MIT EARTH RESOURCES LABORATORY
ANNUAL FOUNDING MEMBERS MEETING 2018

Earth Resources Laboratory

Overview of the Earth Resources Laboratory

Laurent Demanet
DIRECTOR OF ERL, ASSOCIATE PROFESSOR, DEPARTMENTS OF MATHEMATICS AND EAPS

Before we start

LADIES: 1ST FLOOR

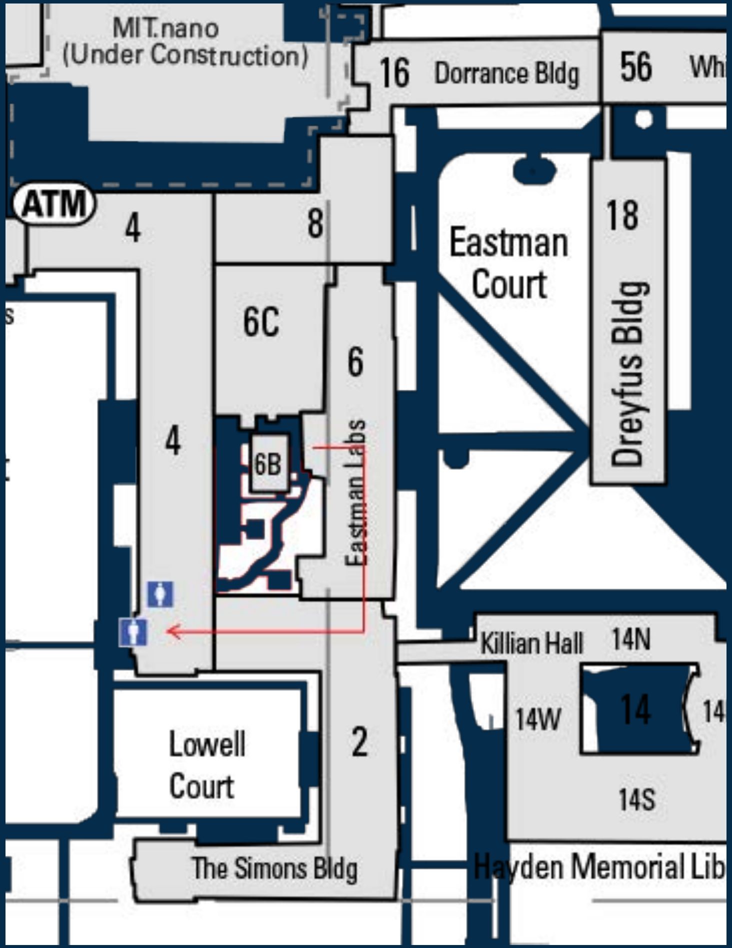
GENTLEMEN: 2ND FLOOR

EMERGENCY EXITS

MEMBER COMPANIES: USB KEY WITH

- 50+ PAPERS
- PRESENTATIONS
- QUAD CHARTS

ALSO ON WEBSITE (COMPANY PASSWORD)



Leadership

NAFI TOKSOZ (FOUNDER AND DIRECTOR 1982-1999)

SEISMOLOGY, BOREHOLE LOGGING, VSP, ROCK PHYSICS

JOHN GROTZINGER (DIRECTOR 1999-2004)

STRATIGRAPHY, GEOLOGY-GEOPHYSICS-GEOCHEM

ROB VAN DER HILST (DIRECTOR 2004-2012)

SEISMOLOGY, RESERVOIR SCIENCE

BRAD HAGER (DIRECTOR 2012-2018)

GEOMECHANICS, RESERVOIR MONITORING

LAURENT DEMANET (DIRECTOR 2018-)

IMAGING, INVERSION, LEARNING





Mission

- **RESEARCH AT THE CUTTING EDGE OF SUBSURFACE SCIENCE**
  - Broad and interdisciplinary
  - Fundamental and high risk/high reward
  - Applications to sponsor-specific problems

- **EDUCATE FUTURE LEADERS OF INDUSTRY AND ACADEMIA**

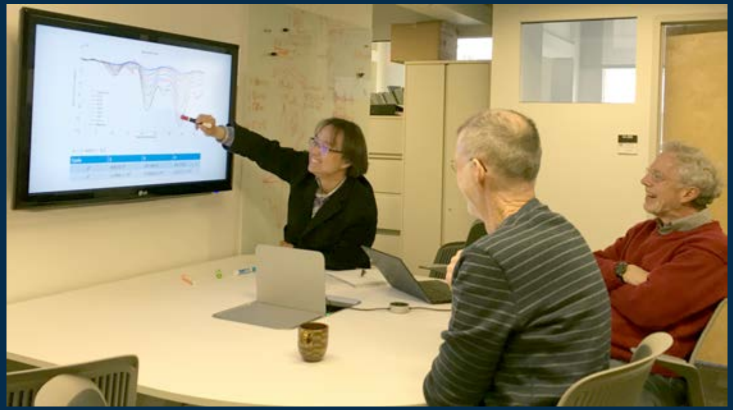
ERL Snapshot

- **INSTITUTIONAL HISTORY**
  - Celebrating 36th year with our 5th leadership transition
  - Over 150 graduates serving as leaders for industry and academia
  - Long track record of technical leadership across multiple disciplines

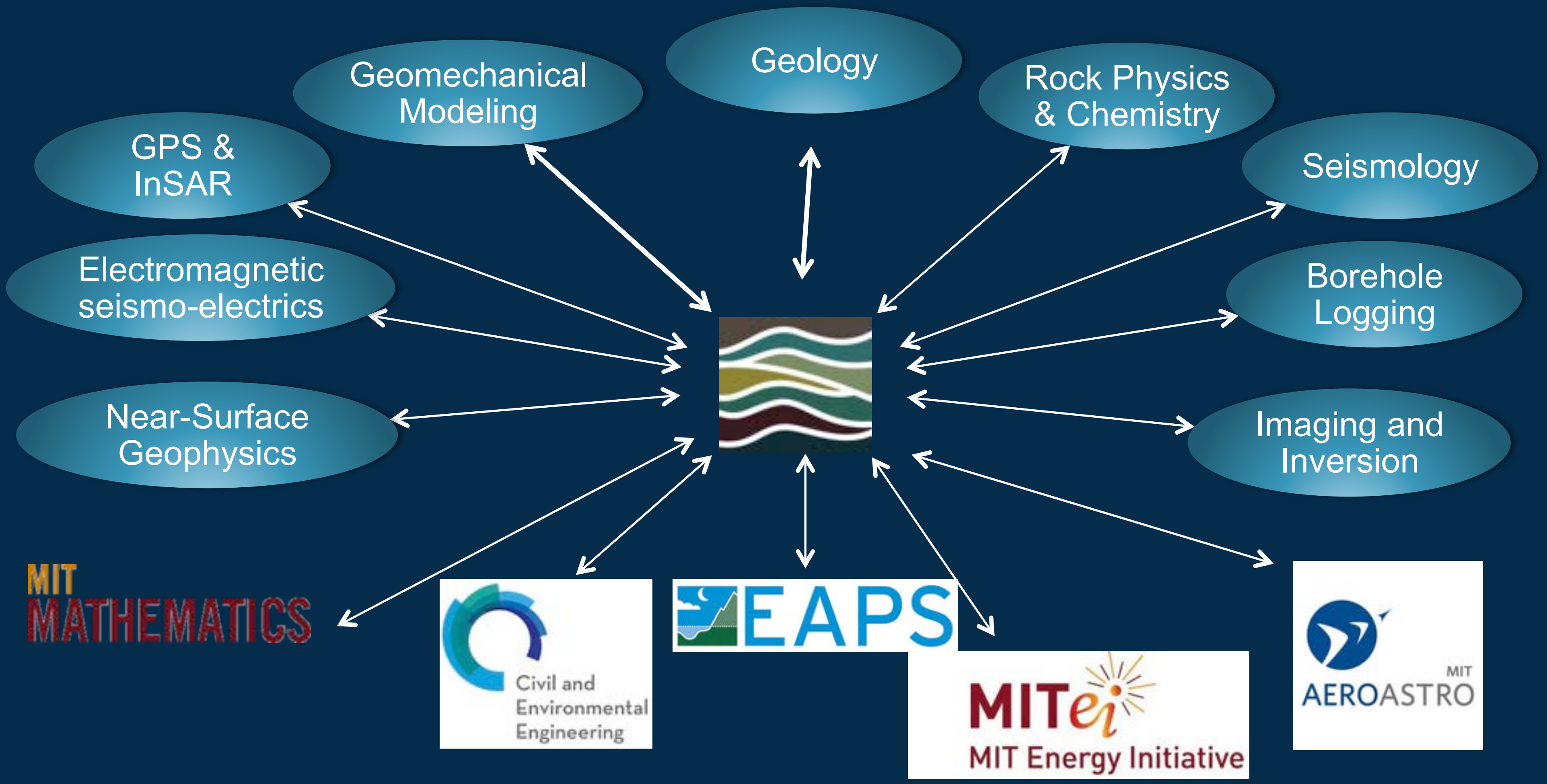
- **DEDICATED TEAM OF OVER 80 PEOPLE**
  - 13 Faculty, 13 Senior Research Staff, 2 Administrators
  - 34 Students and 12 Postdocs
  - 12 Affiliates and Visiting Scientists

Collaborations and Outreach

- DRAW EXPERTISE FROM ACROSS MIT - PROVIDES BREADTH OF KNOWLEDGE WHILE MAINTAINING DEPTH OF EXPERTISE
- ABILITY TO ASSEMBLE TEAMS OF EXPERTS FROM DIFFERENT DISCIPLINES TO SOLVE COMPLEX PROBLEMS
- ATTRACT BEST STUDENTS AND POSTDOCS FROM AROUND THE WORLD



A Culture of Crossing Borders



2018 Agenda Overview

SESSION TITLES

- GEOMECHANICS/INDUCED SEISMICITY
- INVERSION AND IMAGING
- STUDENT AND POSTDOC INTRODUCTIONS
- PLENARY SESSION: OUTLOOK FOR ERL
- GEOMECHANICS: FRACTURES AND FLOW I
- FLUID FLOW AND TIGHT OIL
- DEEP LEARNING IN SEISMOLOGY
- GEOMECHANICS: FRACTURES AND FLOW II

Overview

Thank you!

