

Factors Behind Variation in Geomechanical Properties of a Highly Lithified, Quartzose Sandstone*

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Abstract

Gas is produced from fractured Jackfork Group sandstones in southeastern Oklahoma. A Complex tectonic history has created multiple generations of fractures, leading to a major challenge in interpreting and predicting various factors which control the rock geomechanical properties, strength and fracturing potential. Quasi-static laboratory measurements of change in strain under increasing load were conducted on samples of highly lithified, tight, quartzose Jackfork along a well-exposed outcrop of an asymmetric anticline in south-central Arkansas, while ultra pulse velocity measurements were also conducted. Rock samples, as well as borehole image logs, were obtained from behind-outcrop cored wells and from both the steeply-dipping (average bedding dip 70 degree) and shallow-dipping (almost horizontal bedding) flanks of an asymmetric exposed anticline.

The presence of numerous fractures, primarily on the steeply dipping limb of the anticline, allowed us to capture the variation in the geomechanical properties in both lateral and horizontal directions. Four sets of fractures trending north-south, east-west, northwest-southeast and northeast-southwest are present on the borehole image log at different depth intervals which cross cut each other in a few places. The mechanical parameters such as the stiffness or Young's modulus increase in magnitude towards the axis of the anticline. This observation and measurement is also correlated with the acoustic measurement, in terms of compressional and shear wave velocities. A newly designed rock testing device, the Inclined Direct Shear Testing Device (IDSTD), was used to measure strength- and stress-dependent acoustical properties on cylindrical Jackfork samples of 0.3" in thickness and 0.8" in diameter cut from shallow core. Presence of different grain sizes, microfractures and spatial location compared to the fold axis and bedding dip are the key factors controlling mechanical properties of this tight quartzose sandstone.



Factors Behind Variation in Geomechanical Properties of A Highly Lithified, Quartzose Sandstone

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Outline

- Objective
- Geologic setting
- Results from various laboratory testing for mechanical characterization
- Thin section analysis
- Developing stress tensor
- Conclusions



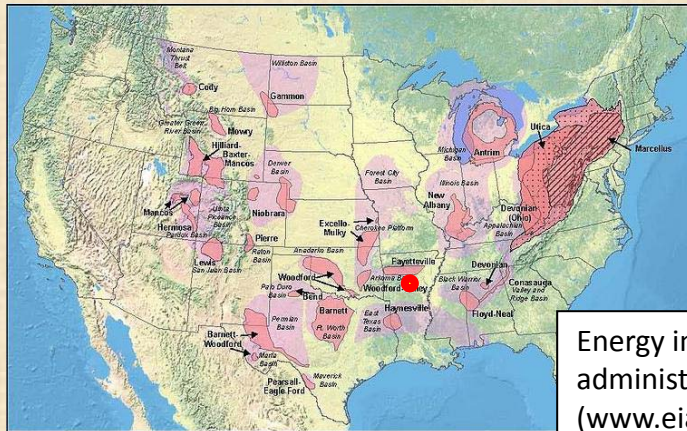
Objective

- Quantify the variation of material properties (elastic constants)
- Correlate mechanical properties with various petrophysical properties
- Apply similar techniques to different setting
- Model building and development of a log for analyzing and identifying geomechanical properties.

•Coupled elastic properties and horizontal stress development in tight gas shale reservoirs results in complex near-wellbore stress concentration (Rivera et al., 2006). This effect plays a critical role for effective hydraulic fracturing, especially for horizontal wells.

•This talk is based on the study performed for Jackfork sandstones.

Geologic setting



Energy information
administration
(www.eia.doe.gov)

- Quachita orogeny
- Pennsylvanian
- Deformed downdip basinal facies tract
- Sheet sandstones, channel sandstone
- Different physical properties



Slatt et al.



Mechanical characterization

- Outcrop samples, Core, Borehole image log, Gamma ray
- Laboratory testing:
 - Unconfined compressive strength (UCS)
 - Triaxial test
 - Inclined direct shear (IDSTD)

