



Physical Properties of Low-rank Coal Samples from the Powder River Basin, Wyoming

Paul Hagin and Mark Zoback

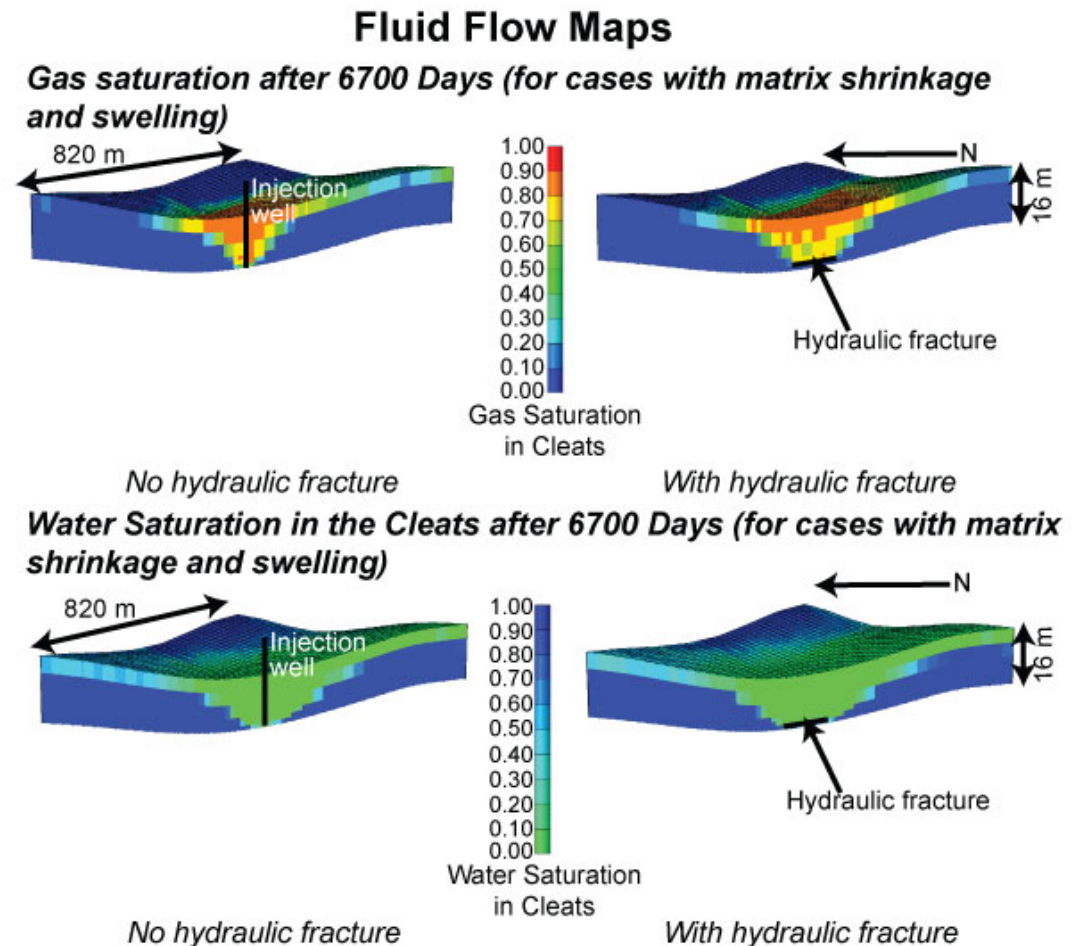
Geophysics Department
Stanford University



Goals and Motivation



- Predictions of sequestration and E/CBM potential rely on numerical models
- Improve constraints and inputs by conducting laboratory experiments
- Better understand effects of adsorption on mechanical properties



(Ross, Zoback, Hagin, 2007)



Structure of Presentation



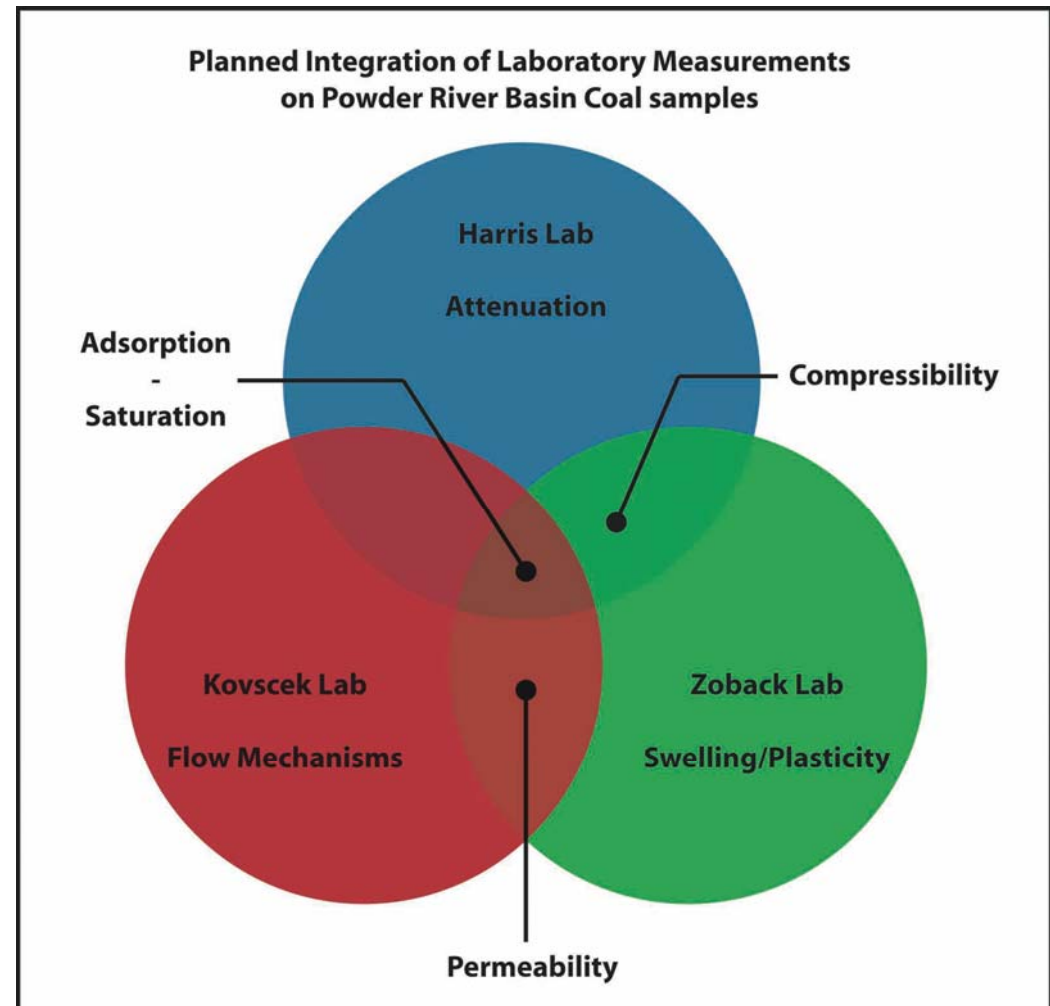
- Overview of the multidisciplinary experimental effort at Stanford
- Describe our particular laboratory apparatus and experimental goals
- Present some initial data and results
 - Adsorption
 - Mechanical Properties
 - Flow Properties



