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Title: Mechanistic Approach to Analyzing and Improving Unconventional Hydrocarbon Production

Author(s): Viswanathan, Hari S.
Guthrie, George Drake Jr.
Carey, James William

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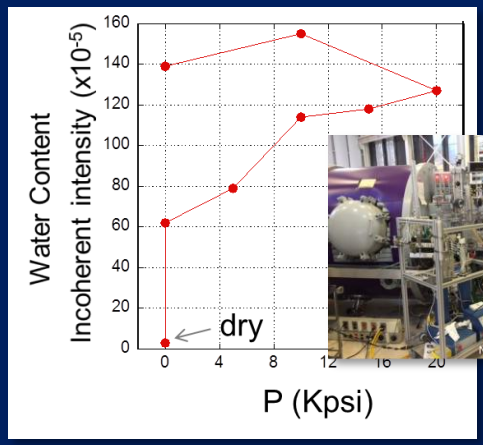
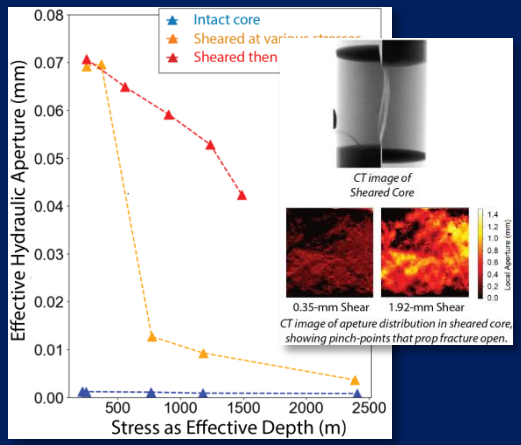
Mechanistic Approach to Analyzing and Improving Unconventional Hydrocarbon Production

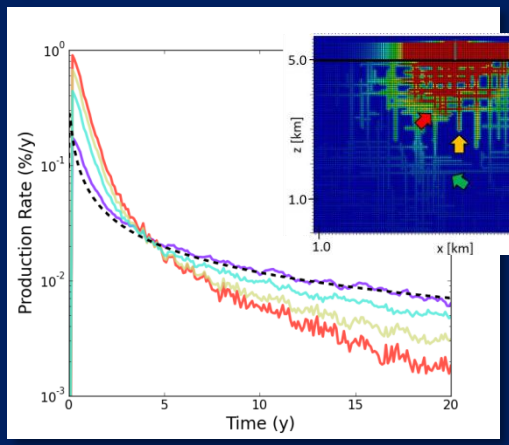
Hari Viswanathan and Bill Carey

Program Manager: Bruce Brown

Pore-Scale → Fracture-Scale → Reservoir-Scale







Luke Frash, George Guthrie, Qinjun Kang, Satish Karra, Nataliia Makedonska, Chelsea Neil, Matt Sweeney, Nathan Welch, Hongwu Xu