Outcrop



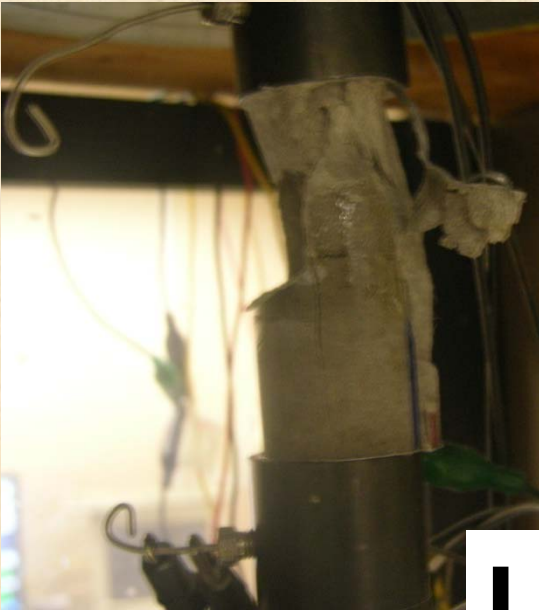
SE quarry wall

Bedding dip 72° - 80°

West quarry wall

Bedding dip 12° - 13°



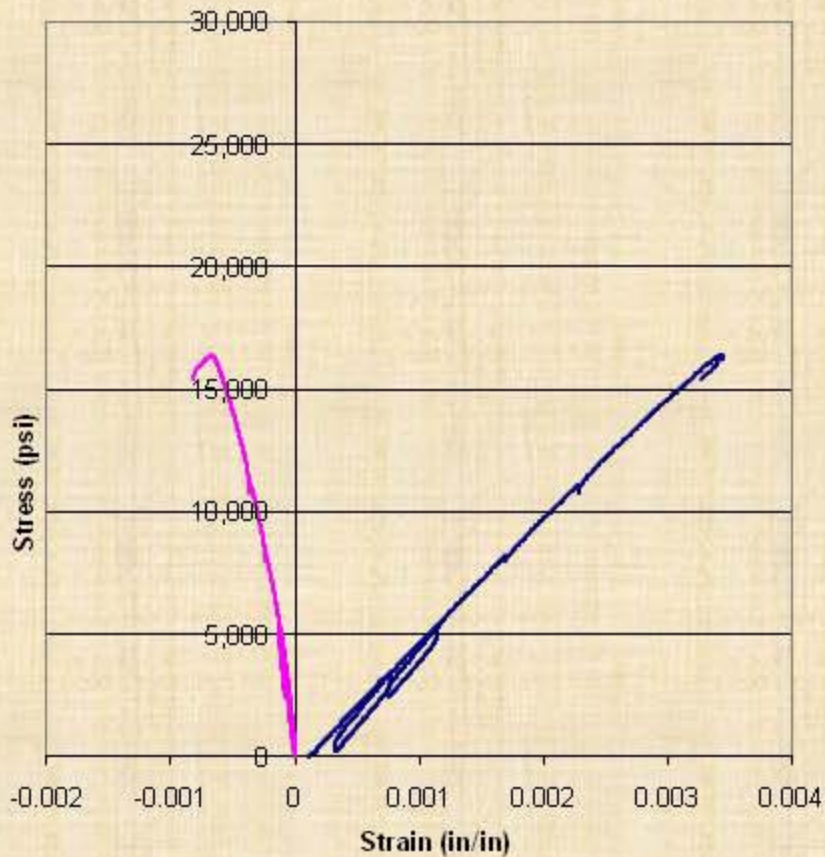


UCS TEST

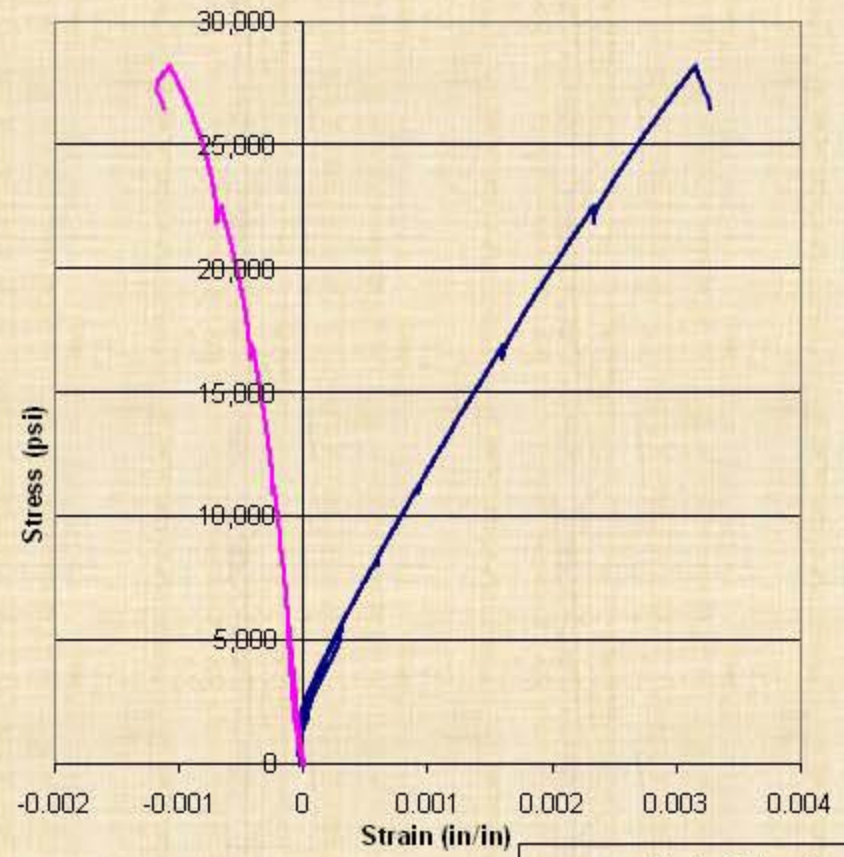


UCS test results

Sample from SE wall