Going Forward:
The Outlook for ERL

Agenda

1 VISION

2 ERL FAQ

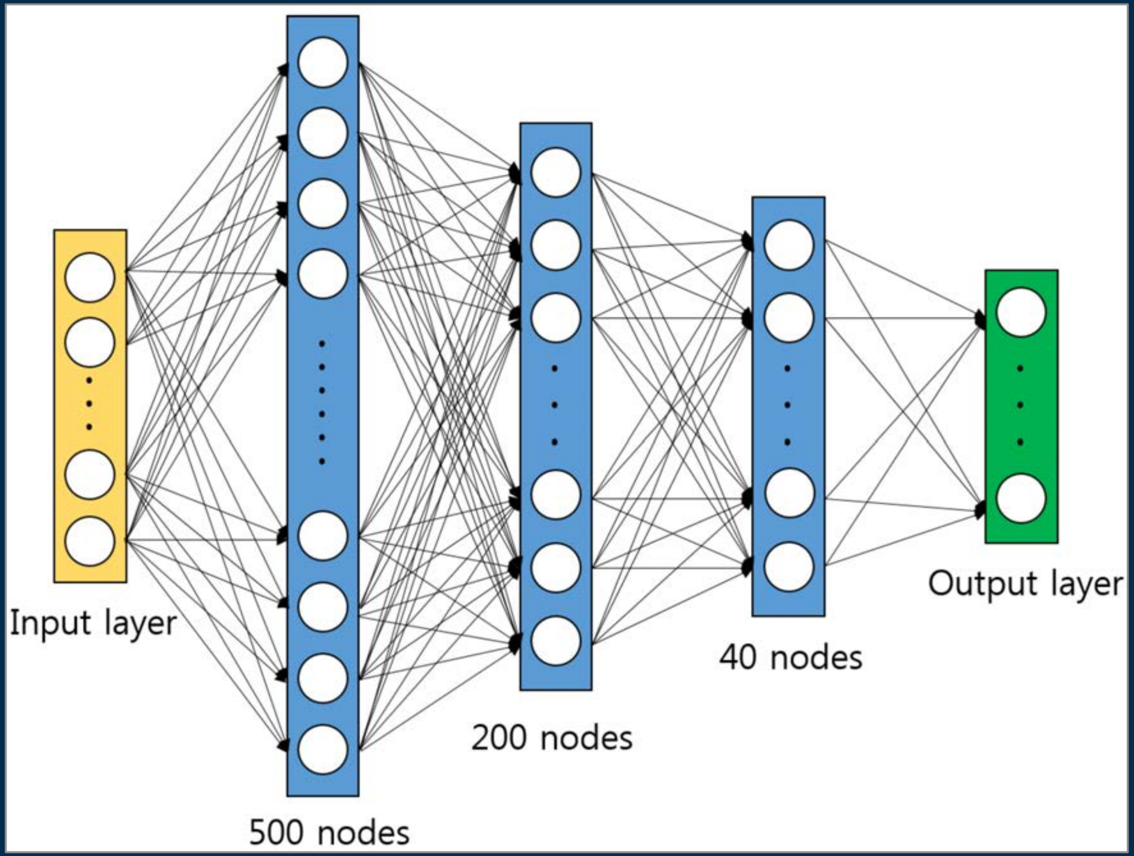
3 WHO + QUAD CHARTS

4 KEEP IN TOUCH

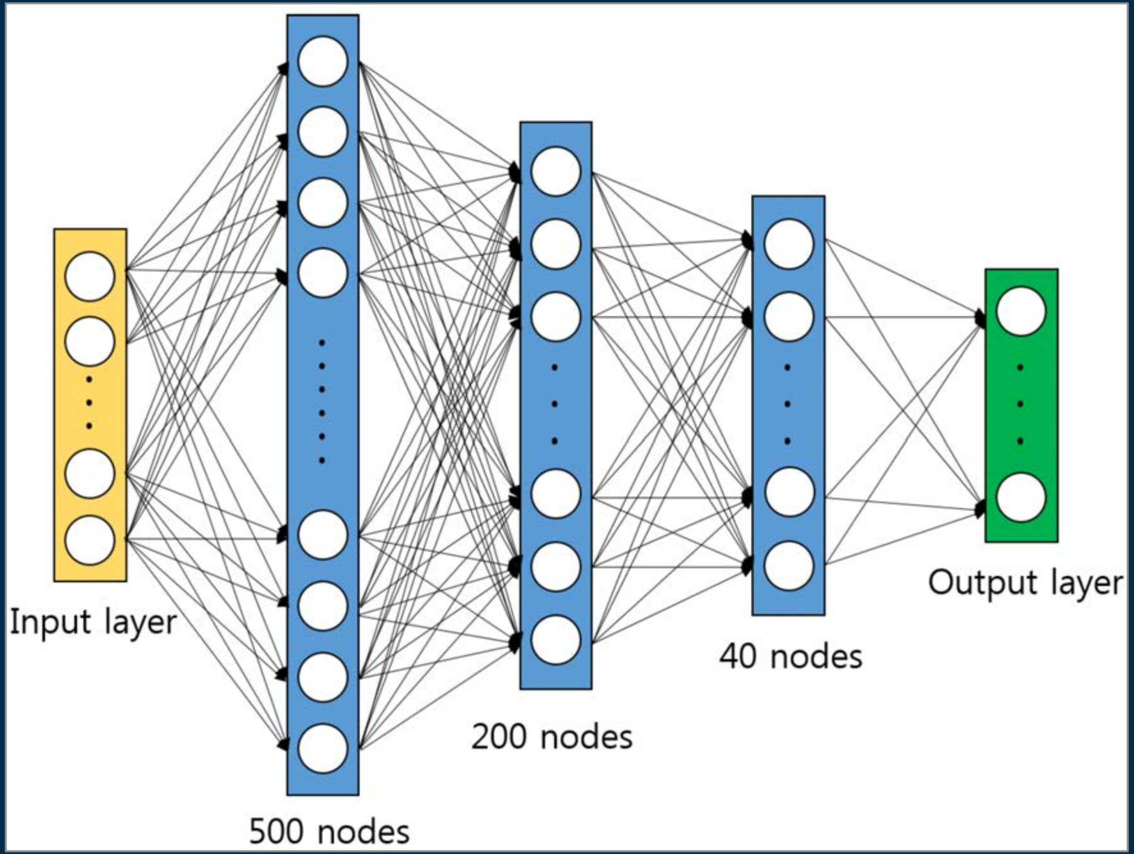
Agenda

1 VISION

Vision



Vision

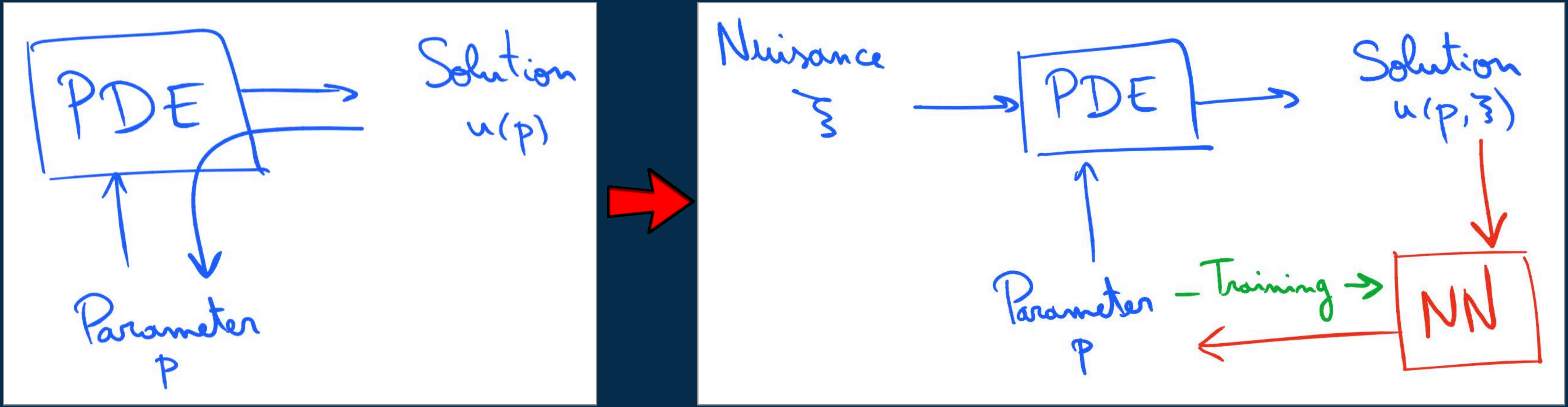


Statistical learning,
inference and inversion
for geophysics

- model-aware
- in all its sophistication
- when it makes sense

New classes of answers
fostering new kinds of questions

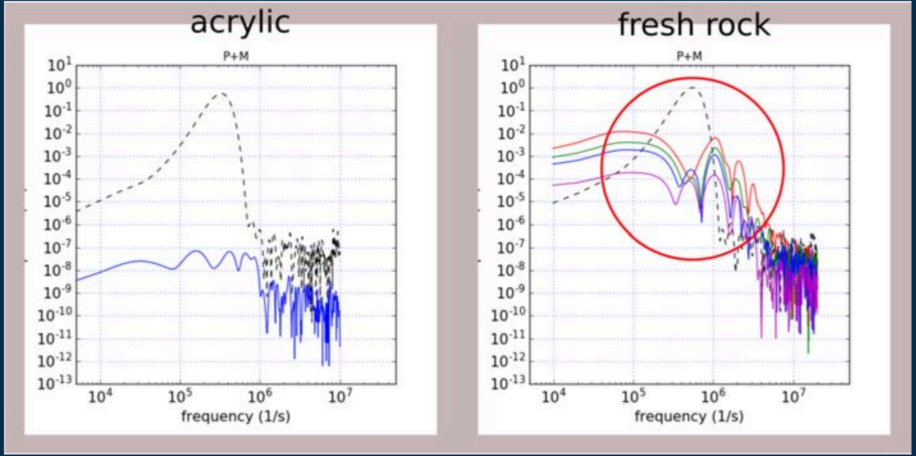
New kinds of inverse problems



Inverse problems: examples

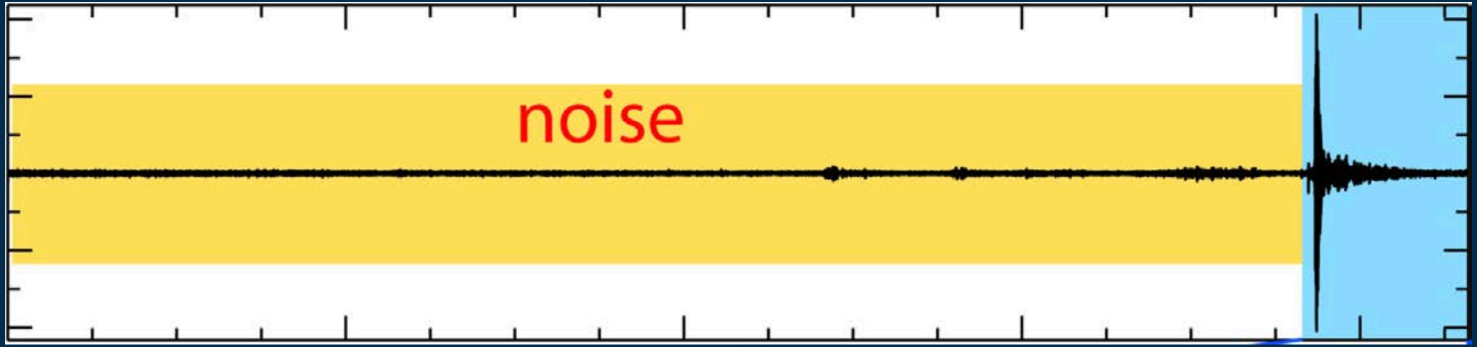
1. Determine nonlinearity vs attenuation in rocks

   Kinematic uncertainties



2. Information in ambient seismic noise

   Source uncertainties



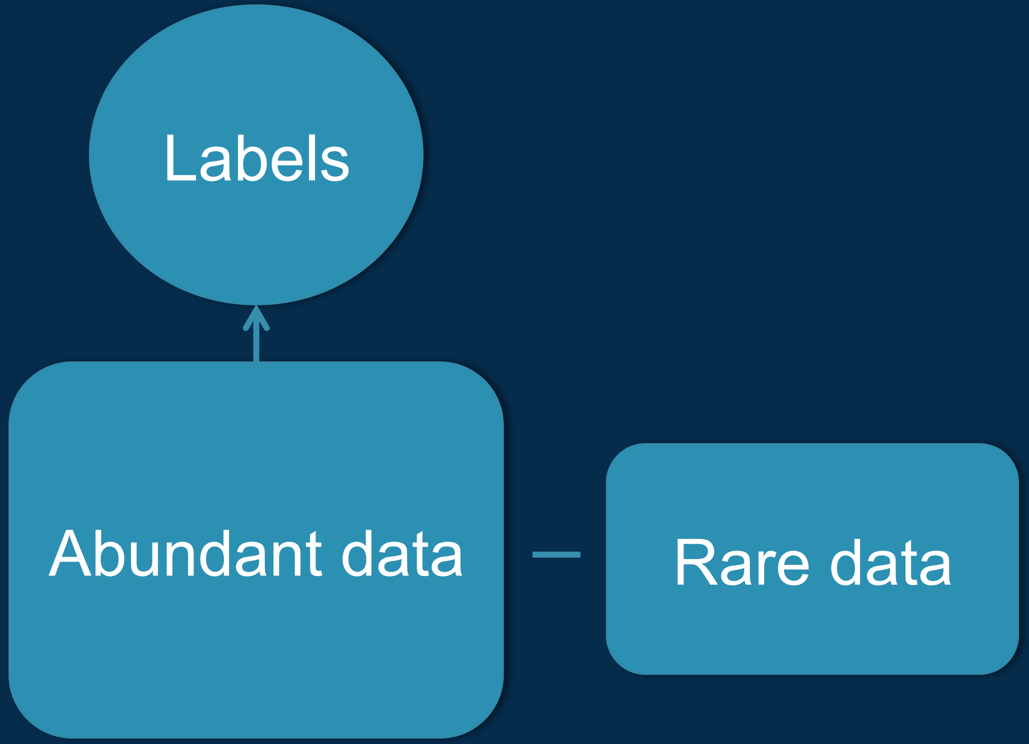
AI for heterogeneous data

Semi-supervised learning: infer labels for *out-of-sample* data

Ex 1: seismic interpretation with abundant, labeled simulations vs rare, unlabeled surveys

Ex 2: well log inversion from well-understood locations vs new location

Transfer learning for *generalizability*



Agenda

2 ERL FAQ

FAQ

At MIT, why ERL?

FAQ

At MIT, why ERL?

We care about geophysics

FAQ

At MIT, why ERL?

We care about geophysics

Is ERL collaborative?

FAQ

At MIT, why ERL?

We care about geophysics

Is ERL collaborative?

Yes

FAQ

At MIT, why ERL?

We care about geophysics

Is ERL collaborative?

Yes

But not as much as we could be

Agenda

3 WHO + QUAD CHARTS

Quad charts

Disclaimers:

- My rendering
- Teams assemble as needed
- Not exhaustive (people listed are those who submitted slides to me)
- On USB key, website

Rock physics, geomechanics

Brian Evans

Herbert Einstein

Brad Hager

Stephen Brown

Rock Mechanics Group – Civil and Environmental Engineering

