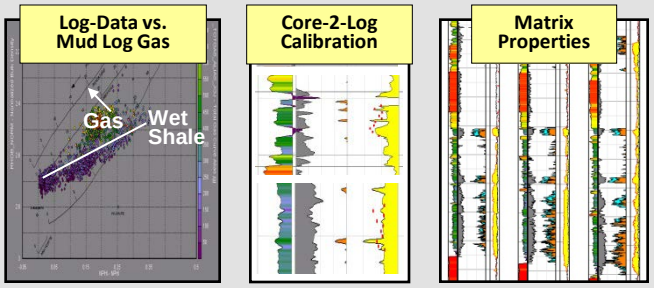
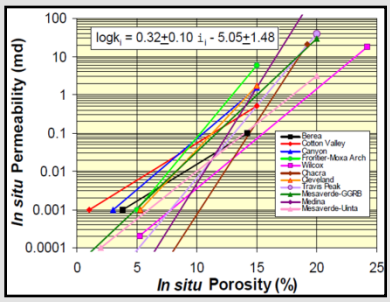
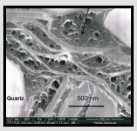
Unconventional Resource Characterization
Key Questions for Resource Plays

1. Are the resource volumetrics sufficient?
Identify matrix pay vertical and area extent.

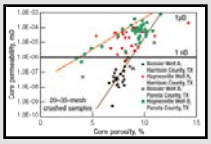


2. Is the matrix permeability adequate to flow fluids?
Estimate the matrix flow contribution.





Denver DWLS – Shale Petrophysics, Passey, Q. R., et al., ExxonMobil Upstream Research Co., October 27, 2010

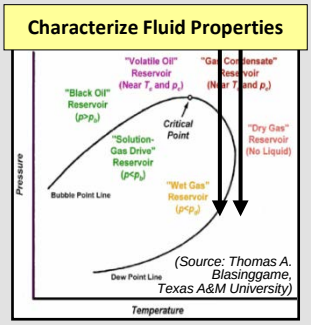


BEG: W Oil June 2010: Fred Wang and Ursula Hammes

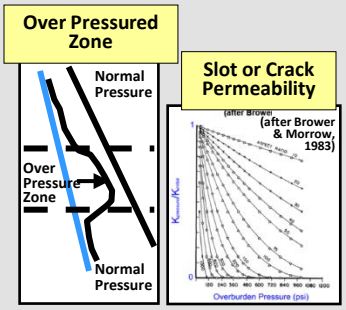
3. Are fluid properties favorable for flow?
Measure PVT, bubble point, estimate recovery factor.

4. Is the reservoir over-pressured?
Estimate reservoir pressures, and reservoir compaction.

Reservoir Fluid Properties

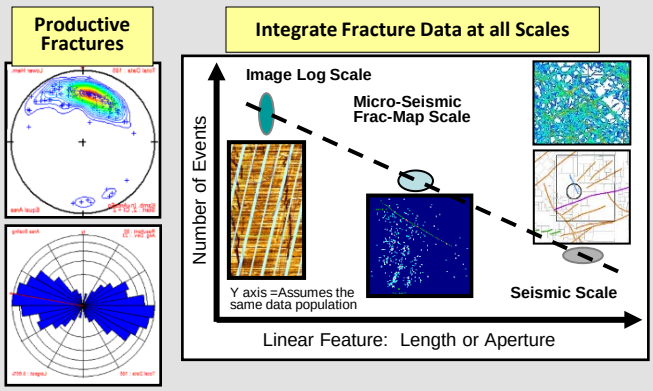


Reservoir Pressure and Compaction



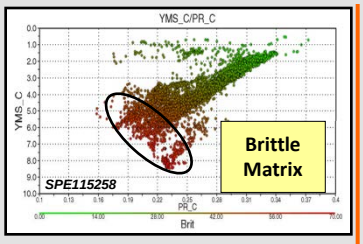
5. Are natural fractures present in the rock?
Characterize the productive fracture network.

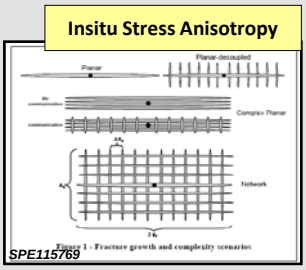
Characterize Productive Fractures

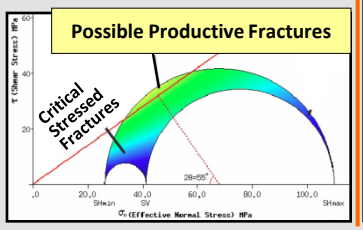


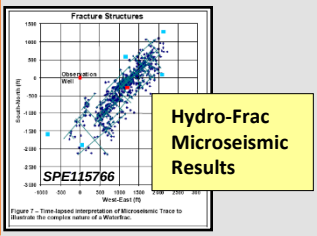
6. Are geomechanical attributes favorable?
Stress anisotropy and brittleness for hydro-frac "SRV".