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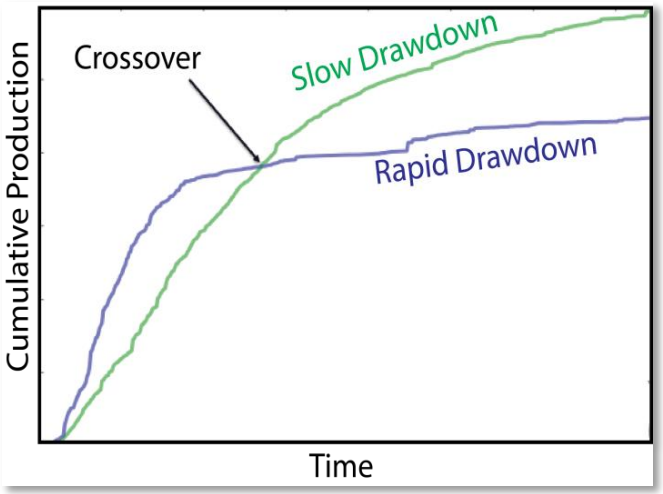
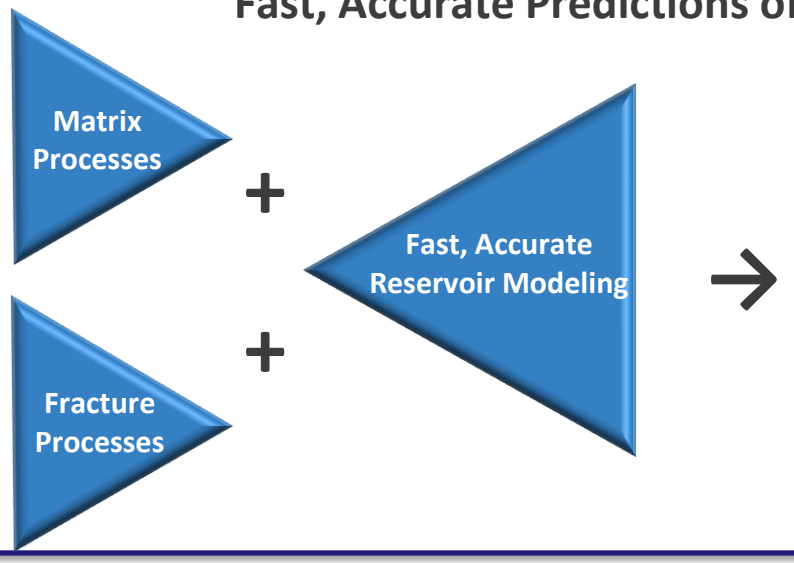
2020 DOE FE Fundamental Shale Progress
July 14 2020

DOE research is developing the physical basis and tools needed to manage pressure effectively to increase recovery efficiency.

- **Slower drawdown rates can lead to improved recovery efficiency in gas production from shale**
  - Anecdotal evidence from field experiences
- **Yet, slower drawdown requires an operator to forego high near-term production for higher overall production.**
- **DOE research will help operators to assess the risk-benefit for managing pressure.**
  - Uncertain site-specific characteristics/behavior (**risk**)
  - Increased recovery with slower drawdown (**benefit**)