Overview of Lab Efforts



- Multidisciplinary approach based on complementary measurements
- Flow/Transport Lab
 - Tony Kovscek, ERE
- Seismic/DARS Lab
 - Jerry Harris, GP
- Geomechanics Lab
 - Mark Zoback, GP

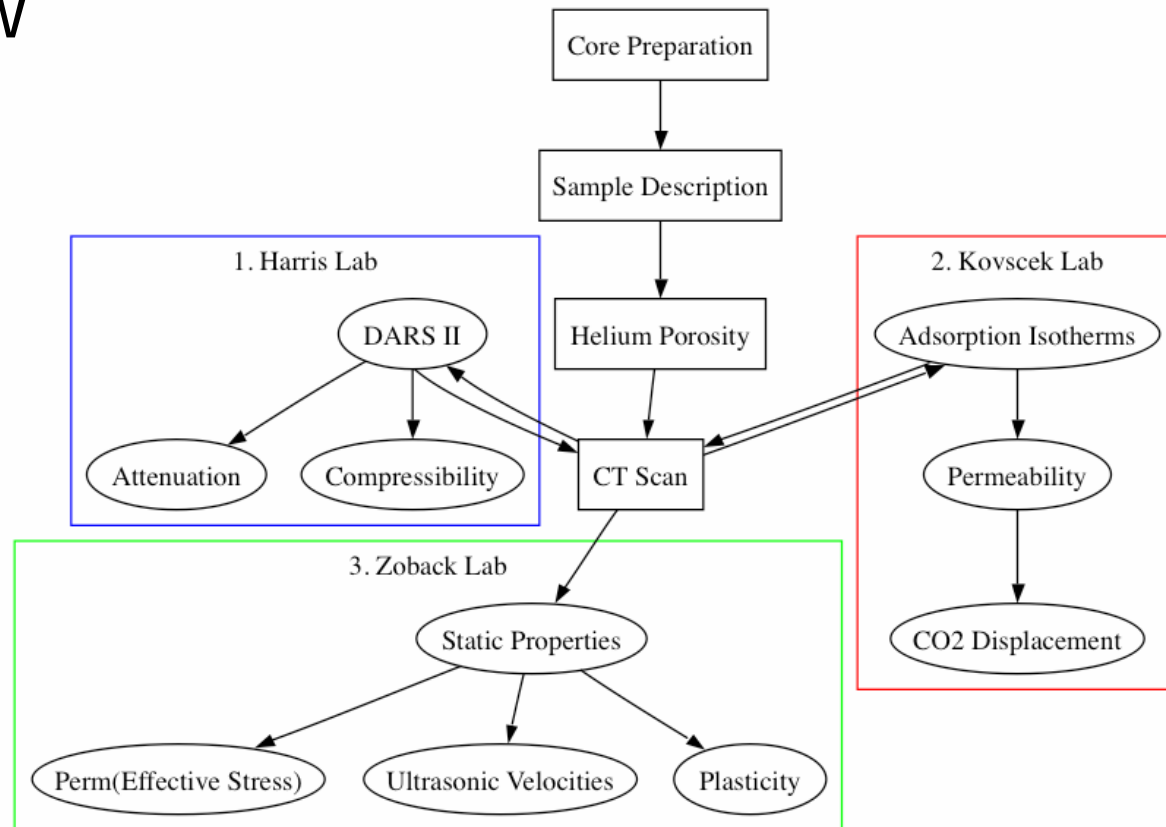




Overview of Lab Efforts



- Integrated Workflow gives us internal validation of results
- Flow/Transport Lab
 - Adsorption/Perm
- Seismic/DARS Lab
 - Q/Moduli
- Geomechanics Lab
 - Vp/Vs/Moduli/Perm

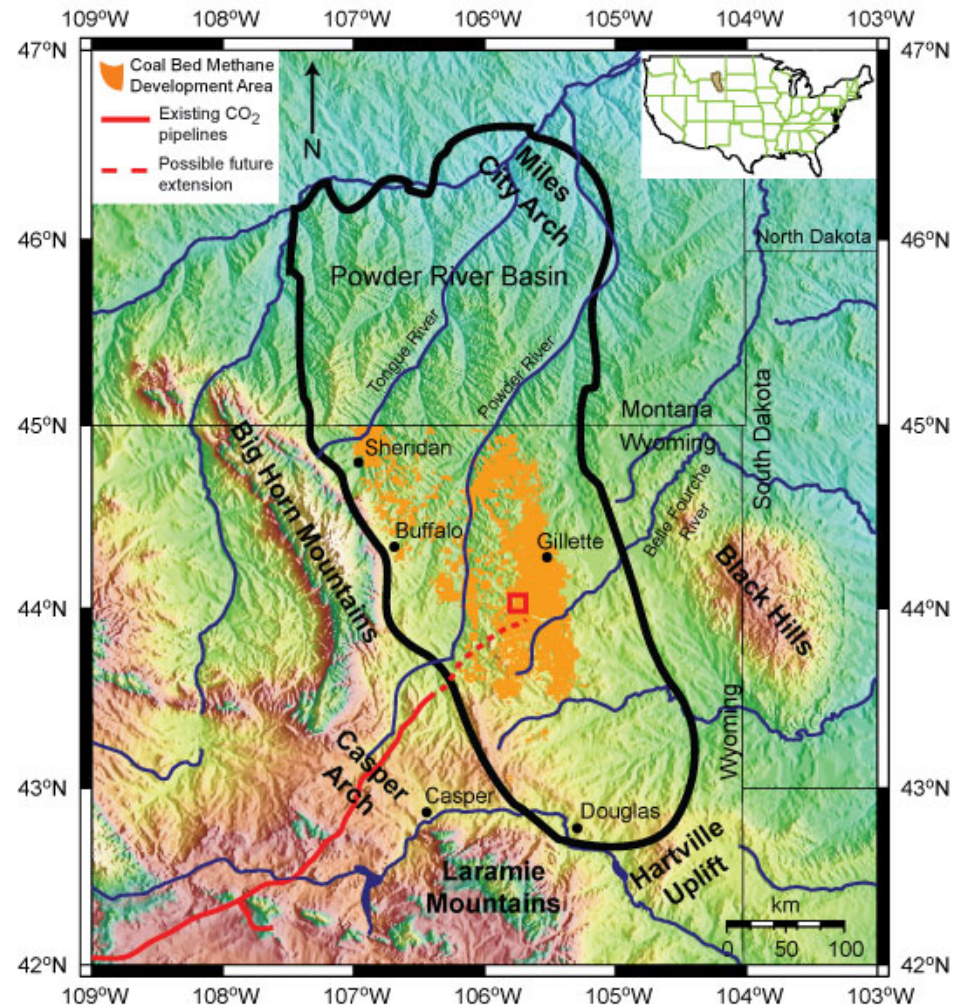




Field Location



- **Powder River Basin**
 - Wyoming/Montana
- Fastest growing CBM play in the USA
 - ~17,000 CBM wells
- Existing CO₂ sources and infrastructure for ECBM or sequestration