Herbert Einstein, CEE

Motivation and Goals:

Rock Matrix and Fractures in the Energy Context

Hydrocarbon extraction and Engineered Geothermal Systems are affected by flow through the rock fractures and matrix
Maximizing flow requires complex intersecting fracture networks and high permeability matrix
Such networks require stimulation of existing fractures or creation of new ones
Matrix flow and dissolution affect porosity and permeability
Fracture flow is affected by characteristics of individual fractures, fracture networks and the stress field

Opportunity:

Creating new fractures usually done through hydraulic fracturing - **difficult to control**
Stimulating existing fractures usually done through hydroshearing- **difficult to control**
Both fracture processes are accompanied by seismic events

- Allow one to indirectly track fractures
- Produce **induced seismicity**

Effect of fracture characteristics and stress field on individual fracture flow is **not well understood**

Approach:

Controlled laboratory experiments:

• To completely understand hydrofracturing and hydroshearing, use unique combination of simultaneous visual and microseism observations

• To completely understand flow through matrix and individual fractures, use combination of visual observations and records of flow/concentration/transport

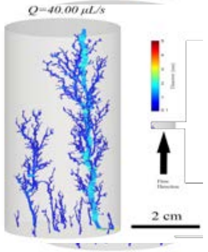
Develop models based on the experiments and calibrate them

Proposed Work:

Hydraulic fracturing and hydroshearing - simultaneous visual and Acoustic Emission observation

e flow tests –
neous stress and
e control and visual
o

Matrix core flood tests - observation of effluent concentration and visual observation of wormholes