Sample from West wall



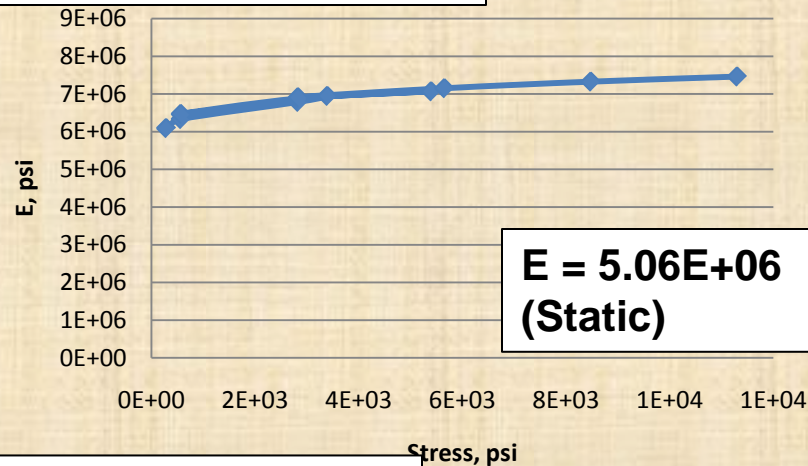
— Axial Strain
— Lateral Strain



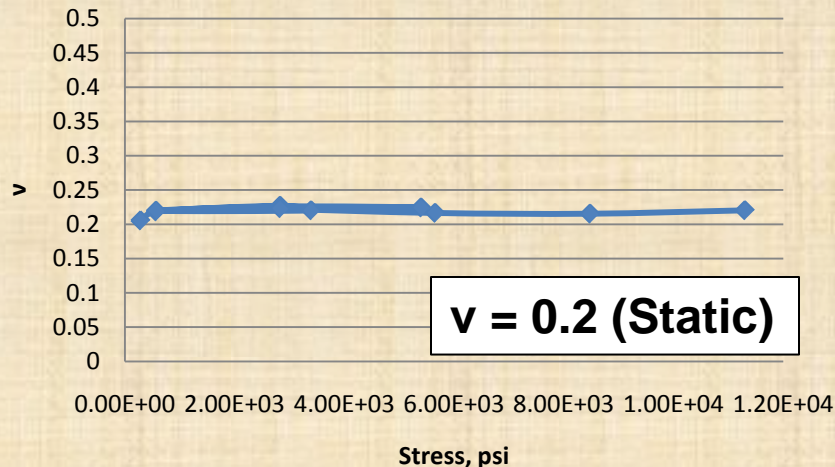
UCS-test results

Sample from SE wall

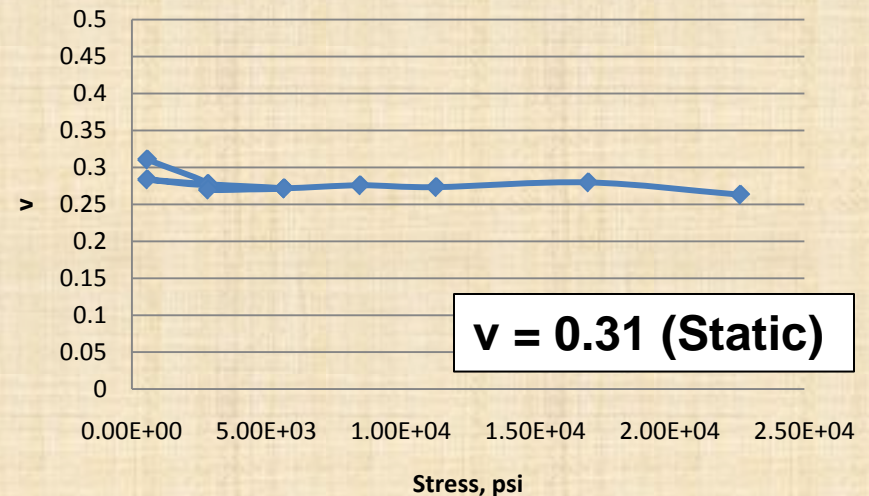
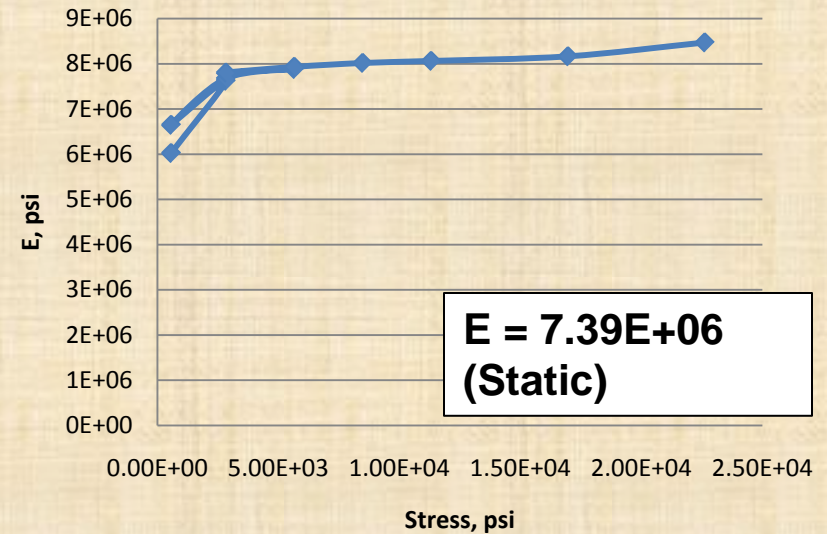
Young's modulus, psi