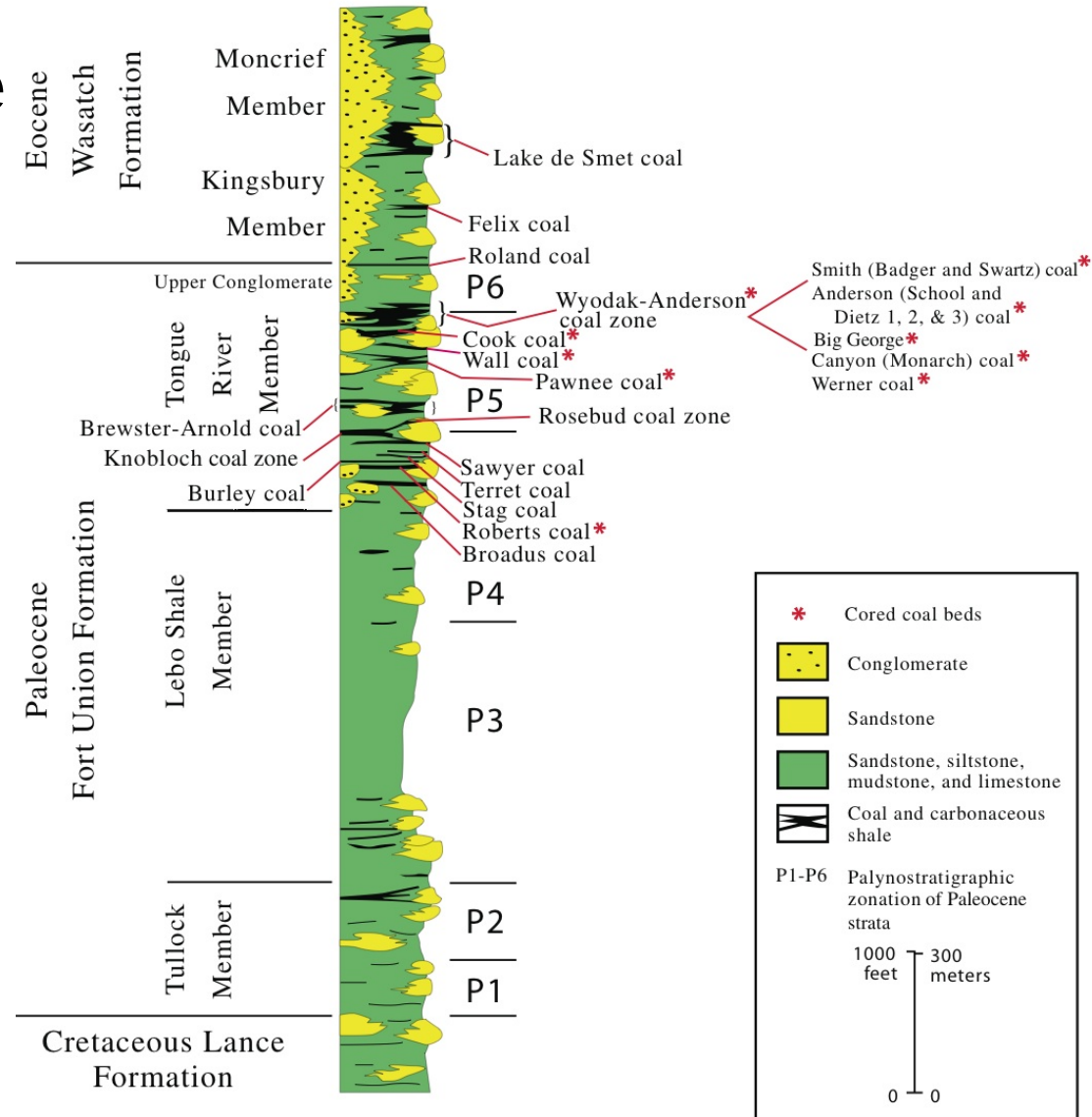




Sample Description

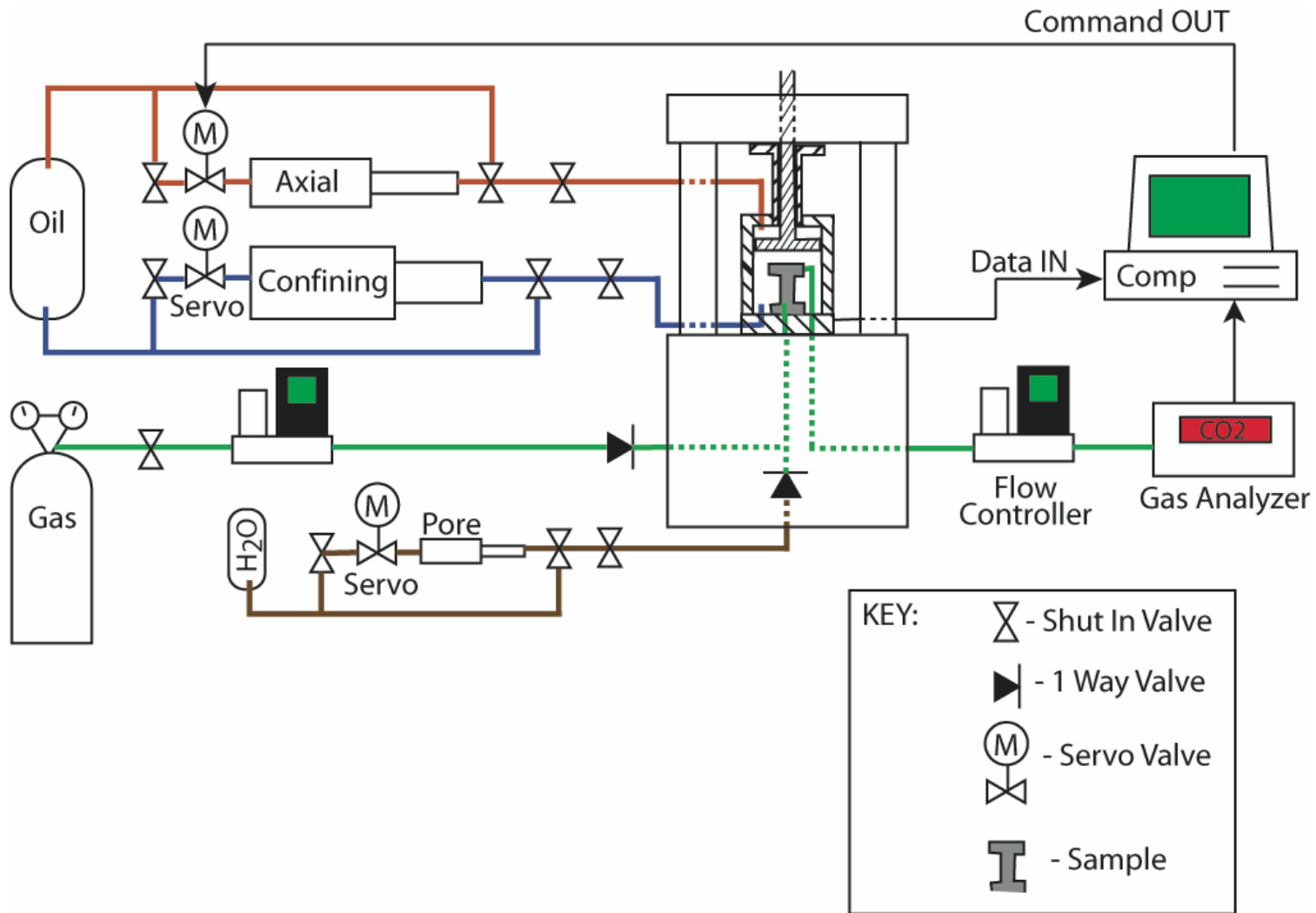


- Samples are from the Ft. Union Formation
 - Roland and Smith Coals
- Depth: 1300-1400'
- Thickness: 20-100'
- Matrix porosity: ~10%
- Density: ~1.5 g/cc
- Ash content: 10-20%



