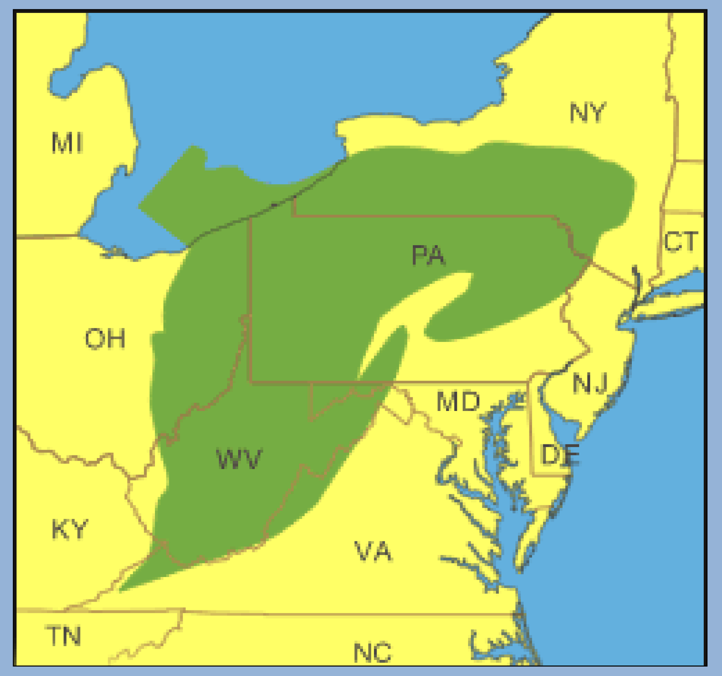
The Effect of Bedding Laminations on Crack Propagation in the Marcellus Shale

Evan McMullen GEOL 394 Advisor: Wen-lu Zhu
Department of Geology, University of Maryland, College Park, MD 20742



Abstract

In this study I conducted deformation experiments on three Marcellus Shale samples, to investigate the effect of laminations on crack propagation. Cylindrical samples were used in the mechanical test. Two of the samples were taken parallel to the bedding planes, and one was taken perpendicular to the bedding planes. Prior to the deformation tests, initial porosity and permeability of the undeformed samples were measured. At the confinements and strain rates used in the study, all three samples failed by brittle fractures. Porosity and permeability measurements were then conducted on the deformed samples. By mechanically fracturing the samples, permeability and crack networks have been enhanced due to the internal features of the shale. I also performed microstructural analysis of undeformed and deformed samples. Comparison of the mechanical data and microstructure of bedding parallel to bedding perpendicular samples supports my hypothesis that the bedding orientation relative to stress orientation affects crack propagation. I also observed that crack growth is not only affected by the thin laminations, but also the strength contrast between silt-sized particles and clay minerals in these Marcellus Shale samples.

Marcellus Shale

- Bedding laminations seen by pre-existing cracks
- Shale anisotropy
- Microfossils seen throughout sample

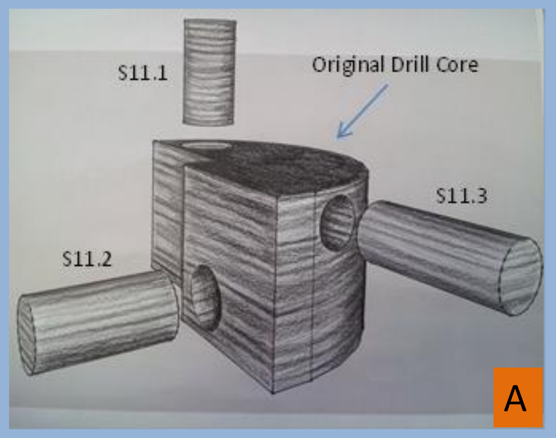
Hypothesis

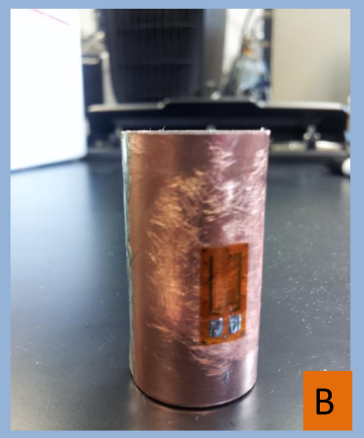
- H0: That that the laminations and bedding planes would not affect the rock properties nor crack growth in the shale
- H1: That the laminations and bedding planes affect some of the rock's properties such as shear strength, permeability and pre-existing planes of weakness

