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# Geologic Factors Associated with Successful Shale Gas Plays


Gaffney, Cline & Associates

Gaffney, Cline & Associates 50 1962-2012 YEARS OF EXCELLENCE

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Society of Petroleum Engineers
Distinguished Lecturer Program
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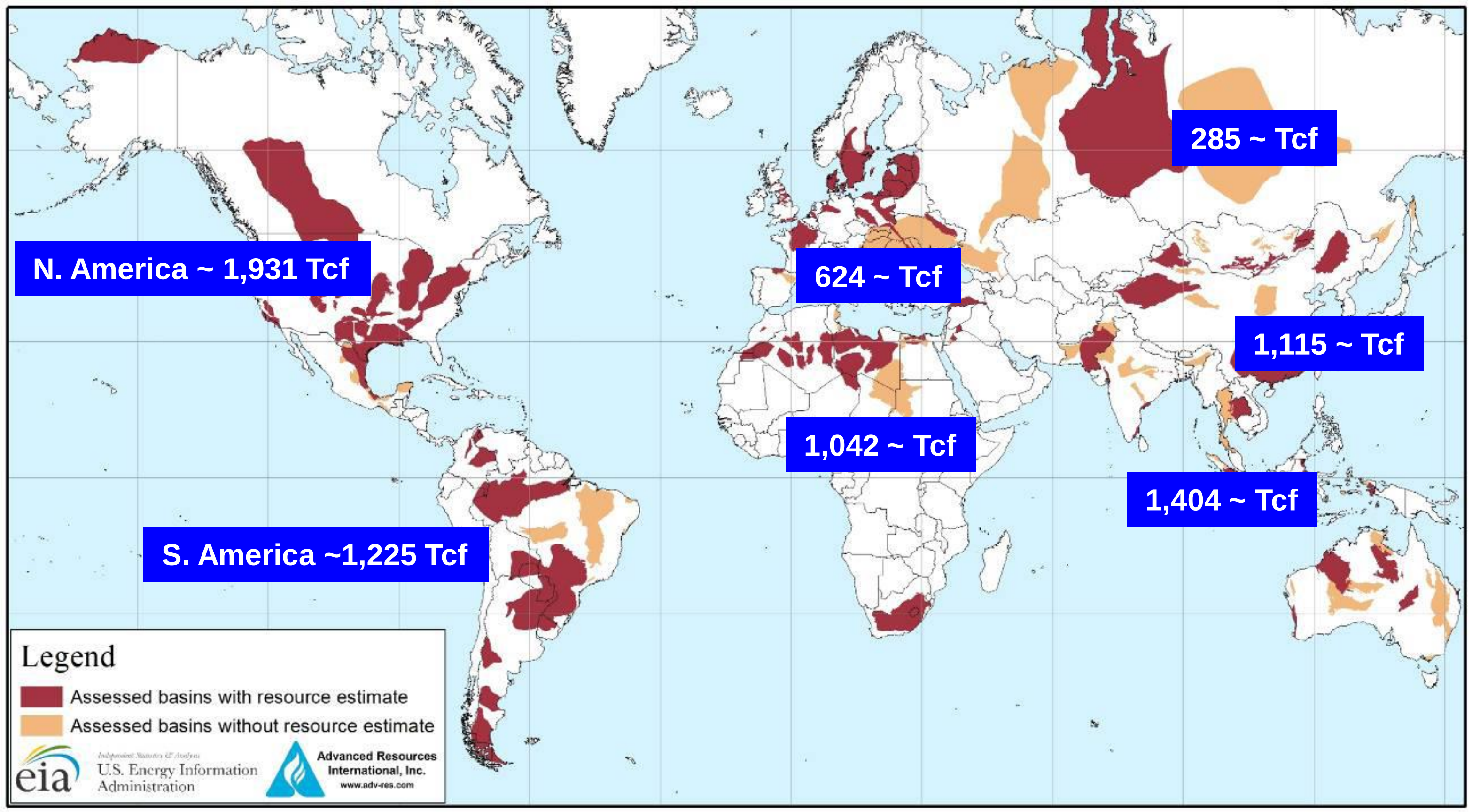
# Presentation Outline

- World potential
- Comparison of conventional / unconventional exploration
- What changed?
- Elements of a successful play
- Geologic example
- What else matters?
- Conclusions

# Worldwide Shale Gas Potential

EIA estimates there are 7,795 Tcf of Technically Recoverable Resources (TRR) shale gas



# Resource Understanding and Technology

- Two most critical factors
  - Having a complete understanding of resource
  - Full utilization of technology

*"By gaining an early understanding of a resource and then applying the appropriate modern technology in its exploitation maximum efficiency/profit can be realized"*

So what do we need to understand about Shale Plays?