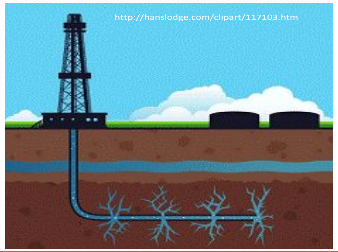
ALL leading to models

Visualising Hydraulic Fractures

Rock Mechanics Group – Civil and Environmental Engineering

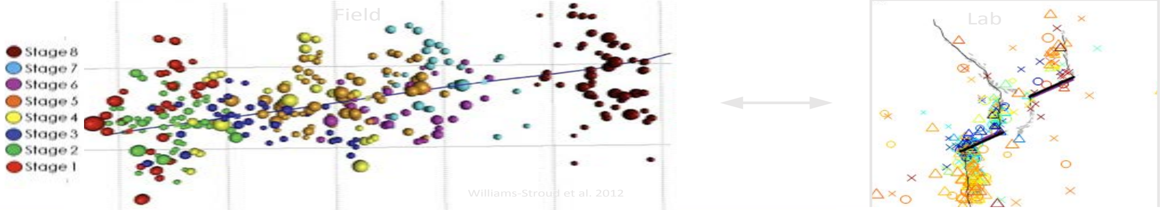
Motivation and Goals:

- Many new avenues to meet continuously increasing global energy demand, specifically unconventional hydrocarbon resources ($k < 0.1mD$):
  - Shale gas/oil
  - Tight gas/oil
- Resources require enhanced permeability of existing rock mass, commonly done through hydraulic fracturing



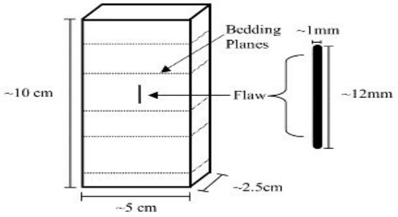
Opportunity:

- Field measurements of induced fracturing primarily determined by microseismic and pumping data (large errors)
- Lack of understanding of actual fracture behavior
- Goal to observe hydraulic fracturing directly (visual) and with indirect (microseismic) methods
  - Relate lab observations (visual+AE) to field measurements (AE only)



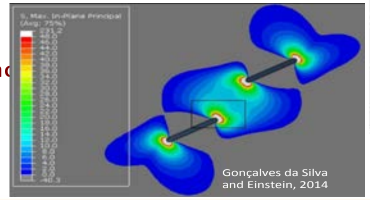
Approach:

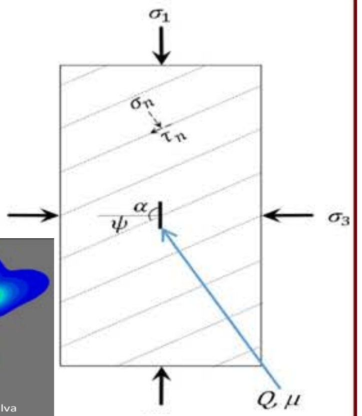
- Laboratory hydraulic fracture setup:
  - Up to 10 MPa (1500 psi) fluid pressure, 900 kN (200 000 lbf) biaxial loads
- Opalinus Shale prismatic specimens (1" x 2" x 4") with pre-existing artificial flaws
- <u>High-resolution</u> and <u>high-speed</u> imaging
  - Qualitative and quantitative processing methods
- <u>Acoustic emissions</u> data acquisition



Proposed Work:

- Laboratory experiments with following control variables:
  - Bedding plane inclination
  - Flaw geometry
  - Fluid injection rate and schedule
  - Injected fluid viscosity
  - External stress conditions (Both isotropic and deviatoric)
- Experimental results used to:
  - understand fundamental frac mechanisms
  - develop and validate models



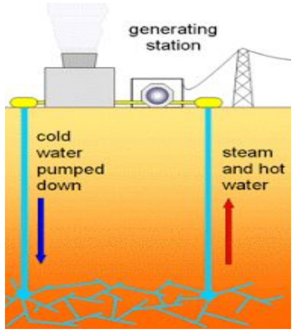


Hydraulic Fracturing for Enhanced Geothermal Systems

Rock Mechanics Group – Civil and Environmental Engineering

Motivation and Goals:

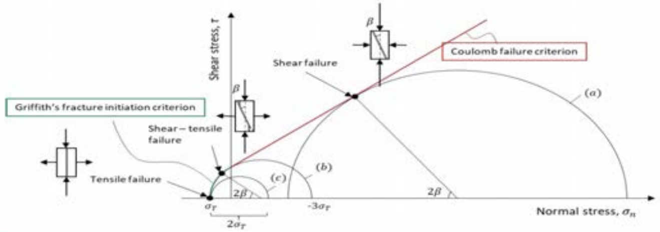
- Enhanced Geothermal Systems (EGS) constitute a large renewable energy source for electricity production
- Hydraulic stimulation in deep dry rock to reactivate existing fractures by injecting pressurized water
- A better understanding on how to avoid fault reactivation leading to induced seismicity is required



http://climatereach.blogspot.com/

Opportunity:

- Understand how shear fractures reach the Mohr failure envelope through hydraulic pressurization (hydroshearing)
- Understand the link between hydroshearing and induced seismicity
- Effect of hydroshearing on fracture permeability
- Fluid penetration into the porous matrix of the rock may affect stimulation

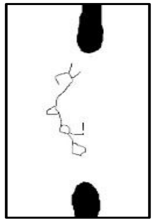


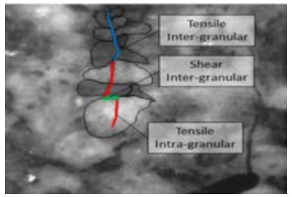
Approach:

- Lab experiments in which hydroshearing is investigated
- Experiments on prismatic specimens of granite containing two pre-cut flaws with different geometries under a uniaxial or biaxial external load
- Use experiments in which the fracturing and fluid penetration can be visually (high-speed imagery) observed while simultaneously recording microseisms (AE)
- Using the same equipment as for shale hydrofracturing

Proposed Work:

- Interaction between hydraulic fractures and pre-existing, non-pressurized flaws
- Observation of the seismic response of shear crack locations through acoustic emissions
- Identify shearing for different flaw geometries and loading conditions
- Investigation of the evolution of the seepage zone of the fluid into a porous matrix and its effect on the breakdown pressure
- Validate the numerical models with the experimental results



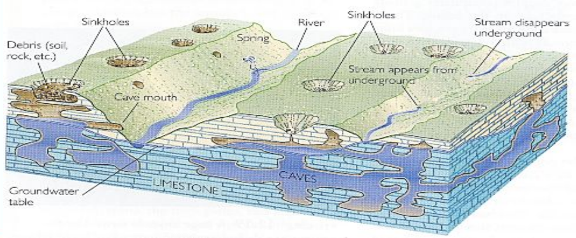


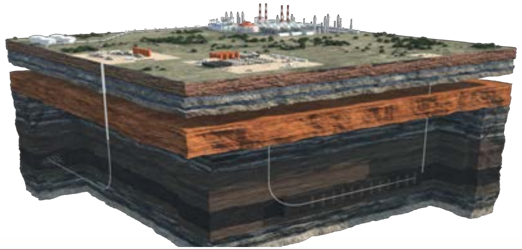
Rock Matrix Dissolution and Wormhole Formation

Rock Mechanics Group – Civil and Environmental Engineering

Motivation and Goals:

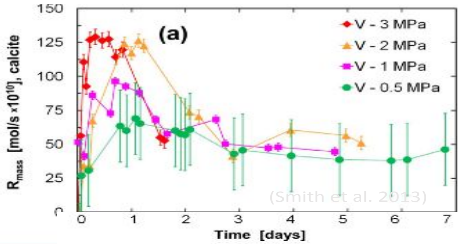
- The dissolution of rock matrix and formation of wormholes are:
  - hazardous processes causing sinkholes, ground subsidence and CO_2 reservoir leakage.
  - favorable processes increasing the hydrocarbon reservoir permeability, hence production.

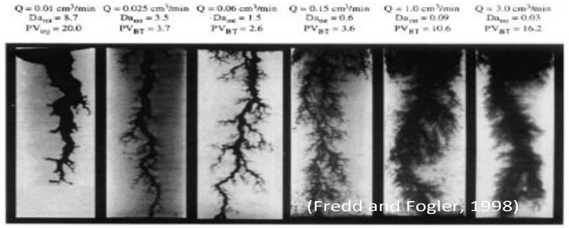




Opportunity:

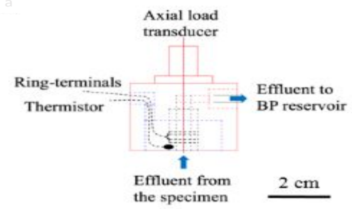
- Core flood tests were often used in experimental studies, but they had limitations:
  - Effluent concentration data were limited.
  - Wormhole geometry description based on CT scan was only qualitative.
- Few existing models simulate the dissolution kinetics when wormhole develops.





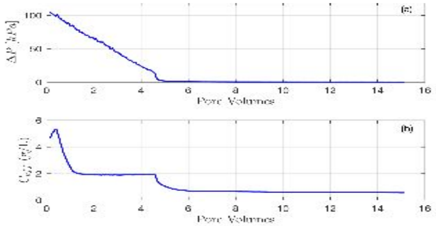
Approach:

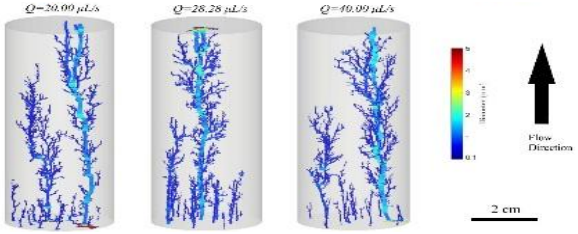
- An effluent chemistry monitoring system was developed to provide continuous concentration measurement during core flood tests.
- Quantitative analysis of the CT scan data pre- and post-test.
- Analytical and numerical models to simulate the wormhole formation in the rock-fluid system.