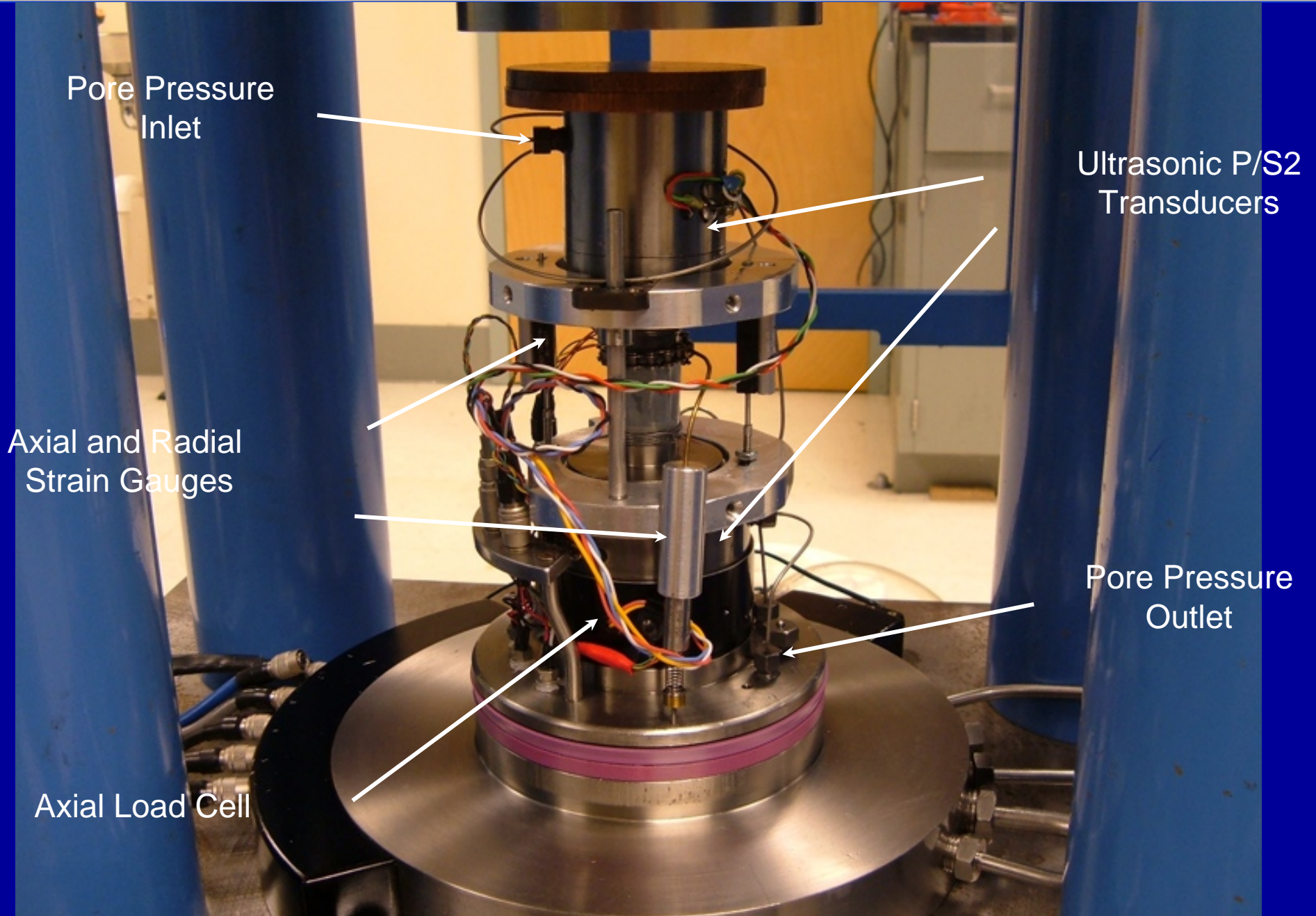


Experimental Setup





Core Holder Assembly



Pore Pressure Inlet

Ultrasonic P/S2 Transducers

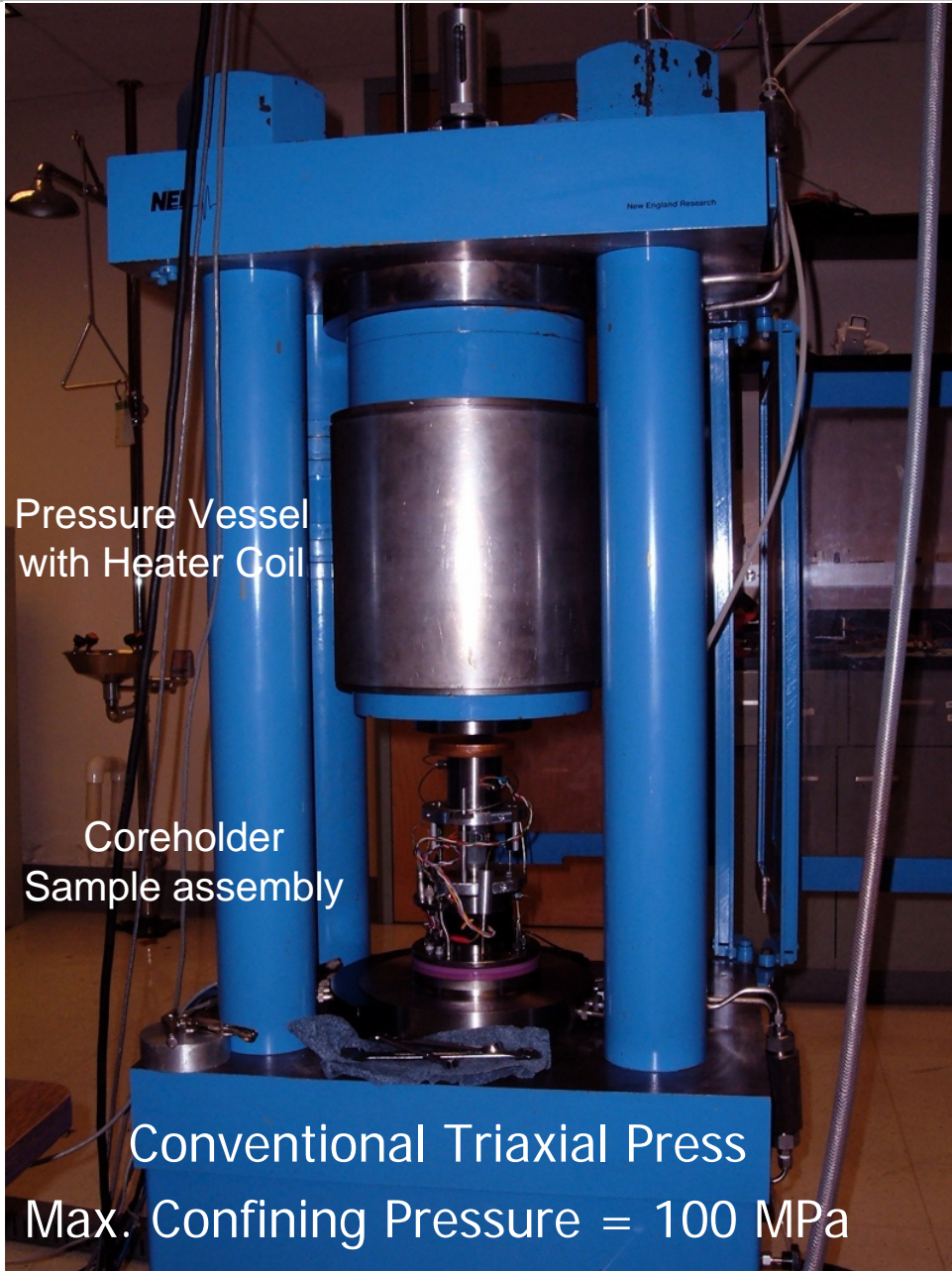
Axial and Radial Strain Gauges

Pore Pressure Outlet

Axial Load Cell



Experimental Goals



Pressure Vessel
with Heater Coil