Fast, Accurate Predictions of the Behavior of Fractured Reservoirs

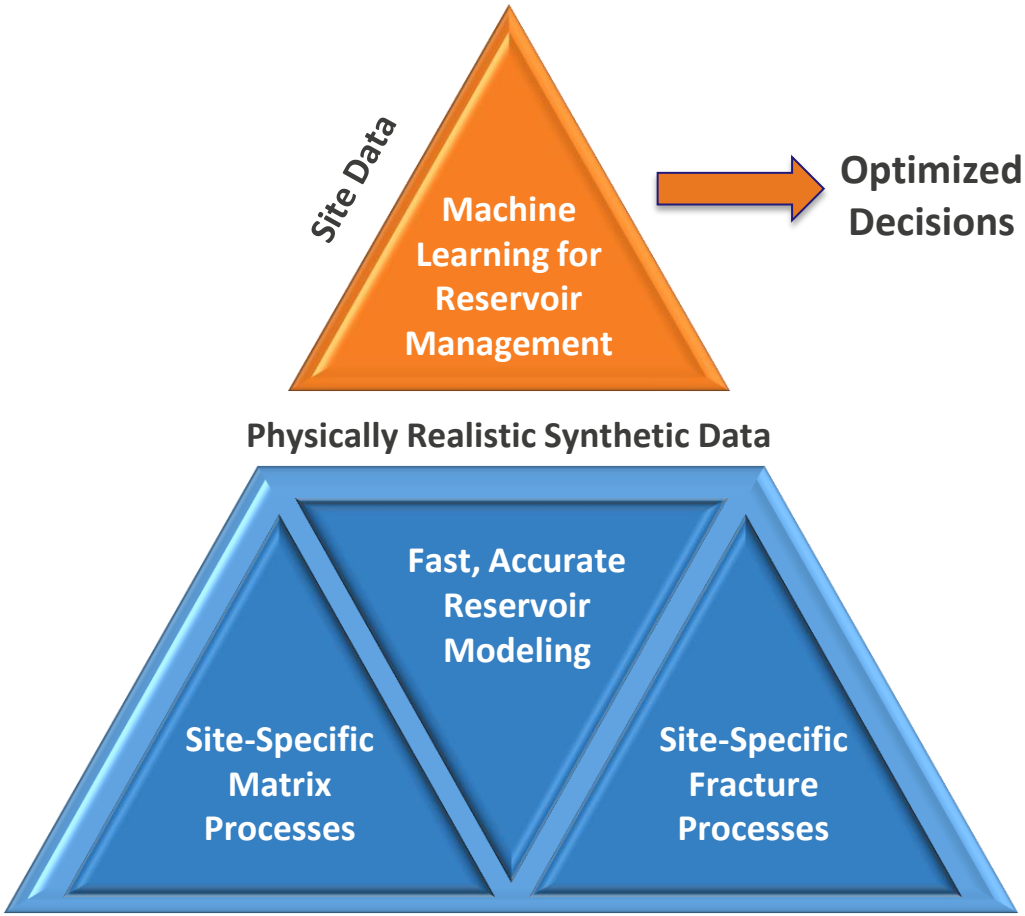


→

Physically Realistic Synthetic Data
(Forecasts of pressure-dependent behavior with an accuracy sufficient to optimize operations)

By coupling fast, accurate physics with machine learning, DOE is producing science-based platforms any operator can use.

Strategy: Physically realistic, site-specific synthetic data can be used in combination with available site data to confidently extrapolate production different operational decisions.



Physical behavior of system described as a combination of fracture transport and matrix-scale transport

- Theoretical development and experimental characterization occurring through FE-30 investments

Fast, accurate reservoir-scale simulations using discrete-fracture network platform in combination with graph-based models & machine learning

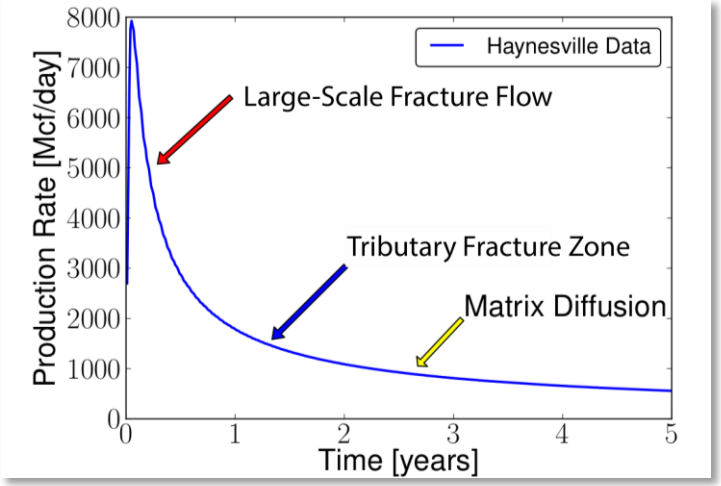
- Initial development with LDRD
- Extension to gas in shales through FE-30

Machine learning applied to scenarios library that augments limited/no field data with synthetic for real-time optimization

- Platform development through FE-30

DOE's research portfolio is targeting hydrocarbon transport at multiple scales, with the goal of increasing recovery efficiency.