Proposed Work:

- Gypsum-water core flood tests to study:
  - effect of different flow rates and durations;
  - as analog system for acid-stimulation given the similar dissolution kinetics
  - effect of fractures in the specimen.
- A pipe network model to simulate the dissolution in the matrix and wormholes.



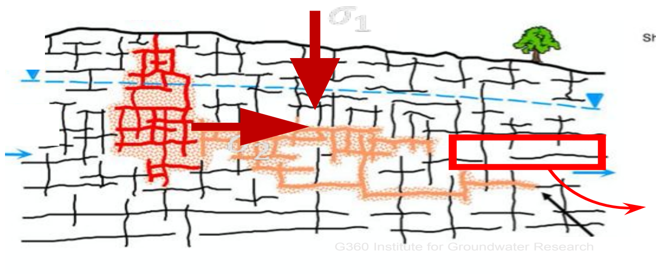


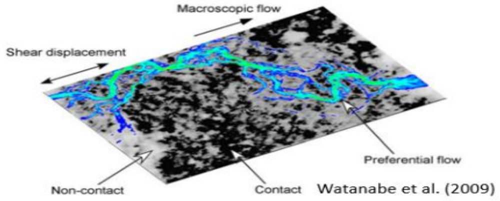
Flow Through Rough-Wall Fractures

Rock Mechanics Group – Civil and Environmental Engineering

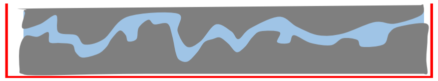
Motivation and Goals:

- Fracture flow is affected by characteristics of the fracture networks, individual fractures and the stress field, as well as fluid properties





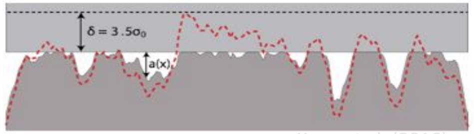
Watanabe et al. (2009)



Opportunity:

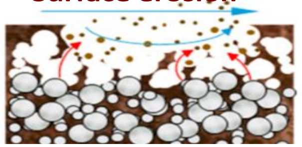
- Fracture permeability and transport depend on a series of coupled processes that are not well understood, e.g.
    - Mechanical deformation (elastic, plastic, asperities crushing)
    - Dissolution/deposition
    - Erosion
    - Non-linear flow

Mechanical deformation



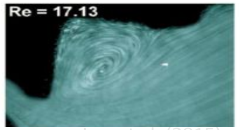
Kang et al. (2016)

Surface erosion



Deng et al. (2015)

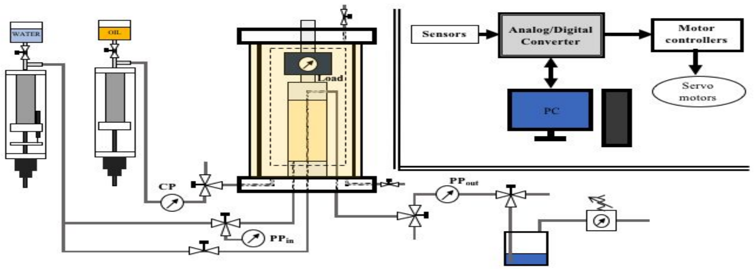
Non-linear flow



Lee et al. (2015)

Approach:

- To completely understand flow through individual fractures, we use a combination of visual (during or after the test) observations and flow/concentration/transport records

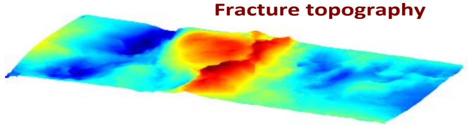


Fractured Musandam core

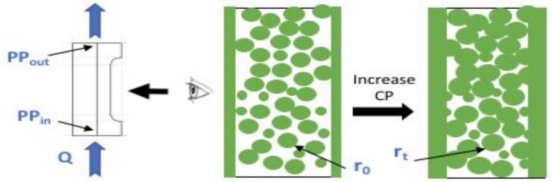
Proposed Work:

- Laboratory experiments with following control variables:
    - Rock materials
    - Fluid pressures and chemistry
    - Fracture geometry and deformation
    - External stresses (isotropic and anisotropic)
- Experimental results are used to validate current models and to develop new ones.

Fracture topography



Visual Measurements



Property changes in reservoir rocks

Y. Bernabe, B. Evans, and U. Mok; Dept. Earth, Atmos., & Planet. Sci.

Motivation and Goals:

- Monitoring and managing reservoirs require input from rock physics and mechanics
- Relate remote geophysics data to "local" variables, e.g., permeability and fluid props.
- Provide constitutive models for mechanical reservoir analyses of reservoir performance

$$\dot{\phi}_m = \Phi\left(\dot{\varepsilon}_v, \sigma_{kl}, T, P_{fluid}, a_p, \phi_r, \ldots\right)$$

State Variable Evolution

$$\dot{k} = \left(\frac{\partial k}{\partial \phi_r}\right) \cdot \dot{\phi}_r$$

Evolution of k

$$k = \mathbf{k}\left(\phi_m, \ldots\right),$$

Relation of k and ϕ

$$Q = -\frac{k}{\eta} \nabla P_{fluid}$$

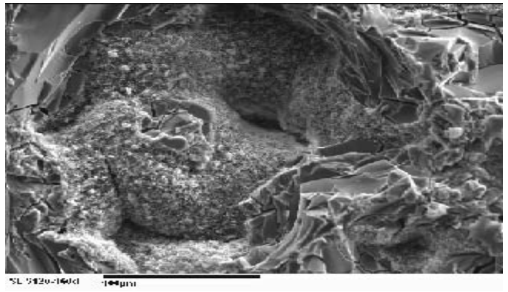
$$\nabla^2 P - \frac{\beta_c \eta}{k} \frac{\partial P}{\partial t} = 0$$

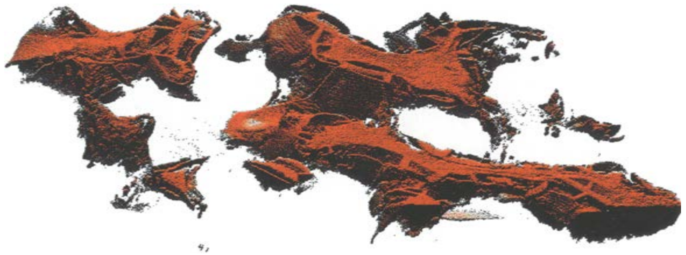
Conservation + Const. Law

Permeability is a dynamic property

Opportunity:

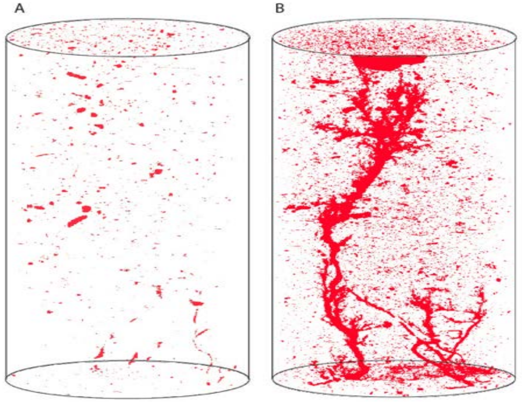
- Improve monitoring of reservoir changes during sequestration
- Investigate possibility to utilize mineral formation to create reservoir seals
- Provide improved insight into pore-scale processes in formations under reservoir conditions





Approach:

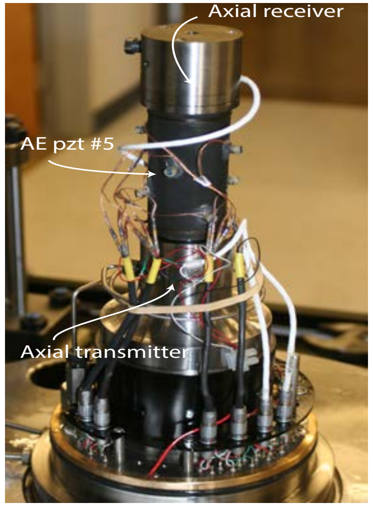
- Measure permeability, acoustic velocity, "static" elastic properties simultaneously at reservoir press. and temp.
- Independent control of pore-fluid composition and pressure during injection
- Characterize pore and mineral microstructure using optical, scanning and transmission electron microscopy, and CT scanning



Wormhole formation in carbonate during core flood with H_2O +CO_2

Proposed Work:

- Correlate changes in pore microstructure and physical properties during core flood tests
- Develop kinetic laws for permeability changes during injection of fluids that are in equilibrium, under-, or over-saturated with respect to rock minerals
- Relate permeability, elastic modulii to acoustic velocities at *in-situ* conditions

