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CO_2 UTILIZATION FOR DEPLETED SHALE GAS & OIL RESERVOIRS

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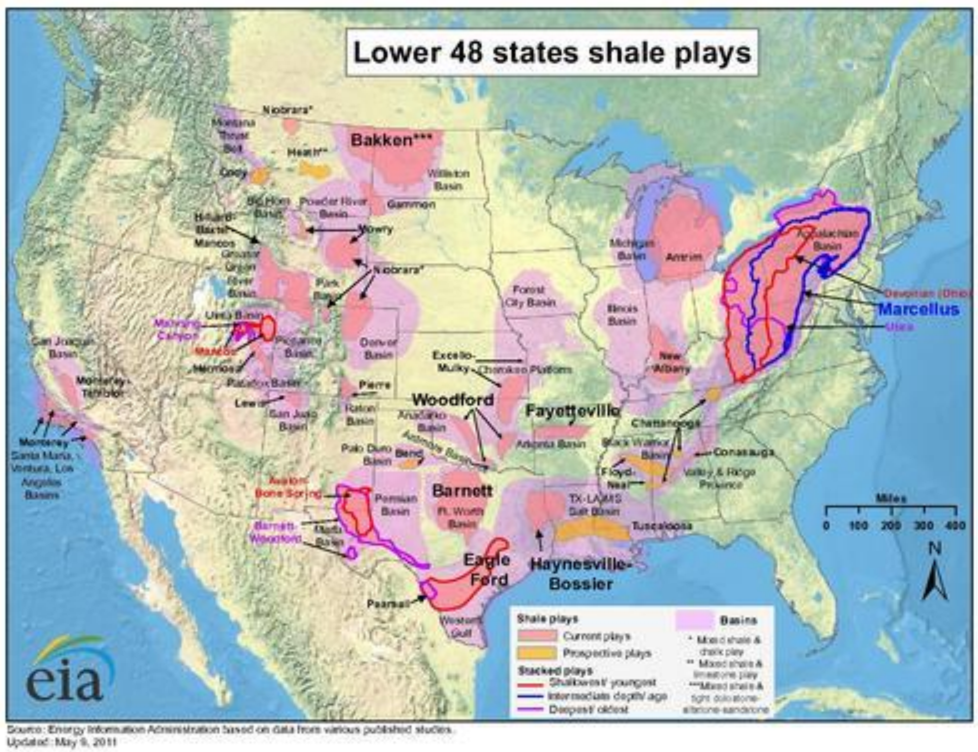
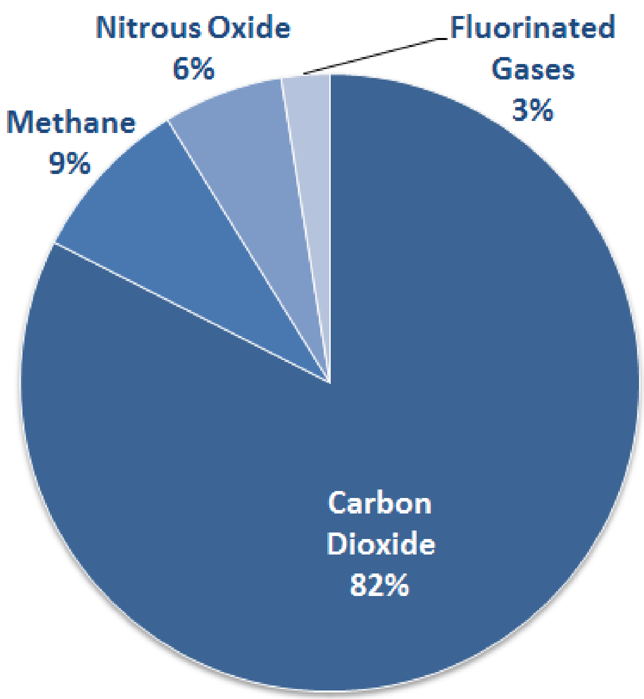
Motivation

- Availability of organic-rich shale deposits
- Lead to lower CO_2 emissions





Picture courtesy: EPA

Economic Impact

- EERC Data Analysis – 1.1% improved recovery by CO_2 translates to additional 1.87 Bbbls of oil (in Bakken)
- Also prolong the life of the field by decades
- If CO_2 EOR technology is effective, results could be applied to other tight oil plays