Poisson's ratio



Sample from West wall

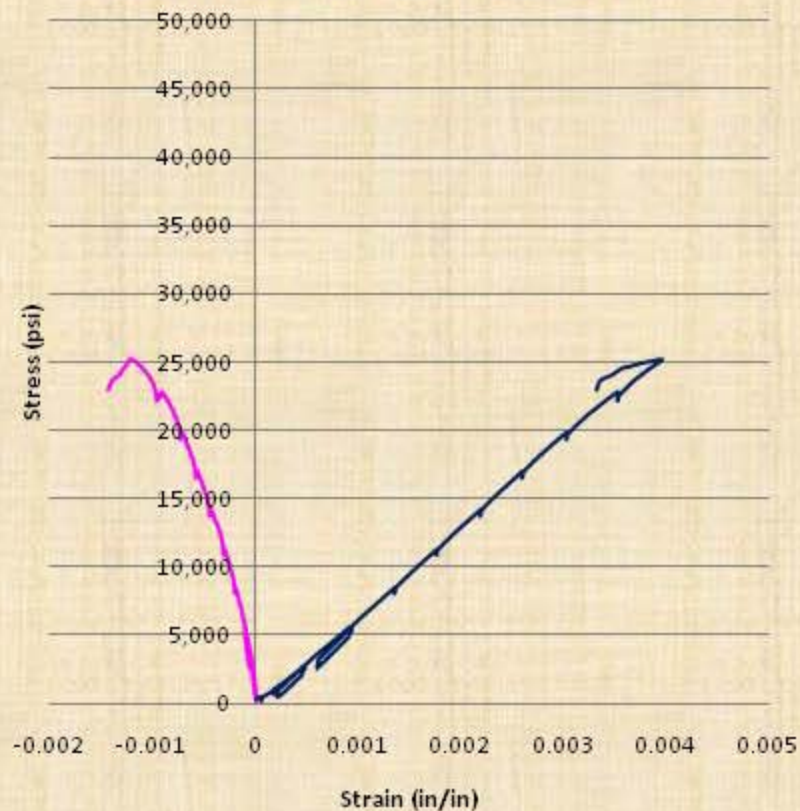




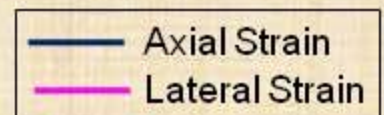
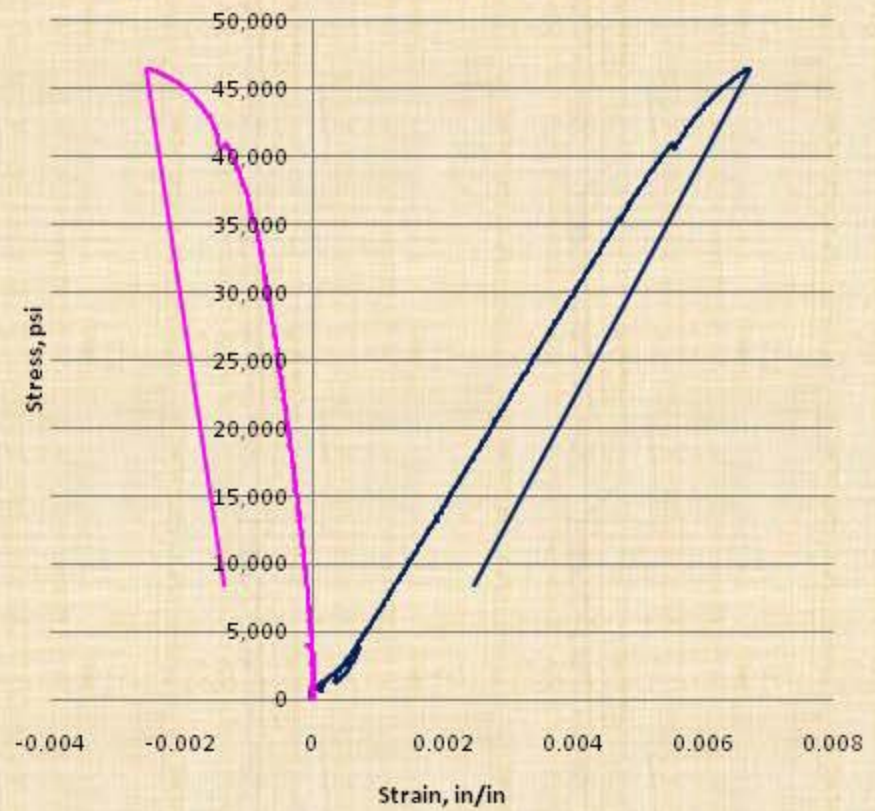
TRIAXIAL TEST