Coreholder
Sample assembly

Conventional Triaxial Press

Max. Confining Pressure = 100 MPa

- Total Adsorption
- Static and Dynamic Elastic Moduli
- Gas Permeability
- Coal Swelling

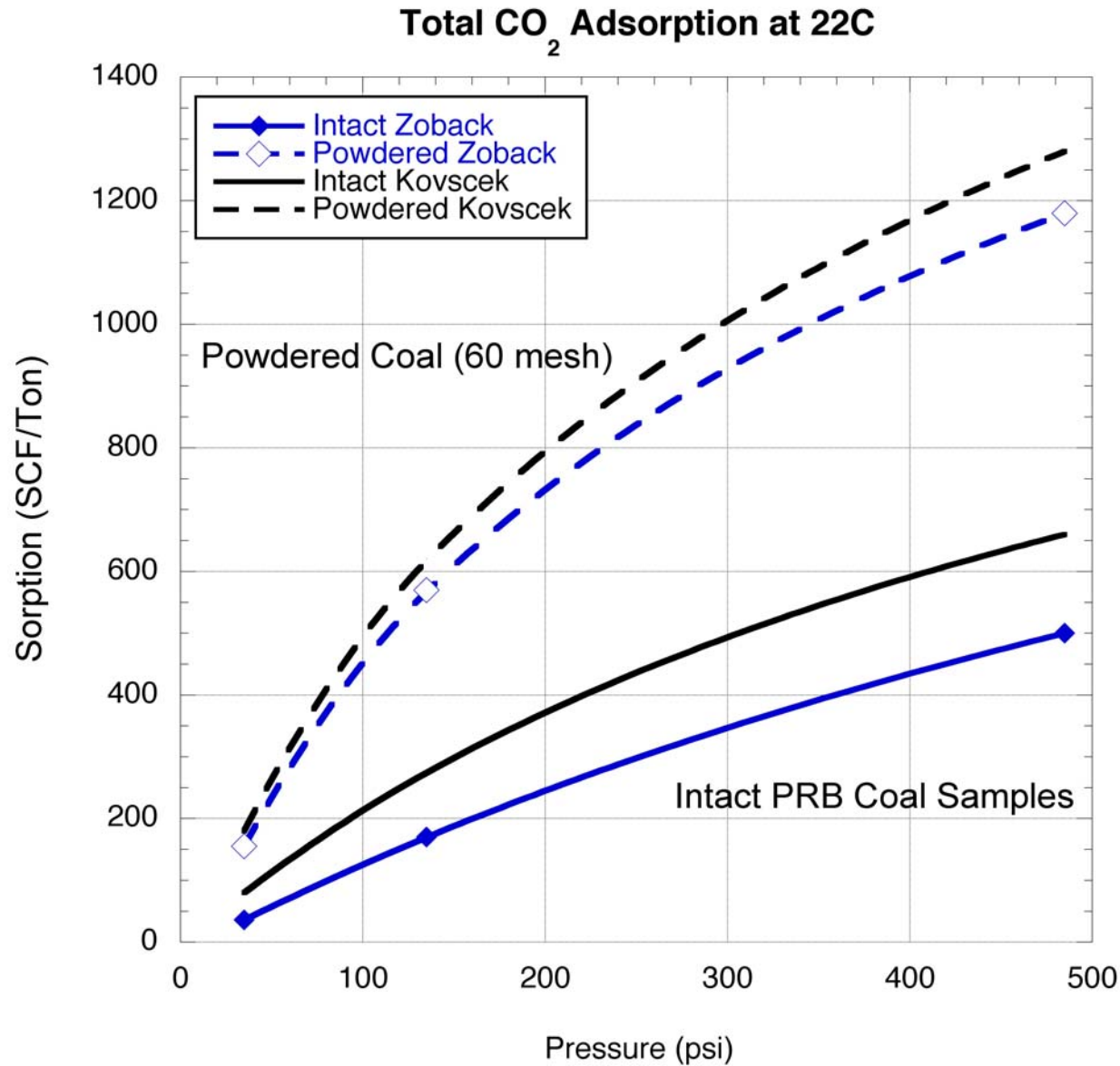
All properties measured as a function of effective stress and He/CO₂ saturation