Experimental Design

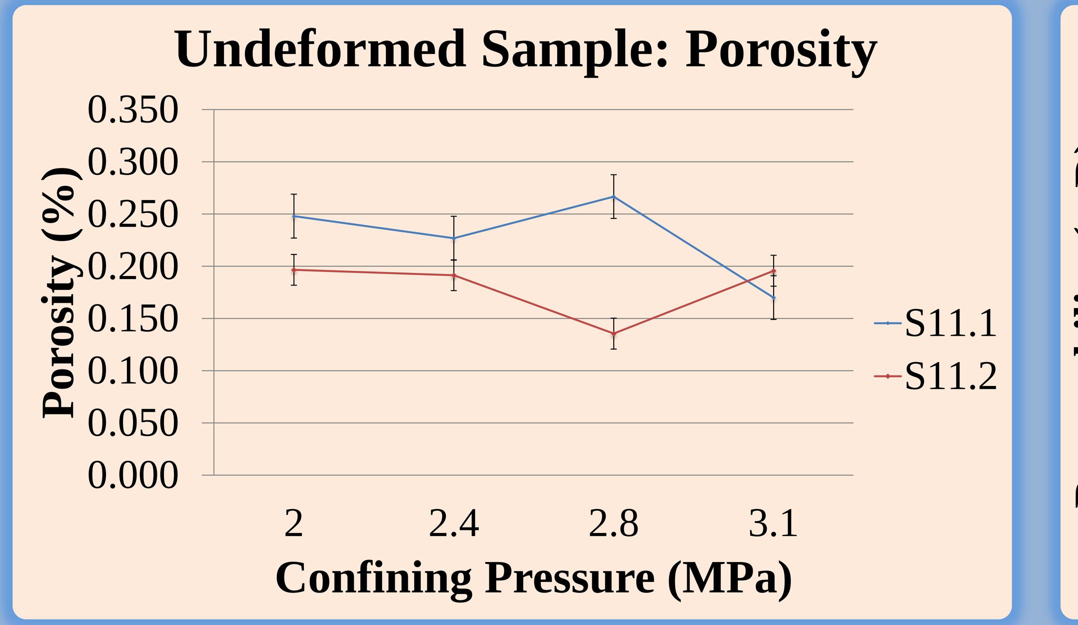
- Three samples taken at different orientations to bedding planes; two parallel and one perpendicular
- Undeformed porosity and permeability measurements were taken
- Deformation occurred at set experimental conditions
- Deformed porosity and permeability measurements were taken
- Microstructure analysis was completed between undeformed and deformed thin sections

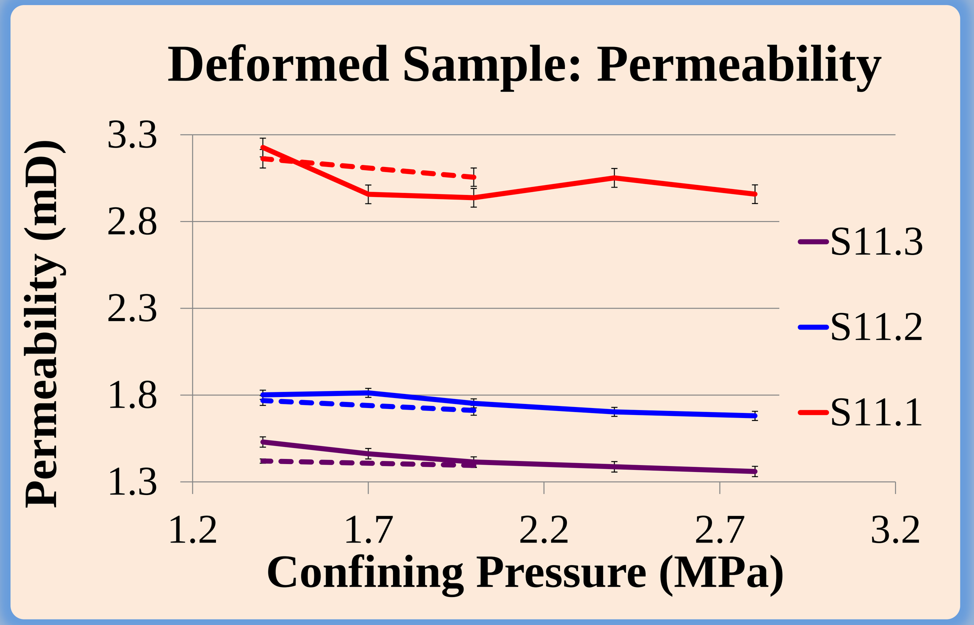
Figure A is a schematic diagram showing the samples bedding orientations
Figure B is a picture of the sample before deformation
Figure C is a picture of the sample prepared to be deformed