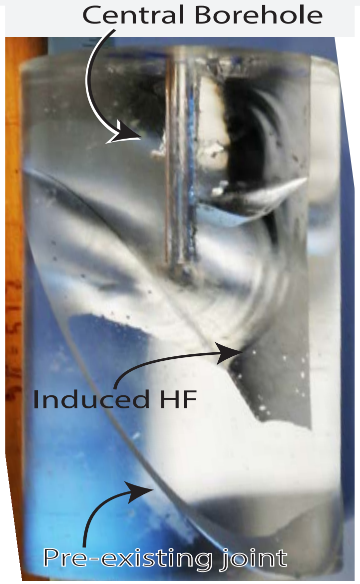


Improved prediction of HydroFracture/NaturalJoint Interactions

B. Hager, S. Mighani, M. Peč, & B. Evans; Dept. Earth, Atmos., & Planet. Sci.

HF/NJ Interactions

- Impact reservoir management
- Activate natural joints
- Affect hydrofracture geometry & reach
- Alter joint transmissivity
- Stimulate micro-seismicity

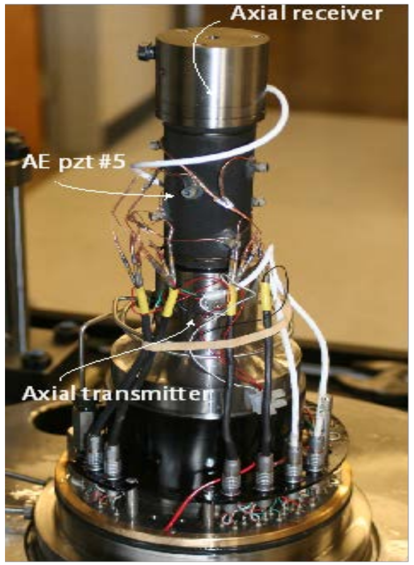


Current experiments:

- Laboratory simulations of HF/NJ interactions
- PMMA, Solnhofen limestone, shale (38 mm x 76 mm)
- Extending the criteria for HF/NJ interactions
- Measure load, load-point displacement & pore-fluid pressure (5 kHz), acoustic emissions (5 MHz)

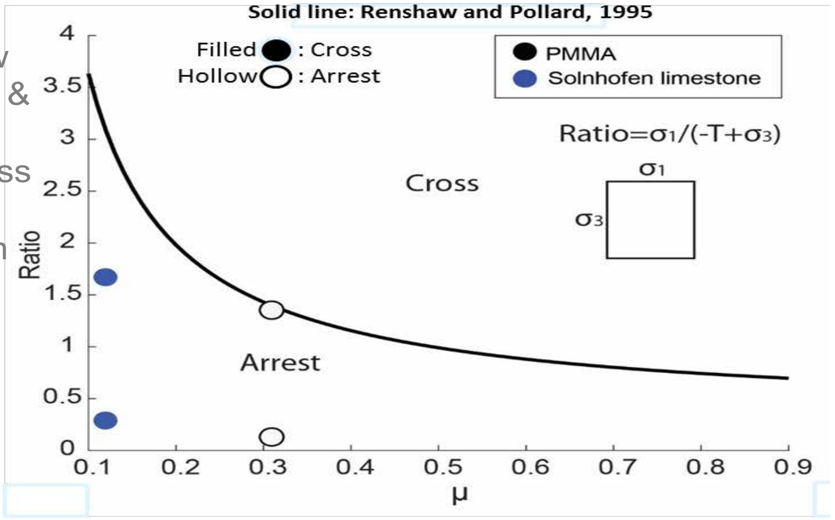
Mighani, S. et al. (2018), *52nd US Rock Mechanics/ Geomechanics Symposium*, ARMA paper 18-0901, Seattle, WA.

Mighan et al. (2018) *SPE Hydraulic Fracturing Technology Conference and Exhibition*, Society of Petroleum Engineers, doi:10.2118/189901-MS.



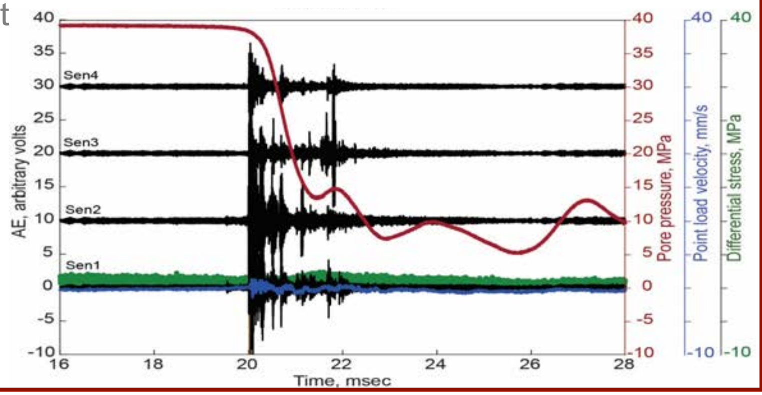
Crossing/arrest criteria:

- Mechanical analyses not including fluid flow don't predict crossing & arrest
- Varying joint roughness from P1200 to #80 increases $\mu_{friction}$ from 0.15 to 0.80, but also increases transmissivity by 2.5 orders of mag.



Proposed Work:

- Independently control loading, pore-fluid pressure, and pumping rate. Concurrent AE recording.
- Analyze influence of joint properties, including, $\mu_{friction}$, joint stiffness, & orientation, with fluid transport
- Predict HF/NJ interactions, including cross/arrest criteria
- Investigate coupling of fluid transport with fault motion & AE generation



Change Detection and Monitoring with Nonlinear Acoustics

S. Brown and D. Burns - MIT/ERL

Motivation and Goals

Move from conventional imaging

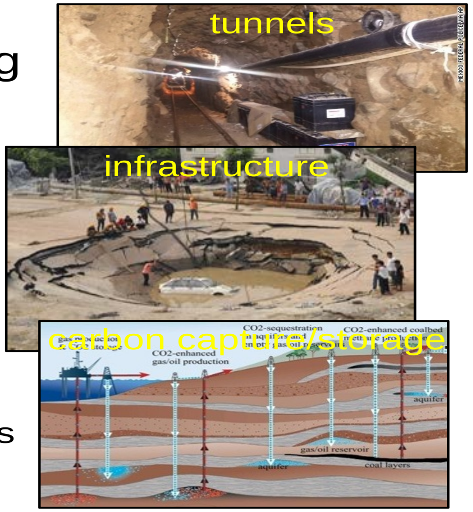
- Heterogeneous properties
- Signal and 'noise'
- Uncertainty

To a medical imaging analogy

- Perturb ('palpate') the system to highlight the property of interest (e.g. rigidity)
- Image the perturbation

With the advantages of

- Heterogeneities become buried sensors
- Up-close imaging of a zone of interest
- Image mechanical response directly



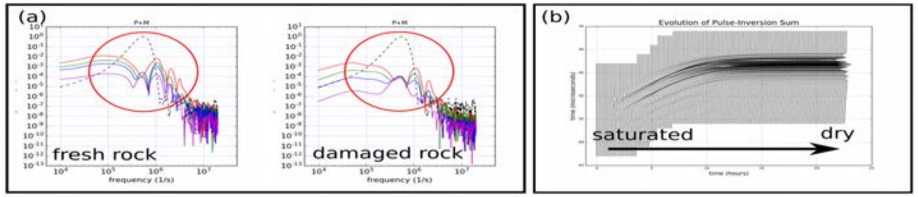
Opportunity

We find in laboratory experiments on rocks

High sensitivity to subtle changes in pore structure due to microcrack damage and to changes in pore fluids including partial saturation

We see an opportunity to develop new change detection and monitoring techniques in the Earth

monitoring damage and fluids



Approach

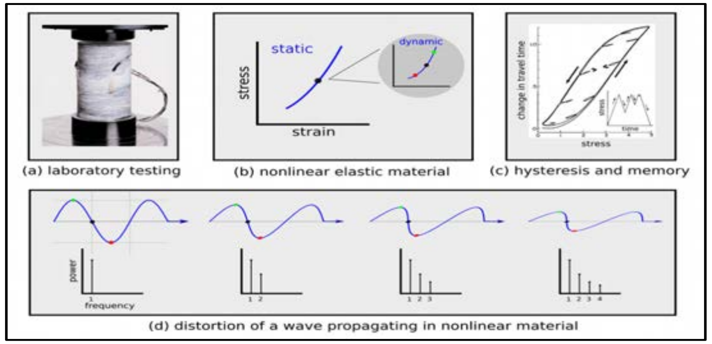
When a wave propagates through a nonlinear material

- Its shape distorts
- Higher harmonics are generated

As observed in the

- **Time domain** - dual wave with active perturbation (pump & probe)
- **Frequency domain** - single wave distortion (harmonic imaging)

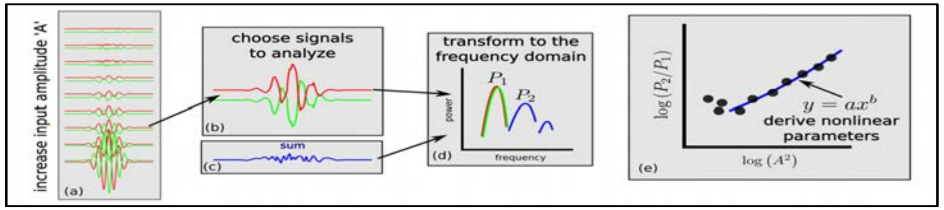
wave distortion in nonlinear media



Proposed Work

- **Practical** - develop robust single and dual wave measurement methods for the laboratory and the field
- **Quantitative** - perform experiments to elucidate the underlying physics leading to quantitative interpretation

design of quantitative methods



Inversion, UQ, learning

Youssef Marzouk

Sai Ravela

Michael Fehler

John Williams

Uncertainty quantification of parameters of interest

Michael Fehler, Oleg V. Poliannikov, William Rodi – Earth Resources Laboratory

Motivation and Goals:

- Many geophysical inverse problems involve very large parameter spaces (e.g., 3D velocity/resistivity models considered separately or jointly)
- Often there are relatively few parameters of interest (POI) (e.g., fracture length/height, reservoir volume)
- Or maybe there are just a few yes-no questions of interest (QOI)
- Can we bypass a full Bayesian solution of the *large* inverse problem to infer the *lower-dimensional* POI (or QOI) directly and quantify their uncertainty?