Geomechanics

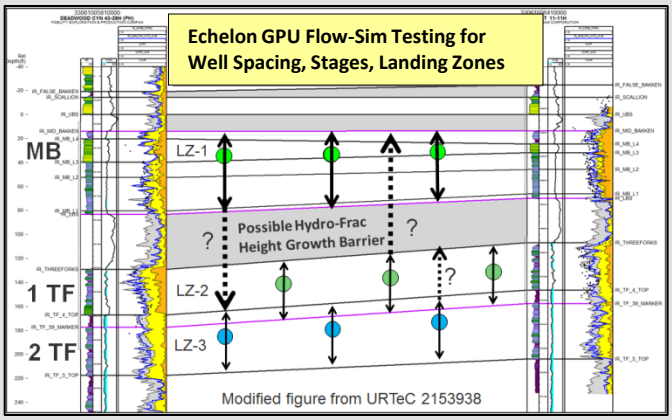








7. How to determine well density, spacing, and landing zones.



Unconventional Resource Characterization
iReservoir's Approach to Resource Plays

Resource Experience

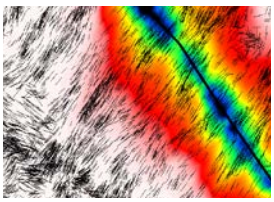
Tight Oil

- Bakken
- Cane Creek
- Cardium, CA
- Codell
- Eagle Ford
- Frontier
- Kreyenhagen
- Lias, FR
- Miss Lime
- Monterey
- Mowry
- Neuquen
- Niobrara
- PRB
- Three Forks
- Vaca Muerta, CA
- Wolfberry
- Wolfcamp

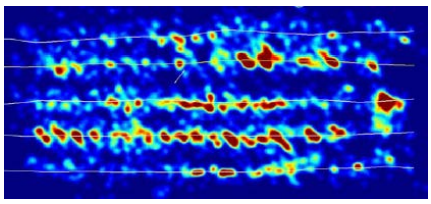
Gas / Rich Liquids

- Antrim
- Appalachian
- Barnett
- Duvernay, CA
- Marcellus
- McClure
- Montney, CA
- New Albany
- Niobrara
- Pearsall
- Utica
- Woodford

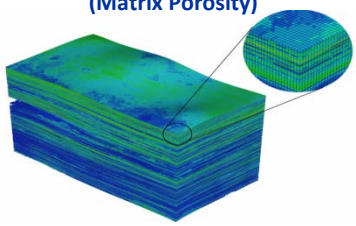
Pressure Field in Fracture Reservoir



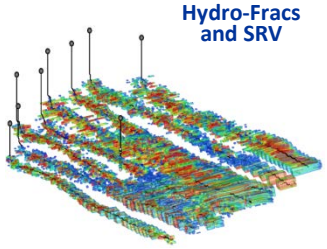
Microseismic Events



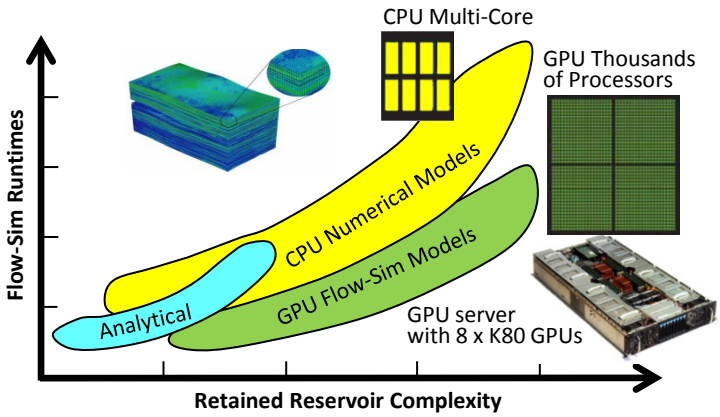
Detailed Reservoir Description (Matrix Porosity)



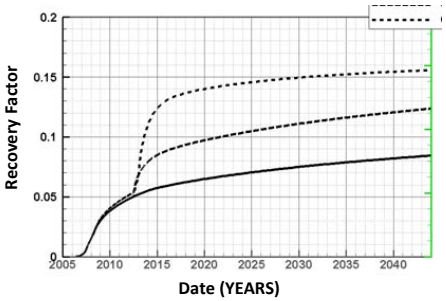
Hydro-Fracs and SRV



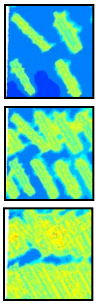
Fast GPU Simulation of Detailed Models



Oil Production Well Spacing Sensitivity



Pressure Depletion Different Spacing



- **Geology:** Depositional geo-controls for net pay, early analog selection, faults, fractures
- **Geochemistry:** Reservoir compartments, maturity uncertainty, gas-vs.-oil ratios
- **Petrophysics:** Pay estimates, free and adsorbed gas, core-to-log calibration, SCAL interpretations (phi-k, Swi), logging choices
- **Rock Mechanics:** Optimizing completions (treatment size, rates, number of stages, well orientation)
- **Rock Physics:** Seismic calibrated sweet-spots, log scale brittleness (Young's modulus and Poisson's ratio)
- **Seismic:** Structure thickness, faults, sweet-spots, seismic scale brittleness, hazard avoidance, anisotropy
- **Micro-Seismic:** Hydraulic fracture complexity, area of influence, height growth
- **Reservoir Engineering:** Fluid behavior, recovery estimates, well spacing and length, number of stages, fast GPU simulation of detailed models
- **Drilling and Completions Engineering:** Vertical vs horizontal, pilot holes, coring, casing design, completion design, hydraulic fracture design, sand and treatment volumes, fluid types
- **Production Engineering:** Long-term reservoir surveillance (pressures, water sampling, interference, calibration to micro-seismic events)
- **Economics:** Risk models, project-optimization

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