Triaxial test results

Sample from SE wall



Sample from West wall

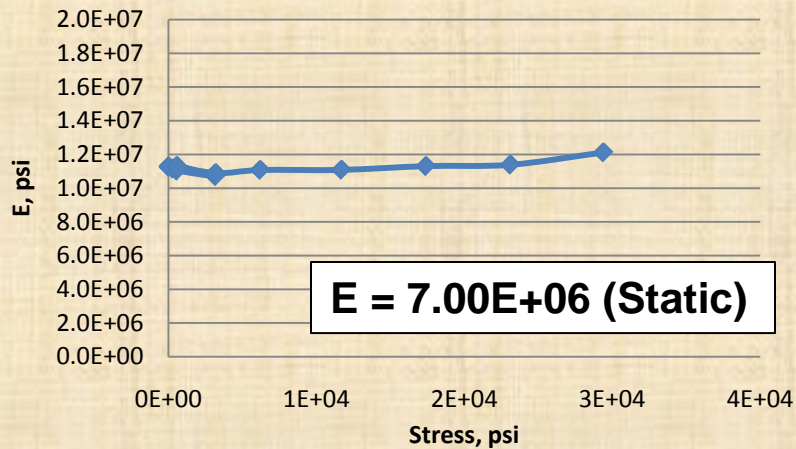




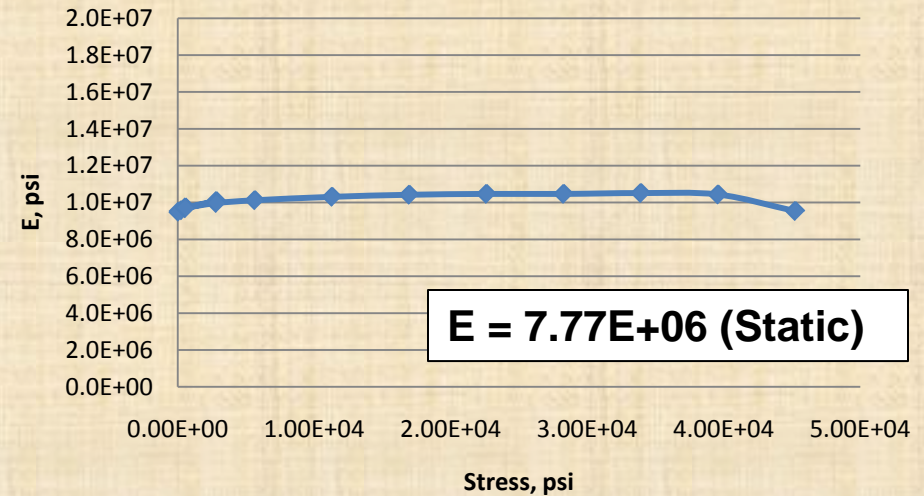
Triaxial-test results

Sample from SE wall

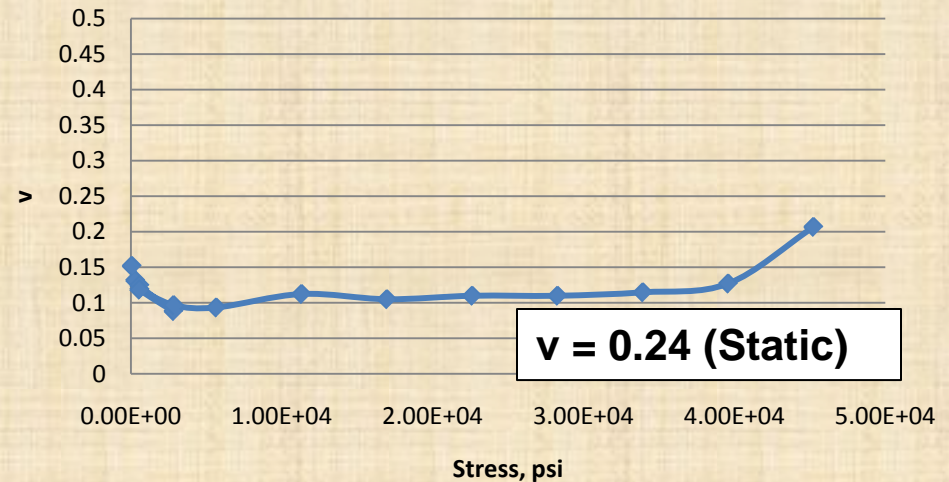
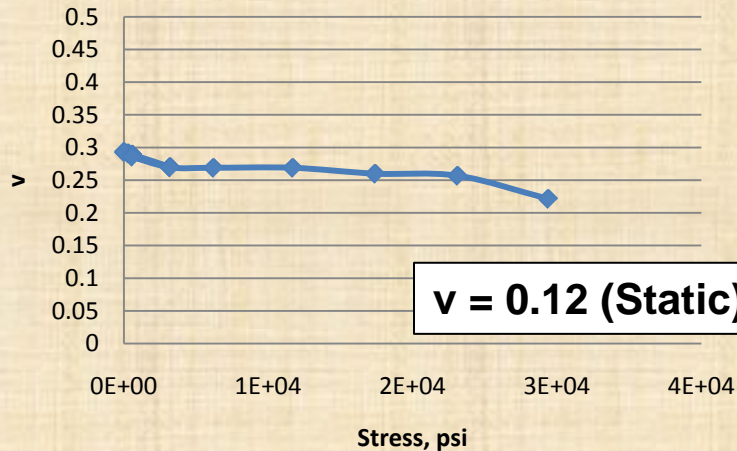
Young's modulus, psi