Outline

- CO_2 Utilization
- Challenges
- Unknown Issues
- Learning from Field Trials

CO_2 Utilization

- As a fracking fluid
- As an EOR agent
- For sequestration

Challenges

- Range of length scales
  - Pore scale: lab & theoretical study
  - Reservoir scale: simulation study
- CO_2/Shale Interaction – affects injectivity
- Transport process – affects recovery estimates
- Adsorption – affects trapping & sealing

Various Length Scales

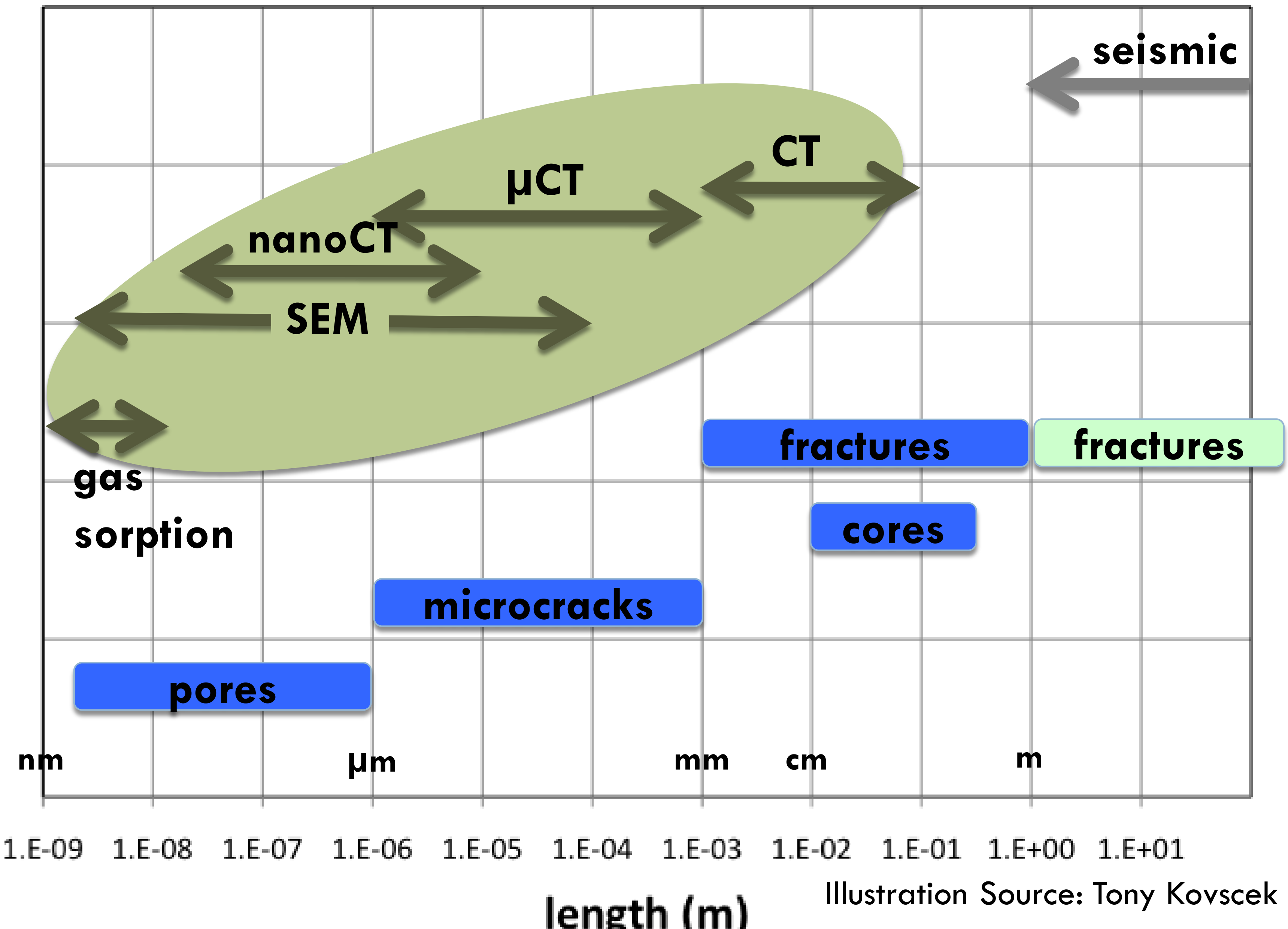


Illustration Source: Tony Kovscek

CO_2 for Fracking

- Proppant issues
  - Crushing, embedment, performance
  - Could lead to fracture closure (crushing in low clay, embedment in high clay)
- Advantage
  - Elimination of formation damage (in gas reservoir) and residual frac fluid
  - Rapid clean-up – cost savings
  - Cost saving associated rig time less than with conventional frac fluid
  - Front loaded expenditure