All measurements are at 22°C

Both pore pressure and total stresses are varied



Adsorption Isotherms

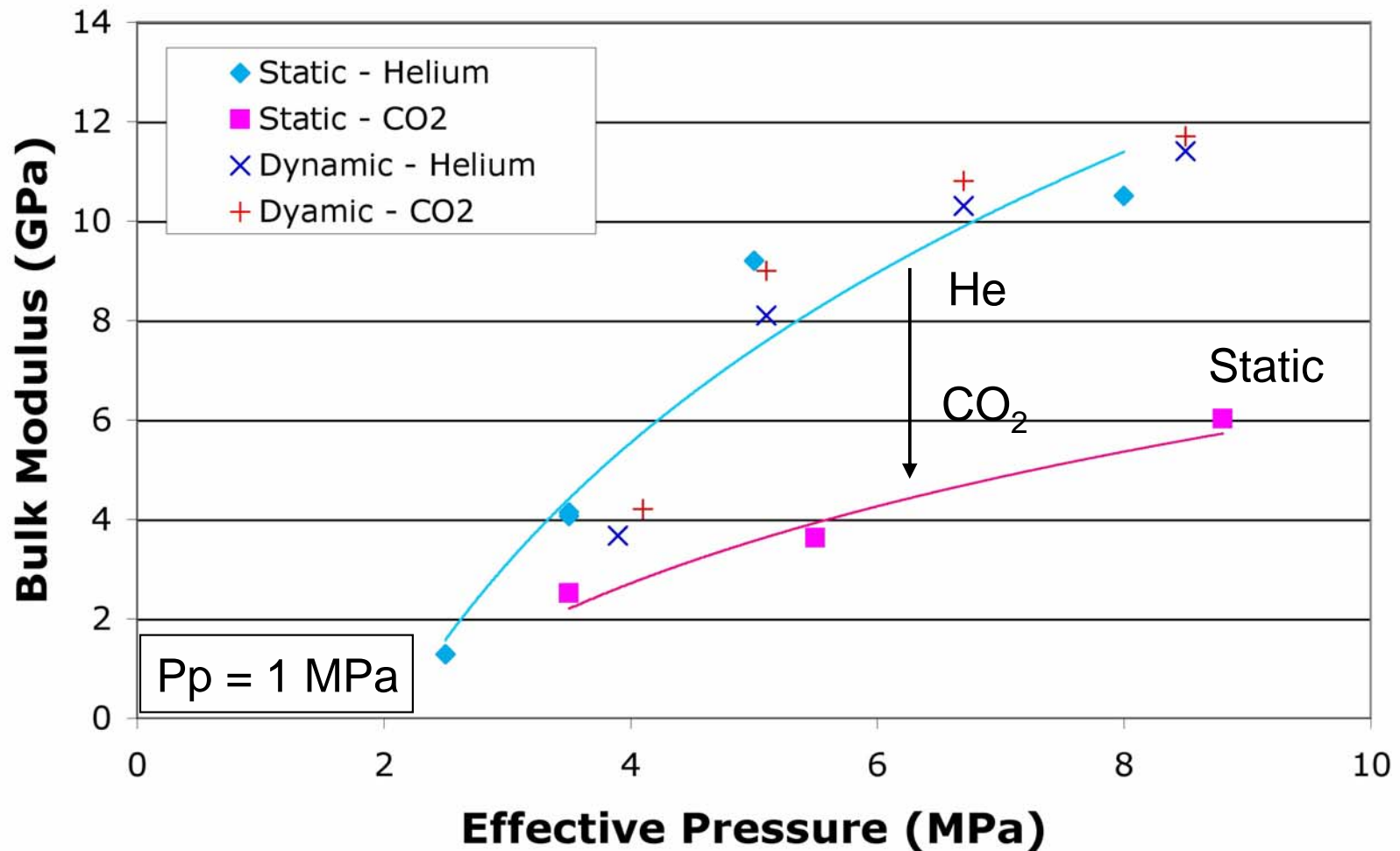




Bulk Modulus As A Function of Adsorption and Effective Stress

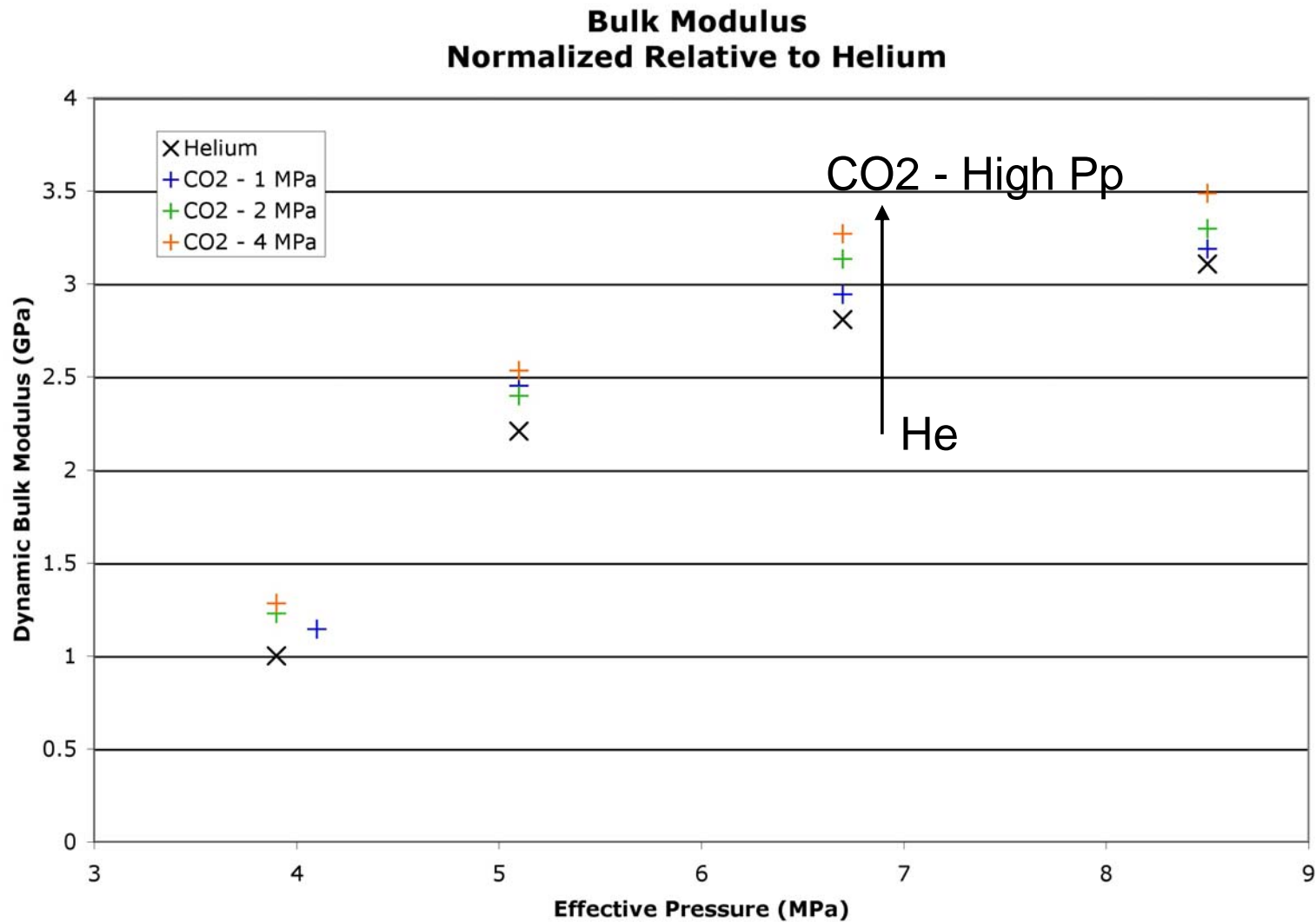


Static and Dynamic Bulk Modulus Intact PRB Coal Samples



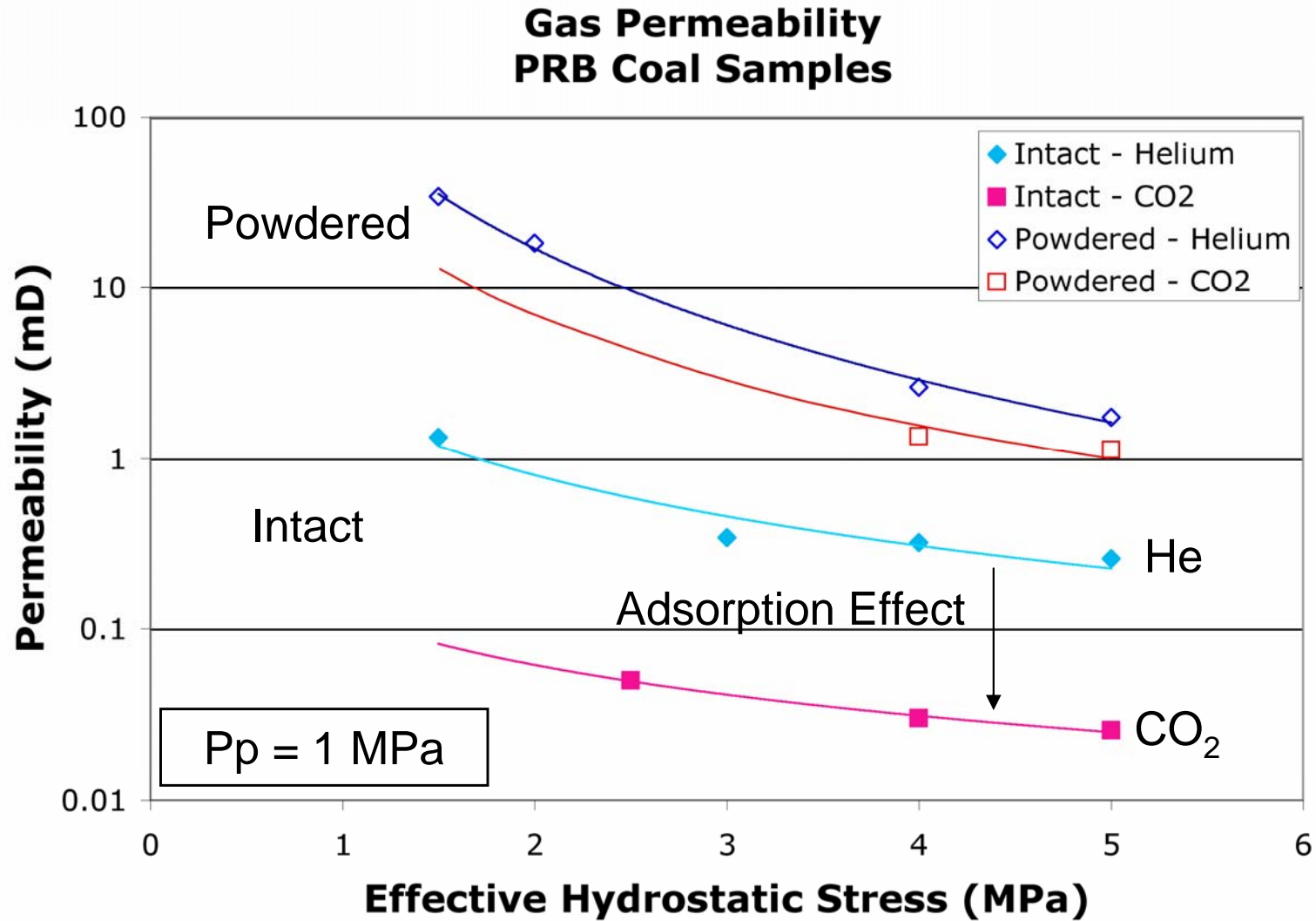


Dynamic Properties As A Function of Pore Pressure



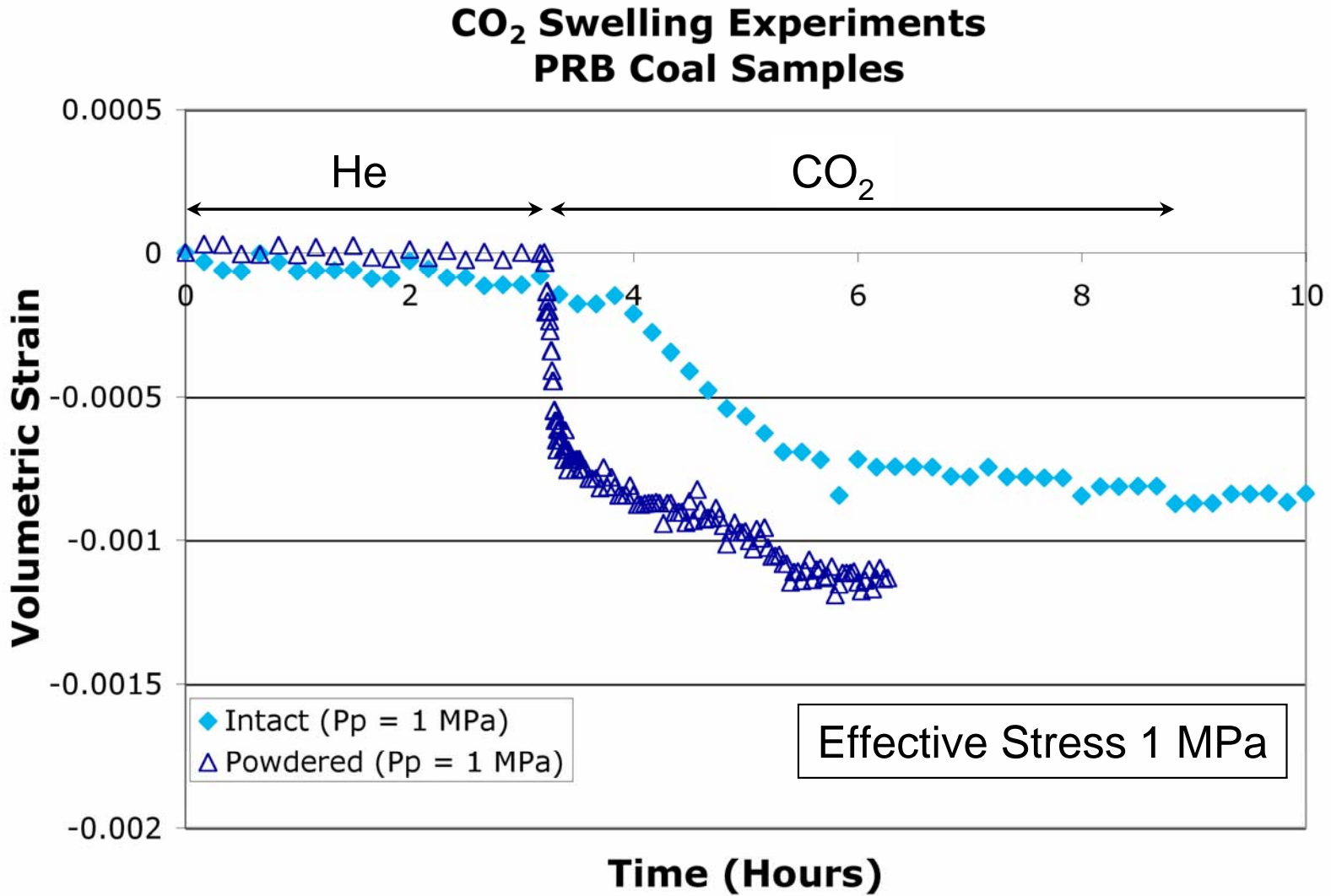