Sample from West wall



Poisson's ratio





IDSTD TEST

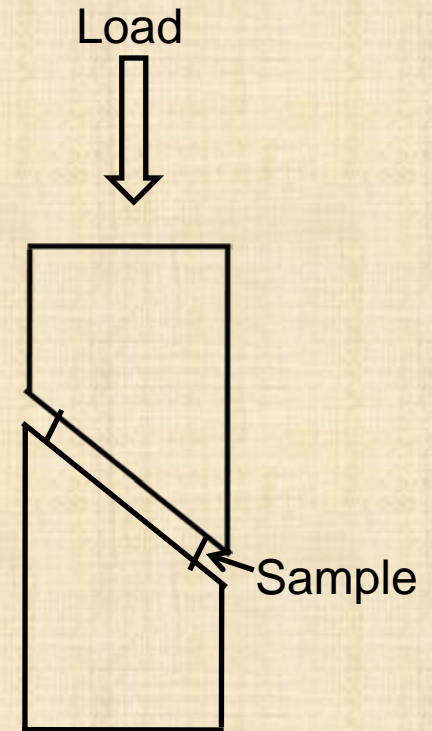
IDSTD



Sample dimensions

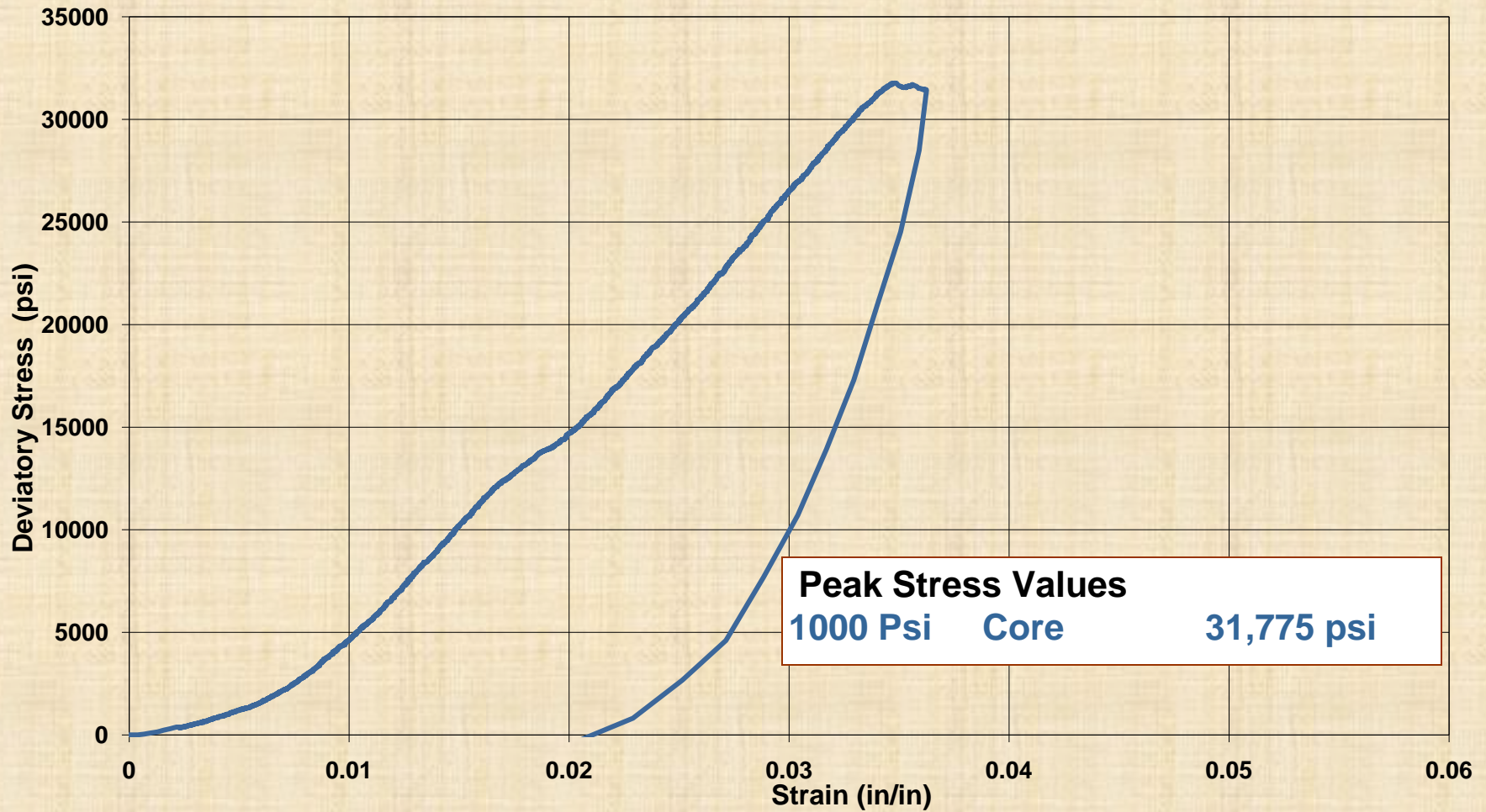
Diameter: 0.796 in