Approaches:

- Likelihood-informed parameter spaces (LIPS)
- Hypothesis testing (Bayesian or non-Bayesian)
- Profile likelihoods are alternatives to classical likelihoods that offer significant computational advantages (maximization is faster than integration)

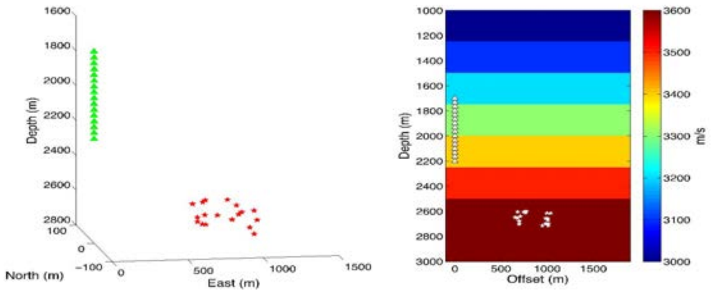
$$L(d|p) = \max_{p=G(m)} L(d|m)$$

Problem setup:

- **Given:** forward model $d = F(m) + n$
  - d – data, m – model, n – noise, p – POI
  - Probabilistically: likelihood $L(d|m)$ and prior $f(m)$
  - $p = G(m)$, where
  - $|p| \ll |m|$
  - G – parameter extractor (projection or general function)
- ***Problem:***
  - Calculate $f(p|d)$ without computing full $f(m|d)$
  - Save calculation costs
  - Allow real-time applications

Example:

- We use microseismic monitoring as an illustration
- Other applications: local area imaging, joint inversion,…
- In situ stress parameters from microseismic data
- Fracture height
- Stress principal directions (or fracture height) are the POI
- Earthquake locations, moment tensors, velocity model are nuisance parameters

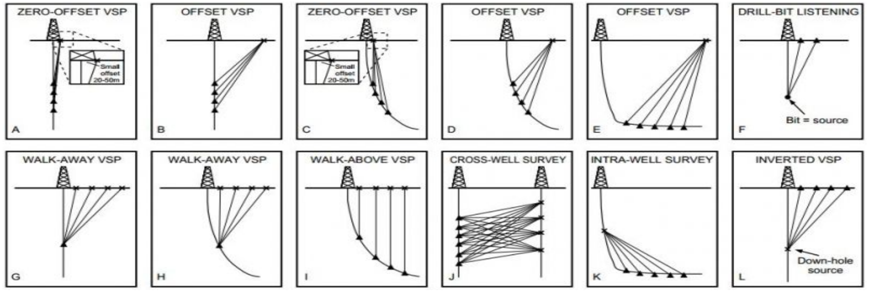


Modeling scattering and intrinsic attenuation

Michael Fehler, Oleg V. Poliannikov, Josimar Alves da Silva – Earth Resources Laboratory

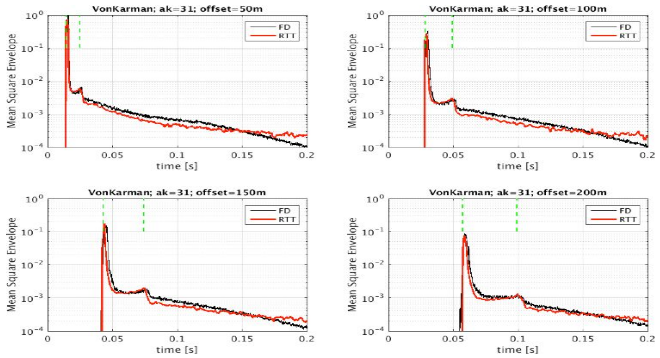
Motivation and Goals:

- Medium heterogeneities give rise to scattered waves
- Intrinsic and scattering attenuations taper and redistribute energy throughout seismogram
- Fractures are strong scatterers so spatial and temporal variation in this scattering may provide information about variations in fractures



Opportunity:

- Extremely fast forward modeling (orders of magnitude faster than finite differences)
- Good fit between modeled envelopes and numerical models
- Possibility to invert using brute force or smarter approaches

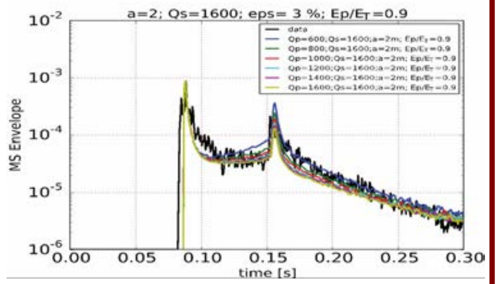


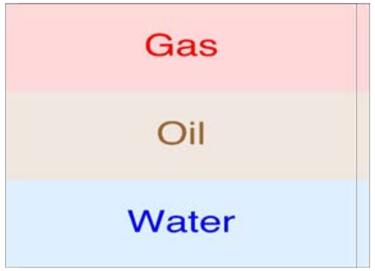
Approach:

- Model trace envelopes recorded in a scattering medium using a Radiative Transfer Theory and a Particle Method
- Achieve orders of magnitude improvement in the computational cost of forward modeling
- Perform deterministic or probabilistic inversion with uncertainty quantification of intrinsic and scattering attenuation from observed envelopes by matching observed envelopes to modeled ones
- Relate inverted parameters to reservoir properties through rock-physical models
- Josimar A. da Silva Jr. et al (2018). "Modeling scattering and intrinsic attenuation of crosswell seismic data in the Michigan Basin." GEOPHYSICS, 83(3), WC15-WC27

Proposed Work:

- Extend the existing cluster-ready numerical code to include layered 3D media with homogeneous or gradient layers
- Implement statistical inversion with Bayesian uncertainty quantification of scattering parameters and analyze resulting uncertainties and trade-offs.
- Apply this inversion to a VSP, surface-seismic dataset to attempt to characterize scattering within the medium, and use it to describe fracturing and/or fluid content inside





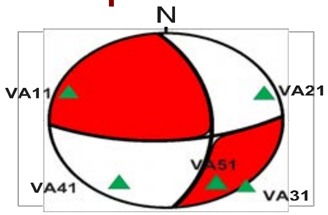
Bayesian modeling in inverse problems

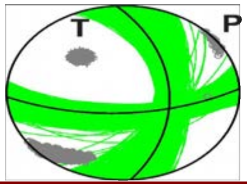
Y. Marzouk – AeroAstro and ERL

Motivation and Goals:

Bayesian modeling provides a rich language for *quantifying uncertainty* in inverse problems:

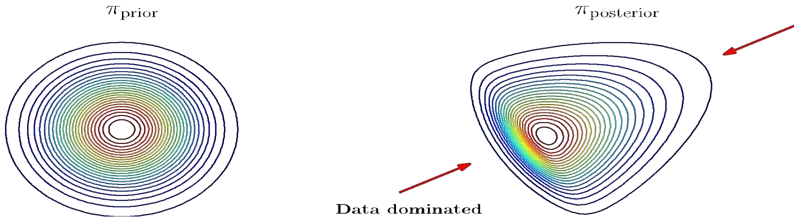
- Fuse heterogeneous data sources and rich varieties of prior information
- Comprehensively account for all sources of uncertainty
- Use quantified uncertainties to drive future data acquisition





Opportunity:

- Exploit a fundamental interplay between *optimization* and *sampling*
- Forward simulators have structure: construct fast and accurate input–output approximations

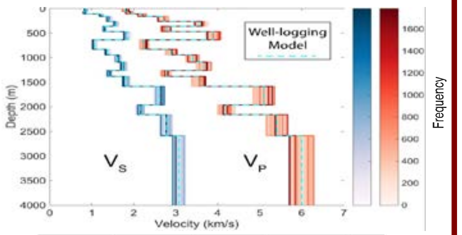


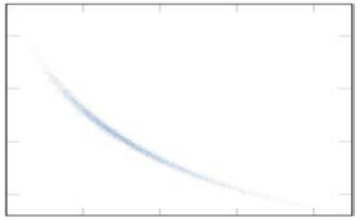
- Data often inform only certain features of the problem; prior information dominates the rest!