CO_2 for Fracking contd…

- Limitation
  - Is not applicable in high permeability reservoir
  - CO_2 (liquid phase) must be stored and transported under pressure
  - Oil reservoirs do not respond as favorably to CO_2 fracture treatment
  - Expensive
- Efficiency with Vertical well compared to Horizontal well

Select References

- CO_2 as a Fracking fluid:
  - Progressive Proppant Embedment in Barnett Shale: Laboratory Experimental Results, Chandong Chang & Mark D. Zoback
  - CO_2/Sand Fracturing in Devonian Shales, A.B.Yost, U.S.DOE, METC; R.L.Mazza, Petroleum Consulting Services; and J.B. Gehr, Natural Gas Resources Corp. (SPE 26925)
  - The Effects of Fracturing Fluids on Shale Rock Mechanical Properties and Proppant Embedment, Ola Akrad, Jennifer Miskimins, and Manika Prasad, Colorado School of Mines. (SPE 146658)
  - Hydraulic fracturing stimulation techniques and formation damage mechanisms - Implications from laboratory testing of tight sandstone - proppant systems, Andreas Reinicken, Erik Rybacki, Sergei Stanchits, Ernst Huenges, Georg Dresen

CO_2 for EOR

- Useful in deeper formations
- Immiscible & miscible injection
- Countercurrent vs co-current injection & importance of diffusion mechanism
- Presence of continuous gas channels
- Lower miscibility pressure for CO_2
- High mobility ratio, Low sweep efficiency

CO_2 for Sequestration

- CO_2 sorption measurements show a large potential storage capacity
- Large reductions in permeability and effective pore radius may occur as CO_2 saturates the pore space
- Significant CO_2 sorption would impact the flow mechanism
- CO_2 shows multilayer sorption – better fits with N-BET model, instead of Langmuir

Select References

- CO_2 for EOR
  - Experimental Investigation of Oil Recovery From Siliceous Shale by CO_2 Injection, A.R. Kovscek, G.Q. Tang, B. Vega, Stanford University (SPE 115679)
  - Experimental Investigation of Oil Recovery From Siliceous Shale by Miscible CO_2 Injection, B. Vega , William J. O'Brien, A.R. Kovscek (SPE 135627)
- CO_2 for Storage
  - Experimental and Numerical Analysis of Gas Transport in Shale Including the Role of Sorption, K.R. AlNoaimi, A.R. Kovscek (SPE 166375)
  - In-Depth Experimental Investigation of Shale Physical and Transport Properties, H. Aljamaan, , K.R. AlNoaimi, A.R. Kovscek (SPE 168837)
  - Laboratory Measurements of Matrix Permeability and Slippage Enhanced Permeability in Gas Shales, R. Heller, M.D. Zoback (SPE 168856)

Unknown Issues

- Organic matter swelling under stress
- Clay/Shale stability
- Flow back and produced water

Swelling

- Swelling behavior of rock-fluid important in
  - Predicting drilling problems
  - Designing proper mud system
- Swelling could lead to detachment, fracturing & increased costs
- Primary factors: Clay fraction, TOC

Shale Stability

- Shale/fluid interaction: capillary, osmosis, hydraulic, swelling, pressure diffusion
- Shale strength affected by
  - Shale properties: mineral content, porosity
  - Fluid properties: wettability, density, salinity, ionic concentration

Flowback & Production

- SlickWater management by
  - Reduced fresh water use
  - Recycle flowback – cutback transportation, treatment & disposal costs
- Issues if CO_2 is used
  - Proppant: Need to carry sand & chemicals
  - Supercritical CO_2 flows back as gas
    - Venting?
    - Capture?

Select References

- Unknown Issues
  - Clay swelling — A challenge in the oilfield, R.L. Anderson, I. Ratcliffe, H.C. Greenwell, P.A. Williams, S. Cliffe, P.V. Coveney
  - Shale Stability: Drilling Fluid Interaction and Shale Strength, Manohar Lal, SPE, BP Amoco (SPE 54356)

Learning from Field Trials?

- Bakken Huff-n-Puff: Wei Yu, HamidReza Lashgari & Kamy Sepehrnoori – Simulation Study with Field Data from a horizontal well in mid-Bakken (SPE 169575)
  - Controlling factors: CO_2 Injection rate & time, number of cycles & diffusivity
  - Less sensitivity to fracture conductivity & half-length, soak time & perm
- ……

Acknowledgements

- SCCS
- CCP3
- Tony Kovscek
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Thank you!