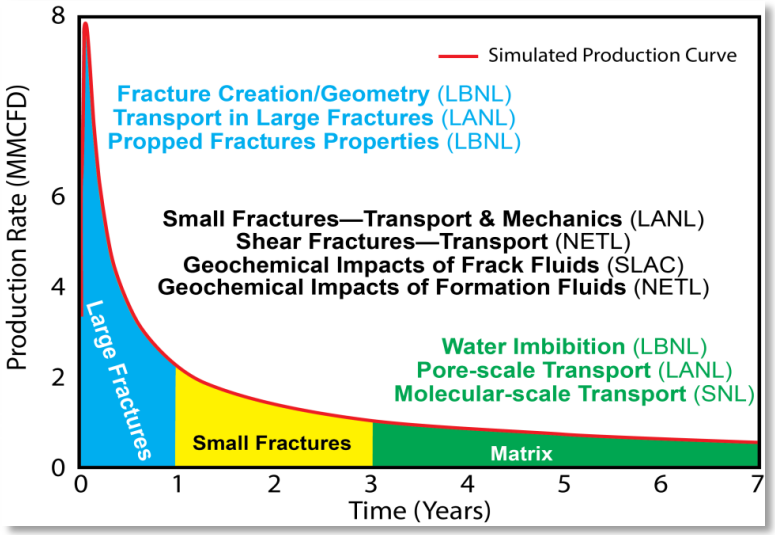
Increasing both the peak and tail are important for increasing recovery.



After the initial flush, transport at small scales dominates the production from fractured shales.

Case Study Using Data from the MSEEL-I Site

Year	1	2	5	10
% Fracture Production	99	95	75	40
% Matrix Production	1	5	25	60



DOE is using its national labs to build the fundamental science on production from shales.

This foundation is being used to develop a new tools for simulating the production of fractured shales based on the physics of transport from pore-scale to reservoir-scale.

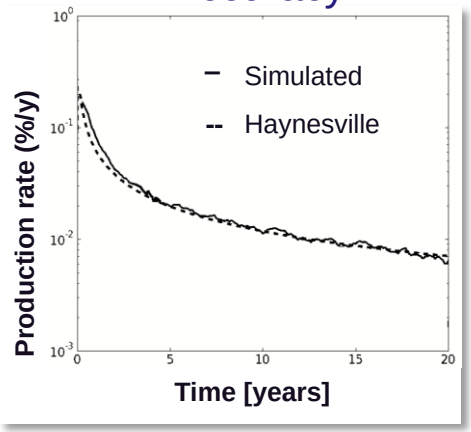
Applying these tools is leading to new strategies for increasing ultimate recovery (e.g., pressure management).

DOE's research has led to new, fast & accurate platforms for predicting gas production from fractured shales .

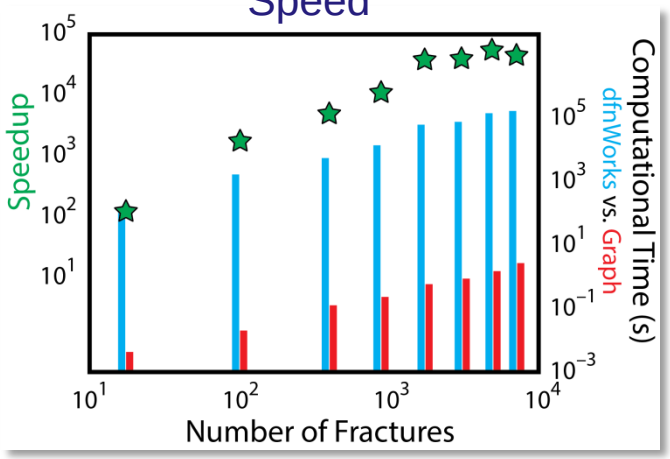
dfnWorks Discrete Fracture Network Modeling Suite

2017 R&D 100 WINNER

Accuracy



Speed



By combining graph-based models with full-physics discrete-fracture models, hydrocarbon production can be predicted accurately with orders of magnitude increases in speed. Full physics model includes matrix-transport and fracture-transport processes. LANL's dfnWorks is an open source software package.