Thickness: 0.282 in



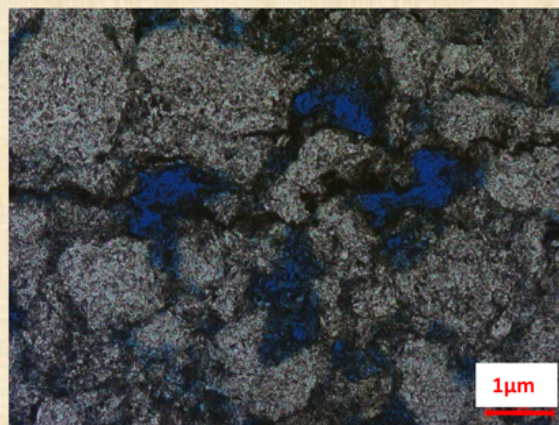
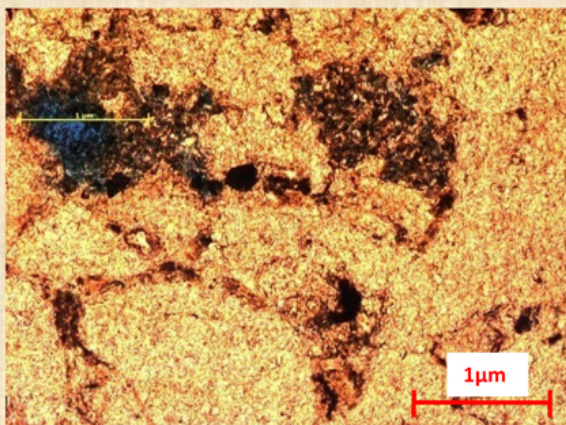


IDSTD result

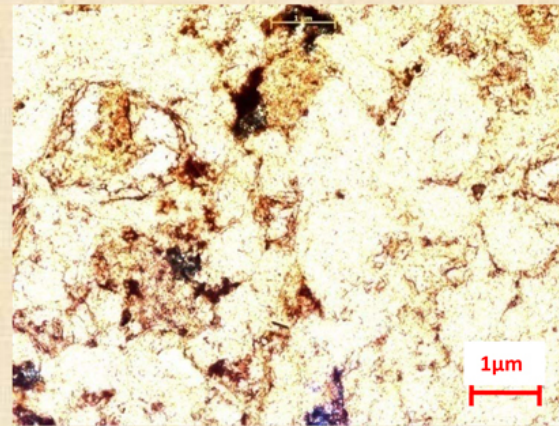
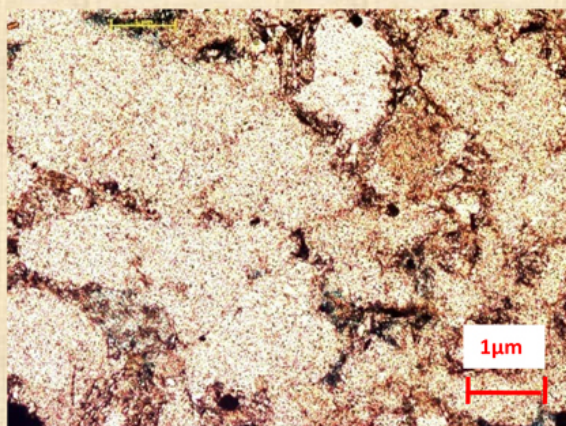