Approach

Advance both *modeling* and *computation:*

- Formulate likelihood (misfit) functions to account for ***model error***
- New Monte Carlo methods to handle ***posterior concentration*** and strong ***non-Gaussianity***
- Principled and infinitely refinable approximations of **computationally intensive** simulators





Proposed Work:

- Optimization-driven samplers: "upgrade" deterministic inversion methodologies to the fully Bayesian setting
- Robust likelihoods based on functional data analysis and hierarchical Bayesian modeling
- Joint inversion and uncertainty quantification with multiple datasets
- Priors for seismic inversion informed by coupled flow/geomechanics simulations (with M. Fehler, R. Juanes)

Tractable Methods for Geophysical System Dynamics and Optimization

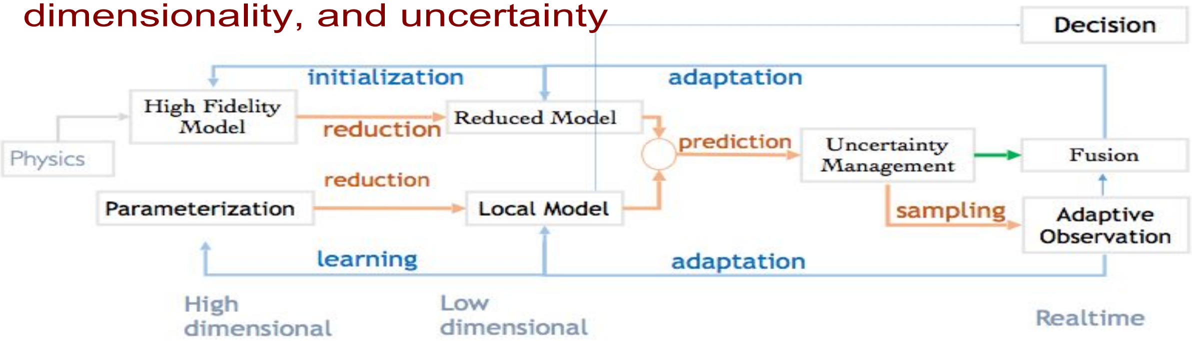
Sai Ravela – ERL

Motivation and Goals:

Geophysical Applications: Hazard Mitigation, Super-Resolution, Core Analysis, Reservoir Modeling, Tool Placement

Challenge: Optimally Coupling Modeling, Estimation, Sensing, and Decisions in Dynamic Data Driven Application Systems:

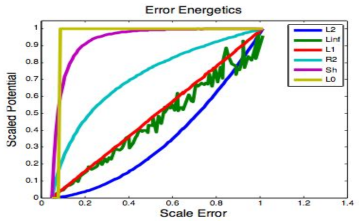
- Joint Optimization is difficult due to nonlinearity, model error, dimensionality, and uncertainty



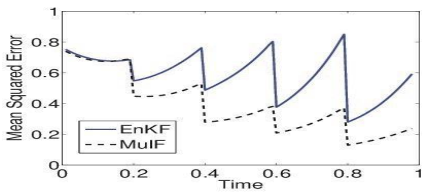
Opportunity:

- New approaches to capture higher order mutual information between multiple geophysical variables
- New tractable methods for variational non-Gaussian inference
- New approaches to deal with ambiguous uncertainties and extreme/rare events.

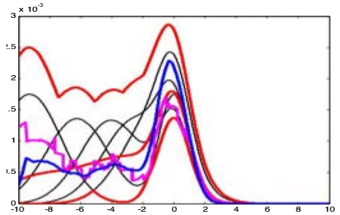
Tractable Inference



Non-Gaussian inference



Ambiguous Uncertainty



Approach:

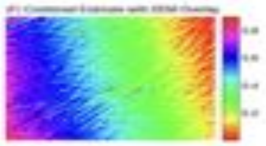
- Exploit new methodological opportunities for solving individual inference problems using the three adcances:
- Scale-recursive and time-recursive graphical models (for estimation), manifold learning (for UQ), deep learning (for modeling), ensemble learning (for model error), information gain (sampling) and stochastic dynamic programming/reinforcement learning (for decision making)
- Formulate and solve the coupled problem for dynamic data driven application systems

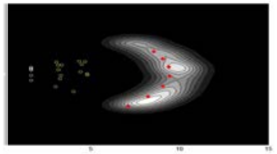
EAPS Earth, Atmospheric and Planetary Sciences

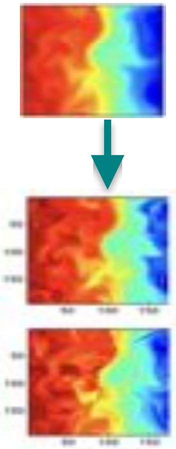
Earth Signals and Systems Group
Informatics and Intelligent Systems for Earth, Atmospheric, and Planetary Science

Proposed Work:

- Develop methodology as listed in Opportunity for problems in Approach
- Develop uses for Application in panel Motivation and Goals with direct sponsor engagement
- Release Software Toolkit







Applications: Natural Hazards, Mapping, Sampling/Placement and Super-resolution

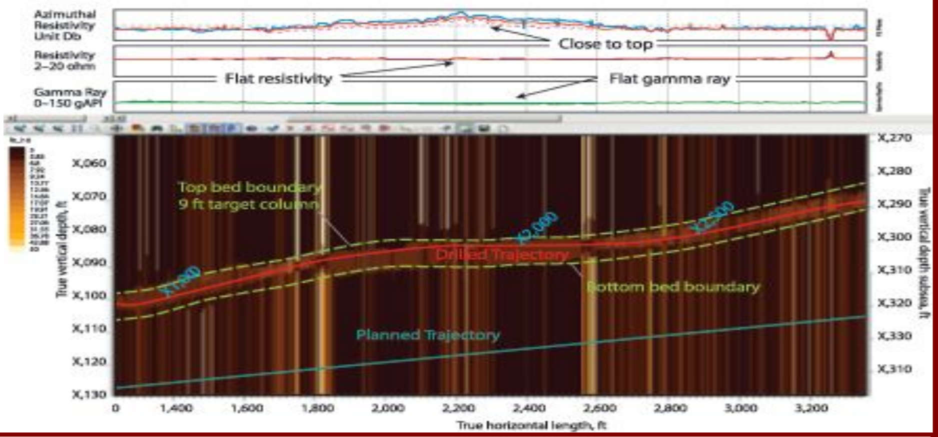
Optimal wellbore and completion design with neural networks

J. Williams and J. Montgomery – Civil & Environmental Engineering and ERL

Motivation and Goals:

Geosteering and engineered completions based on log data can improve unconventional O&G well economic performance. This requires understanding impact on production from:

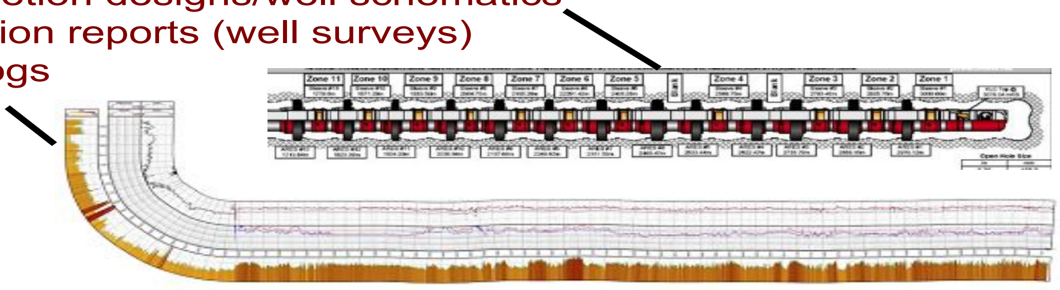
- Placement / design of wellbore and fracture stages
- Tortuosity (dog-leg severity) throughout wellbore



Opportunity:

Uncertainty about fracture propagation and proppant placement makes it difficult to physically model and quantify impact of wellbore and completion design choices on production. Machine learning can be used to model this complex relationship by leveraging abundant and diverse data including

- Production data
- Completion designs/well schematics
- Deviation reports (well surveys)
- Well logs

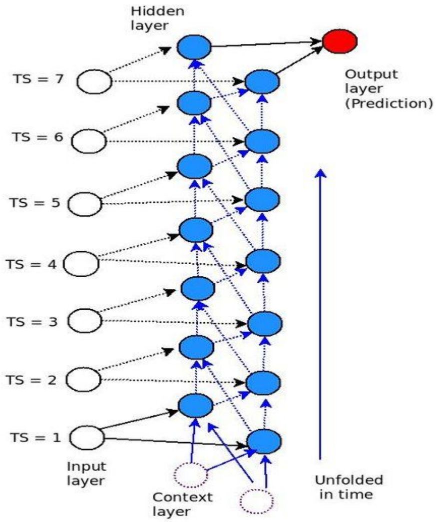


Approach:

- Data treated as multivariable 1-dimensional sequence across completed length of well
- Using backpropagation, recurrent neural networks will be trained to predict production rates based on interrelationship of properties across wellbore
- Available public data will be utilized but can be supplemented with private datasets from partner (e.g. fiber optic stage-level production data)
- Computer vision will be used where image data is necessary (e.g. well schematics)

Proposed Work:

- Project focused initially on data acquisition/processing, implementing model and training/testing with actual data
- Development of algorithm based on open source software (Python, PyTorch, TensorFlow) capable of linking production trends to measured wellbore and near wellbore properties
- Later stages of project will expand model capabilities and applications (e.g. full design optimization using model)



Agenda

4 KEEP IN TOUCH

Keep in touch

SOCIAL MEDIA

Twitter: follow mit_erl, for
- job openings
- research highlights
- SEG info

Also on *linkedin*

Youtube: subscribe and click bell

Facebook: comprehensive

In China: work in progress

QUESTIONS TO YOU

Can a collaborative (shared IP) consortium work, on a specific major undertaking?

Are the following of interest to you:

1. training in up-and-coming areas
2. “retreats” with graduate students
3. livestreams of seminars
4. visits/residencies in ERL