Golder Associates | FracMan Technology Group | U.S. Department of Energy, Fossil Energy, Office of Oil & Natural Gas | Los Alamos National Laboratory, Est. 1943 | dfnWorks Discrete Fracture Network

FracMan / dfnWorks Continuous Workflow

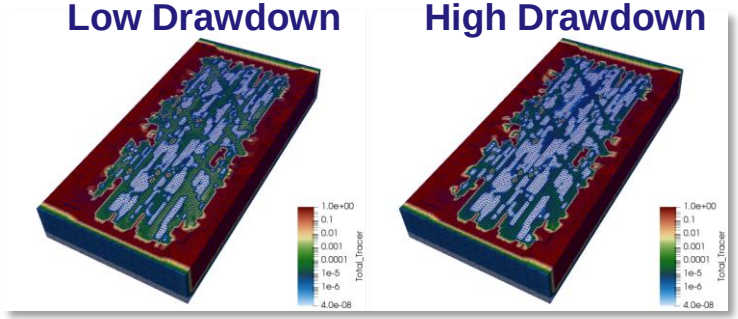
From Field Observations → To Flow & Transport Predictions

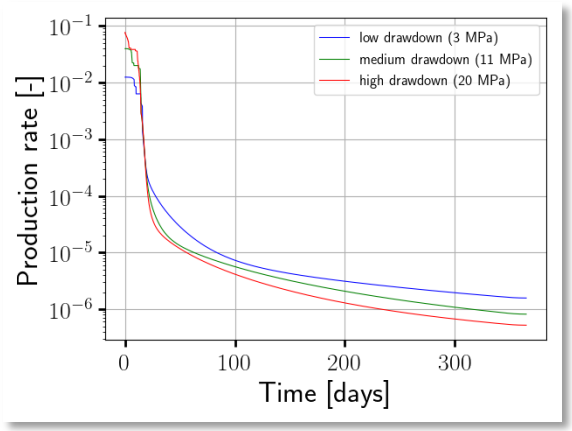
DOE's Technology Commercialization Fund is helping to couple dfnWorks and graph-based models to Golder's FracMan platform

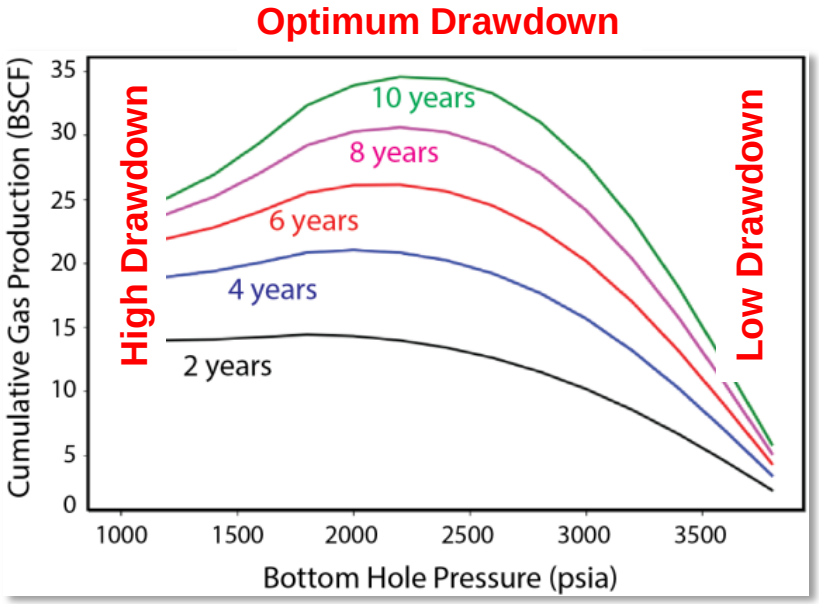
Using data from the MSEEL-I site to calibrate our physics-based model, we have early results on pressure management.

Next year, DOE hopes to provide quantitative insights for basins/plays.

We have demonstrated the physical basis for pressure management using data from DOE's MSEEL-I field laboratory. Next year, we anticipate quantitative insights for both MSEEL & other basins/plays.