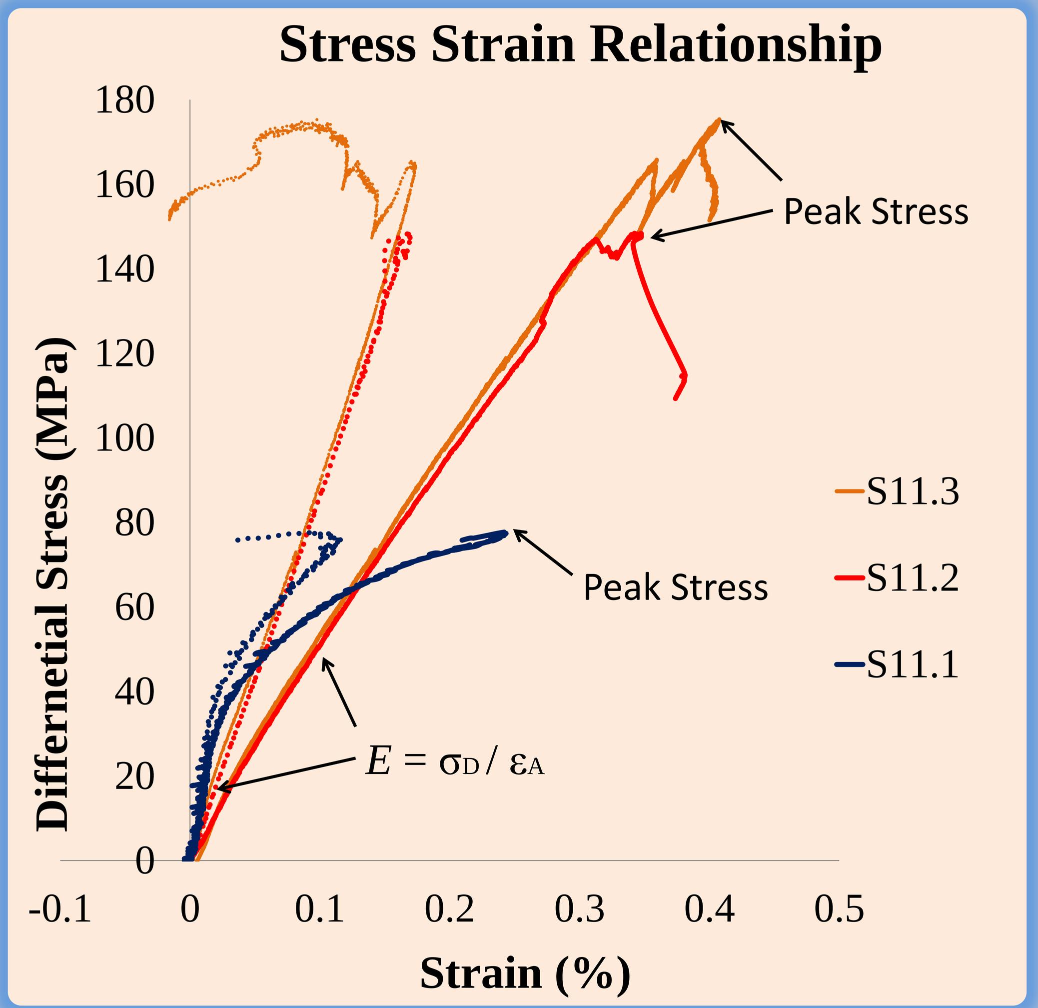


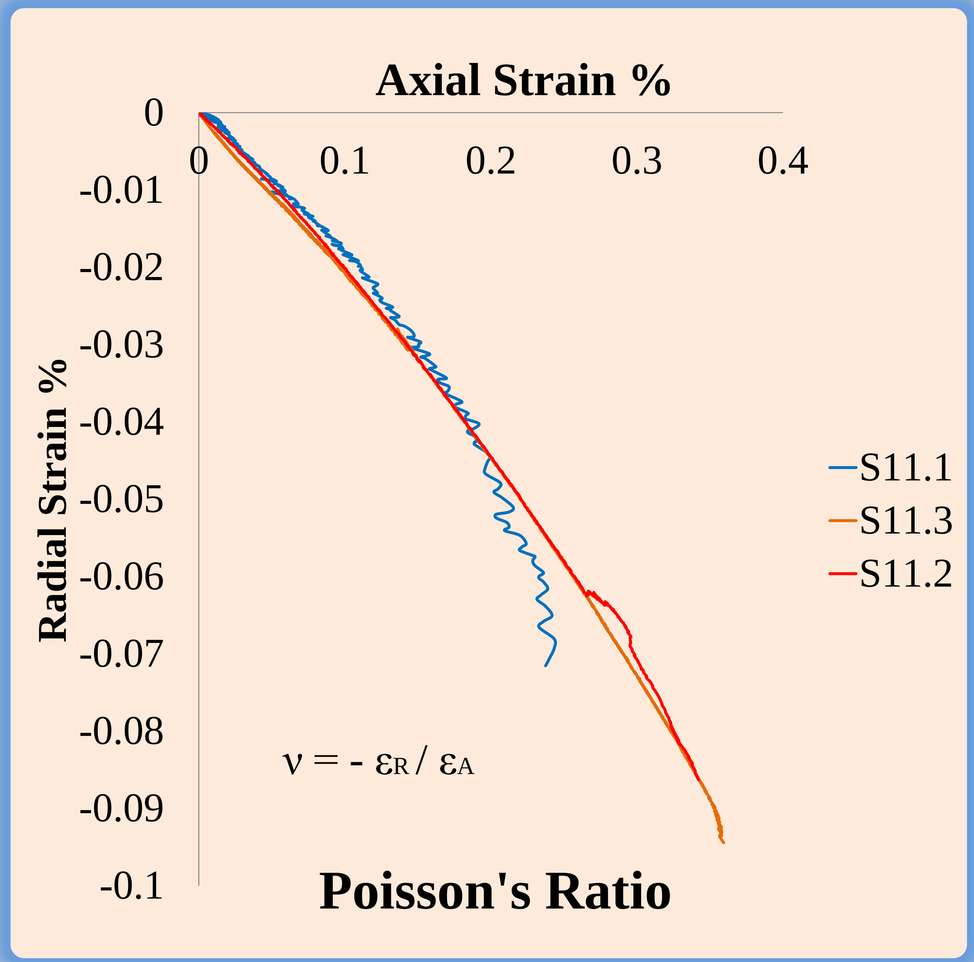


Experimental Results

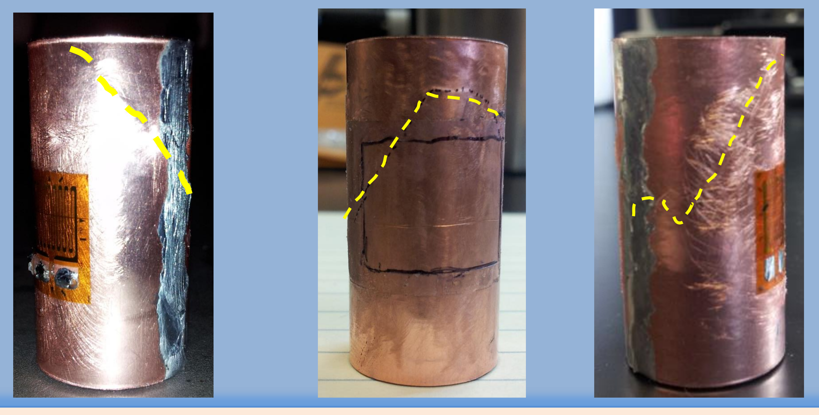


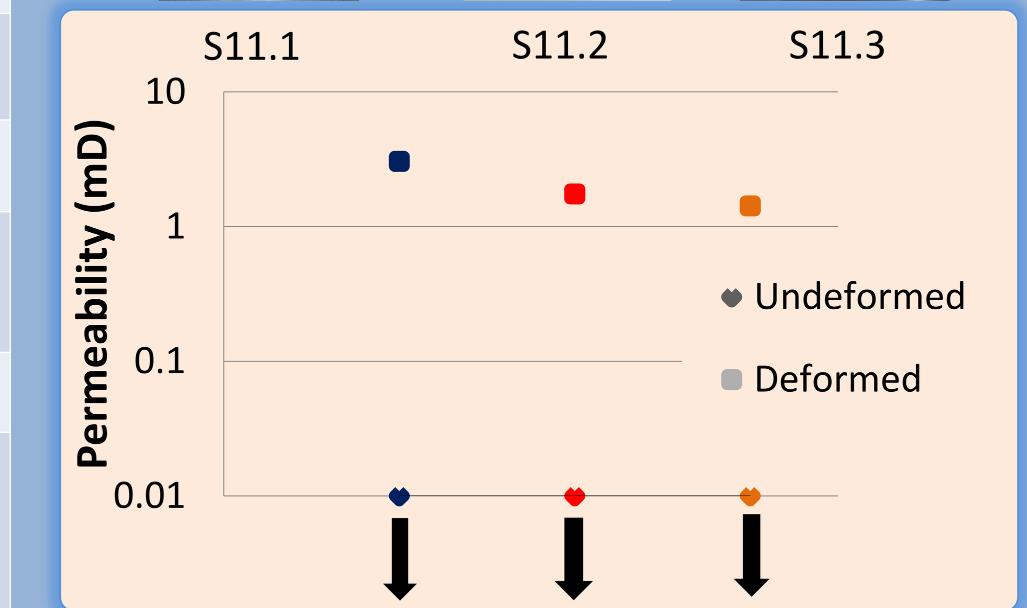






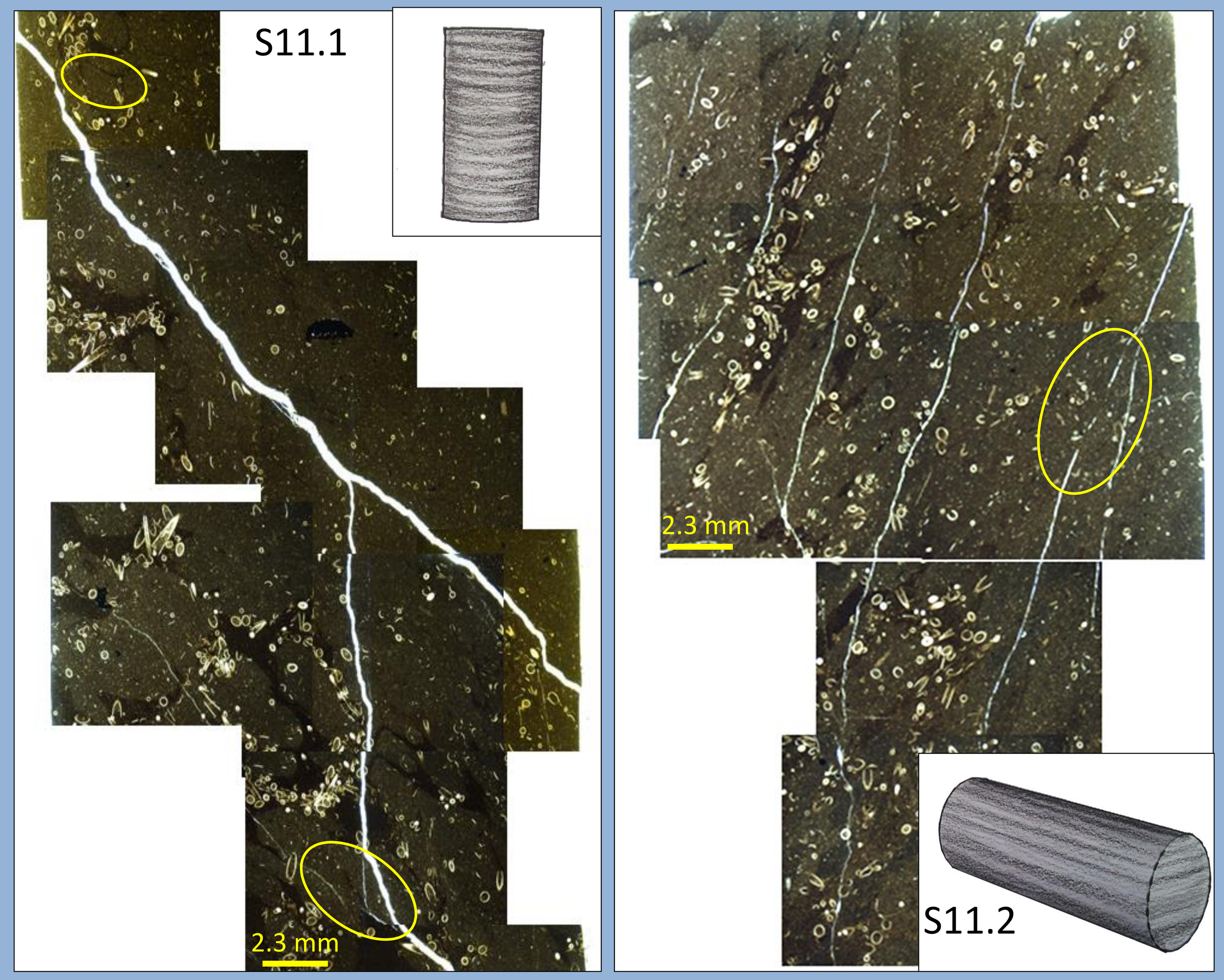
	Sample S11.1	Sample S11.2	Sample S11.3
Sample Orientation			
Confining Pressure (MPa)	15	15	30
Strain Rate [$\dot{\varepsilon}$] (s^{-1})	5×10^{-6}	5×10^{-6}	1×10^{-6}
Peak Stress (MPa)	78	146	177
Young's Modulus [E] (GPa)	1.4	0.472	0.465
Poisson's Ratio [v]	0.2414	0.248	0.25