Thin sections



Outcrop
samples



Core
samples

Porosity 4% maximum
Air permeability 0.011 md maximum

- Thin section under 10X, plane polarised light.
- Thin section study support the hypothesis about the rock homogeneity and isotropic nature.
- Thin section study revealed that they are Quartz arenite with more than 95% Quartz. Rest includes feldsper, mica, clay, few opaque minerals, rock fragments and very small amount of porosity.
- Laboratory characterization started with HQ because of isotropic nature and only two valid compliances. Easy to characterize.



Jackfork in Hollywood Quarry

Samples are homogeneous and isotropic.

Hence, 21 compliances in the stress tensor reduce to only 2

$$\begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu & -\nu & 0 & 0 & 0 \\ -\nu & 1 & -\nu & 0 & 0 & 0 \\ -\nu & -\nu & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(1+\nu) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(1+\nu) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(1+\nu) \end{bmatrix} \begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{xy} \\ \sigma_{yz} \\ \sigma_{zx} \end{bmatrix}$$

- Laboratory characterization started with HQ because of isotropic nature and only two valid compliances. Easy to characterize.

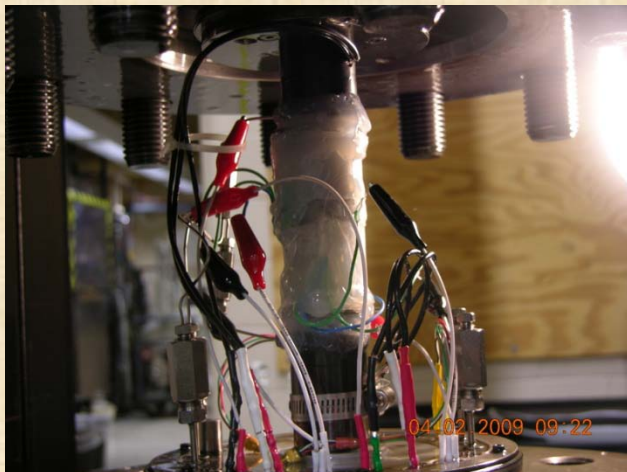
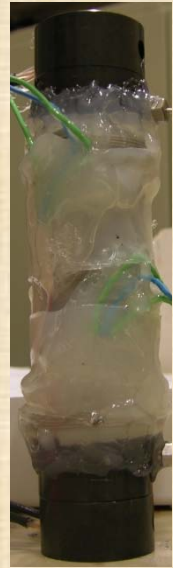
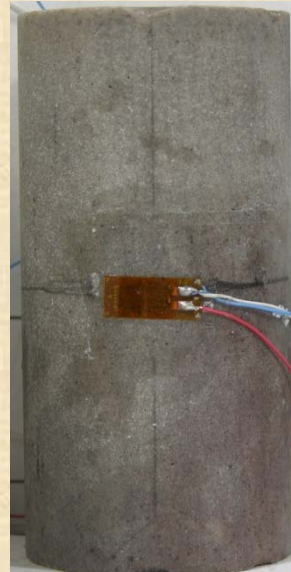
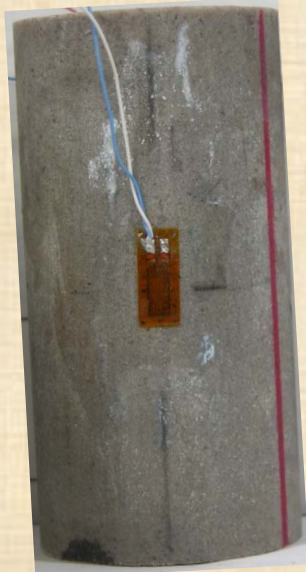


Conclusions

- Difference in mechanical properties despite of compositional and morphological similarities.
- Framework supported rocks (90% quartz). Minor changes in the proportion of different grain size, porosity.
- Presence of 2% more cement has decreased the failure strength by 45% compare to no cement in some samples (samples with sutured grain boundary).
- The difference between static and dynamic moduli is also controlled by compositional differences of the rock samples.
- Differential deformation, compaction history along with petrophysical properties like variation in grain size, sorting and slight mineralogic variations seem to be the controlling factors behind the variation in mechanical characteristics of these rocks.

Some samples were closer to channel margin compare to some from channel axis.

Sample preparation for triaxial test



Sample(SE) failed under UCS, at 45000lb