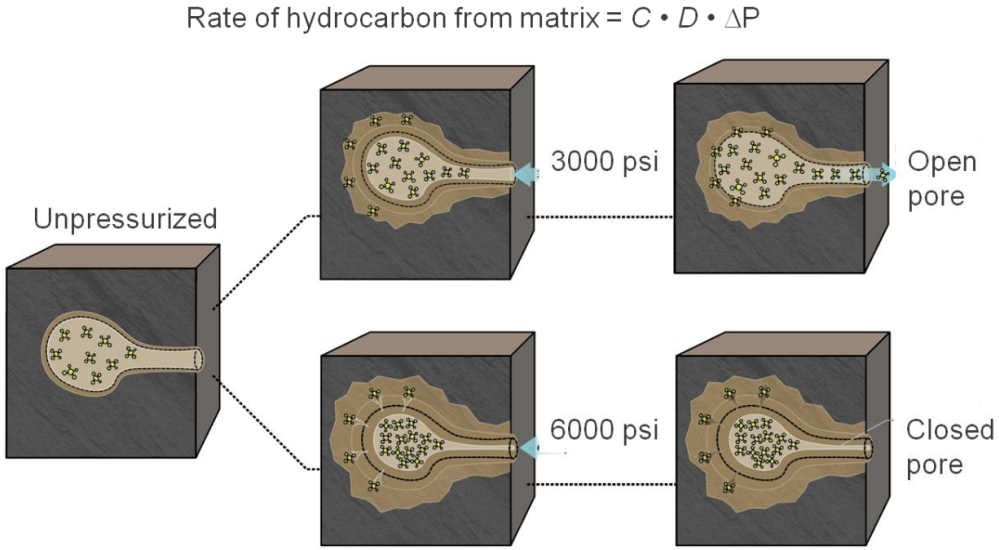


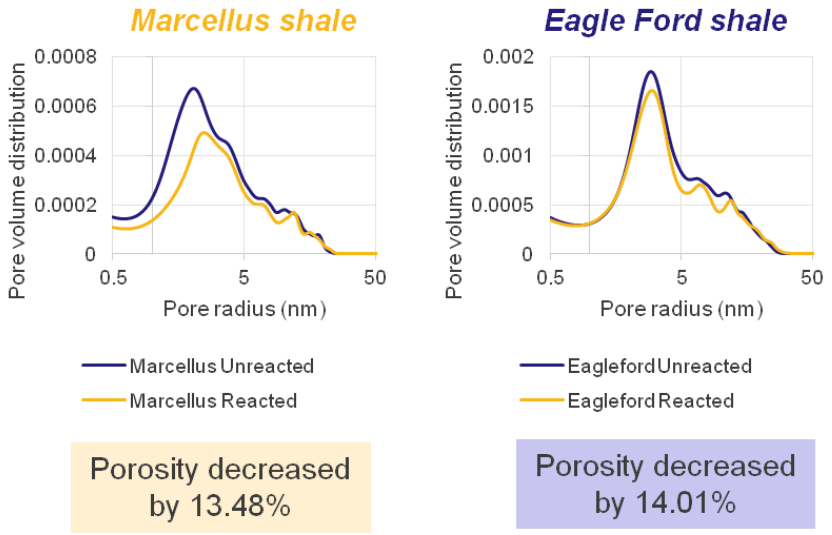




*For MSEEL-I, there appears to be an optimum drawdown rate that could increase recovery **significantly** over a rapid drawdown.*

We have shown that both mechanical and chemical processes in the matrix can negatively impact production.





Identified damage in matrix at can occur at high ΔP; impacts both *C* and *D* depending on reservoir history

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Based on our current work, we can only provide qualitative insights to operators today. An additional year of work would lead to quantitative guidelines on critical drawdown rates and chemical reactions that could damage reservoirs in different basins/plays.