Undeformed Porosity [Φ] (%)	0.228 +/- .18	0.180 +/-0.068	Too Low
Deformed Permeability [k] (mD)	3.05 +/- 0.18	1.747 +/- 0.04	1.424 +/- 0.04





Microstructure Analysis

- White cracks were created during deformation
- Cracks propagated along bedding laminations
- Pre-existing cracks are oriented with bedding laminations



Conclusions

- Shear strength of the Marcellus Shale samples depend strongly on bedding laminates.
- Crack growth in the deformed Marcellus Shale samples is controlled by the interplay between stress, bedding laminates, as well as the silt-clay strength contrast within the sedimentary layers.
- Comparison of the permeability values of the deformed samples to those of the undeformed samples indicates that stress-induced crack growth enhances permeability of the shale.

Acknowledgments

I would like to thank Wen-lu Zhu for being my adivsor for the past two semesters. I would also like to thank Audrey Ougier-Simonin, Harry Lisabeth and Jeremy Banker for help in the Rock Physics Lab.

References

Crawford, B. R., N. L. DeDontney, B. Alramahi, and S. Ottesen. Shear Strength Anisotrophy in Fine-grained Rocks. Thesis. Houston Texas, 2012. N.p.: American Rock Mechanics Association, n.d. Print.
Li, Yawei and Ghassemi, and Ahmad. Creep Behavior of Barnett, Haynesville, and Marcellus Shale. Thesis. Texas A&M University, 2012. N.p.: American Rock Mechanics Association, n.d. Print.
Soeder, Daniel J. "The Marcellus Shale: Resources and Reservations." EOS, Transactions, American Geophysical Union 91.32 (2012): 277-88. Print.