Permeability Decrease Due To Adsorption and Effective Stress





Coal Swelling Observations

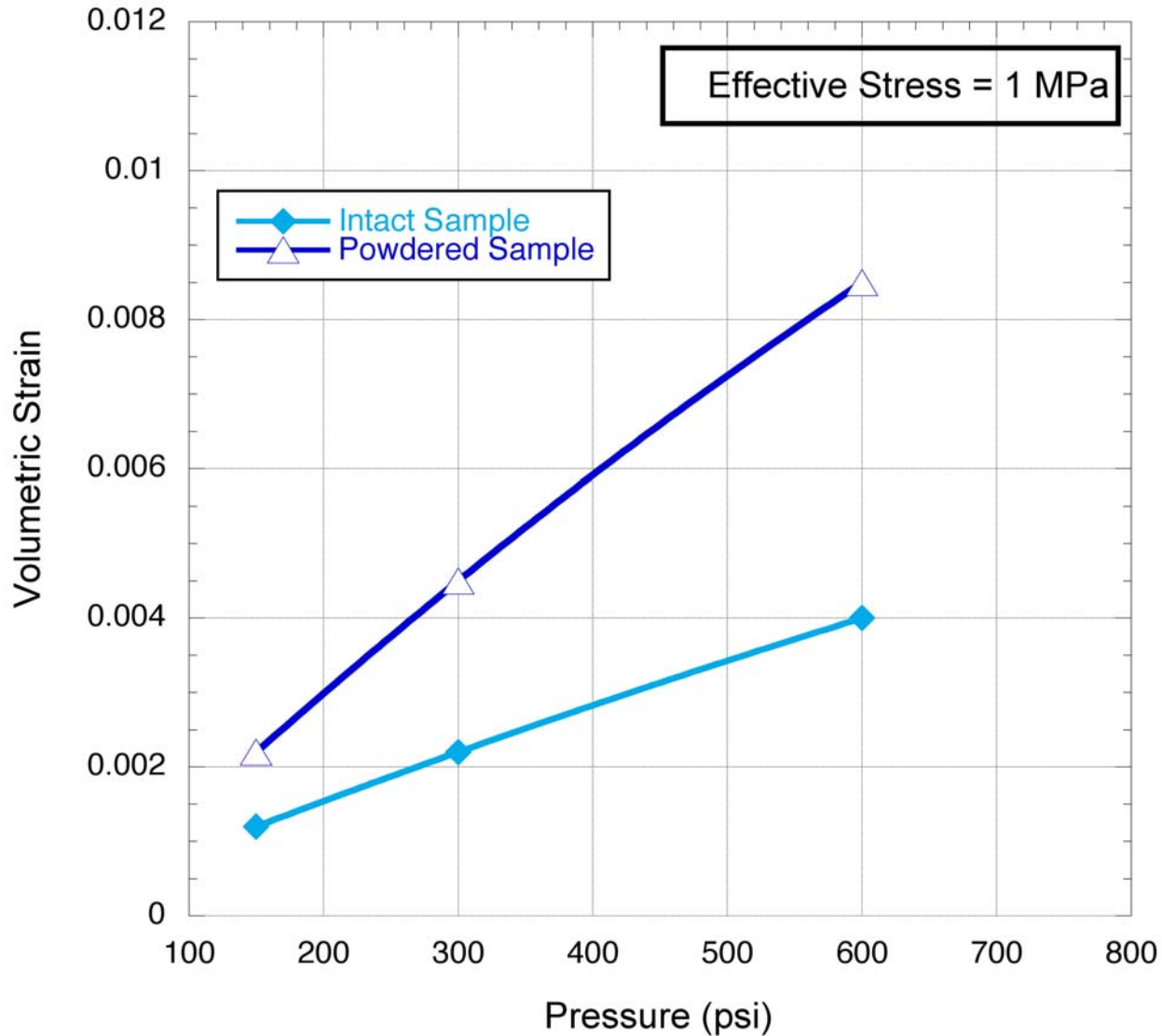




Coal Swelling As A Function of Pore Pressure



Volumetric Swelling Data
PRB Coal - CO₂





Summary of Observations



- Static Bulk Modulus *decreases* with adsorption of CO₂ at a given effective stress
- Dynamic Bulk Modulus *increases* with adsorption of CO₂ at a given effective stress
- Permeability decreases due to effective stress and adsorption of CO₂ are approximately the same magnitude



Future Plans



- Measurements at Higher Pore Pressure and Effective Stress
- Measurements as a function of Temperature (50 - 100 degrees C)
- Measurements for gas mixtures and as a function of water saturation



Acknowledgements



- The Global Climate & Energy Project (GCEP) for financial support (<http://gcep.stanford.edu>)
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- Apache for field data and core samples