# Conventional Gas Reservoirs

- Gas molecules are stored under pressure within rock pores
  - Gas is buoyant on water
  - It accumulates in structural and stratigraphic traps
- Gas-In-Place analysis is a simple volumetric calculation
- No significant gas molecule-reservoir rock interaction
- Gas stored by compression within specific pore volume is calculated using temperature, pressure & volume relationships
  - derived from fundamental gas laws
- Gas-In-Place is a direct function of
  - Effective rock porosity and gas saturation
  - Reservoir temperature
  - Reservoir pressure
  - Gas composition
- Typical conventional gas reservoir recovery ~ 60-90%

# The Shale Reservoir (Unconventional)

- **What is shale?**
  - Shale defines a grain size; not minerology
- **Shale plays are continuous type deposits**
  - Unconventional reservoirs do not require a traps
- **Gas in shale gas reservoirs is stored in:**
  - Pore space (free gas)
  - Voids of natural fractures (NF)
  - Adsorbed to mineral surfaces
  - Absorbed to organic & mineral surfaces

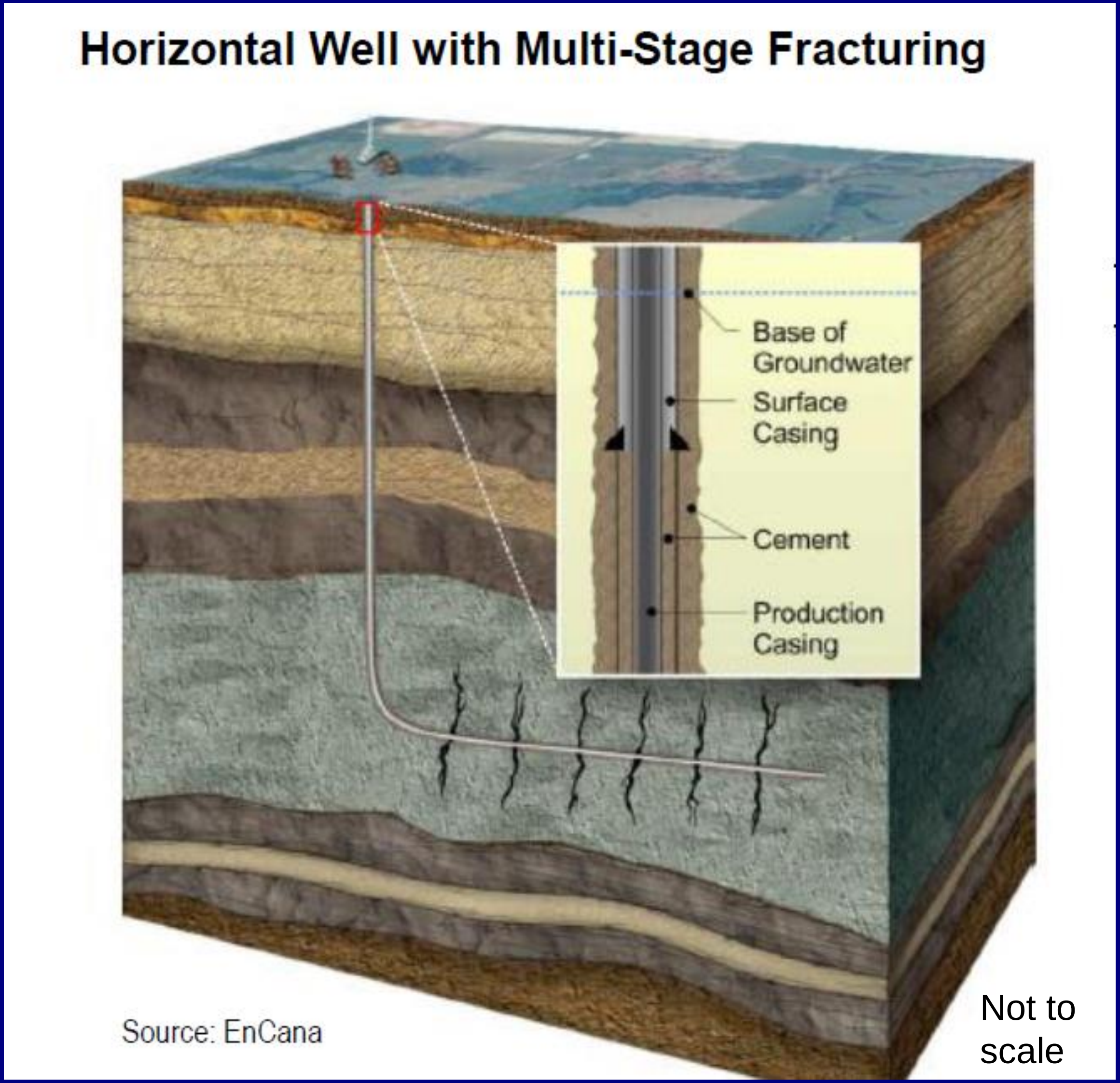
# The Shale Reservoir (Unconventional) - continued

- **Hydrocarbons found in shales are:**
  - Self-sourced
  - Generated from thermally mature organic content
    - Total organic content (TOC)
    - Vitronite reflectance (Ro)
- **Shales must be fracture-stimulated to produce commercially**
  - Maximum reservoir contact
  - An artificial reservoir is achieved by:
    - Horizontal wells
    - Multi-stage fracturing

# Exploring for Conventional vs. Unconventional Hydrocarbons

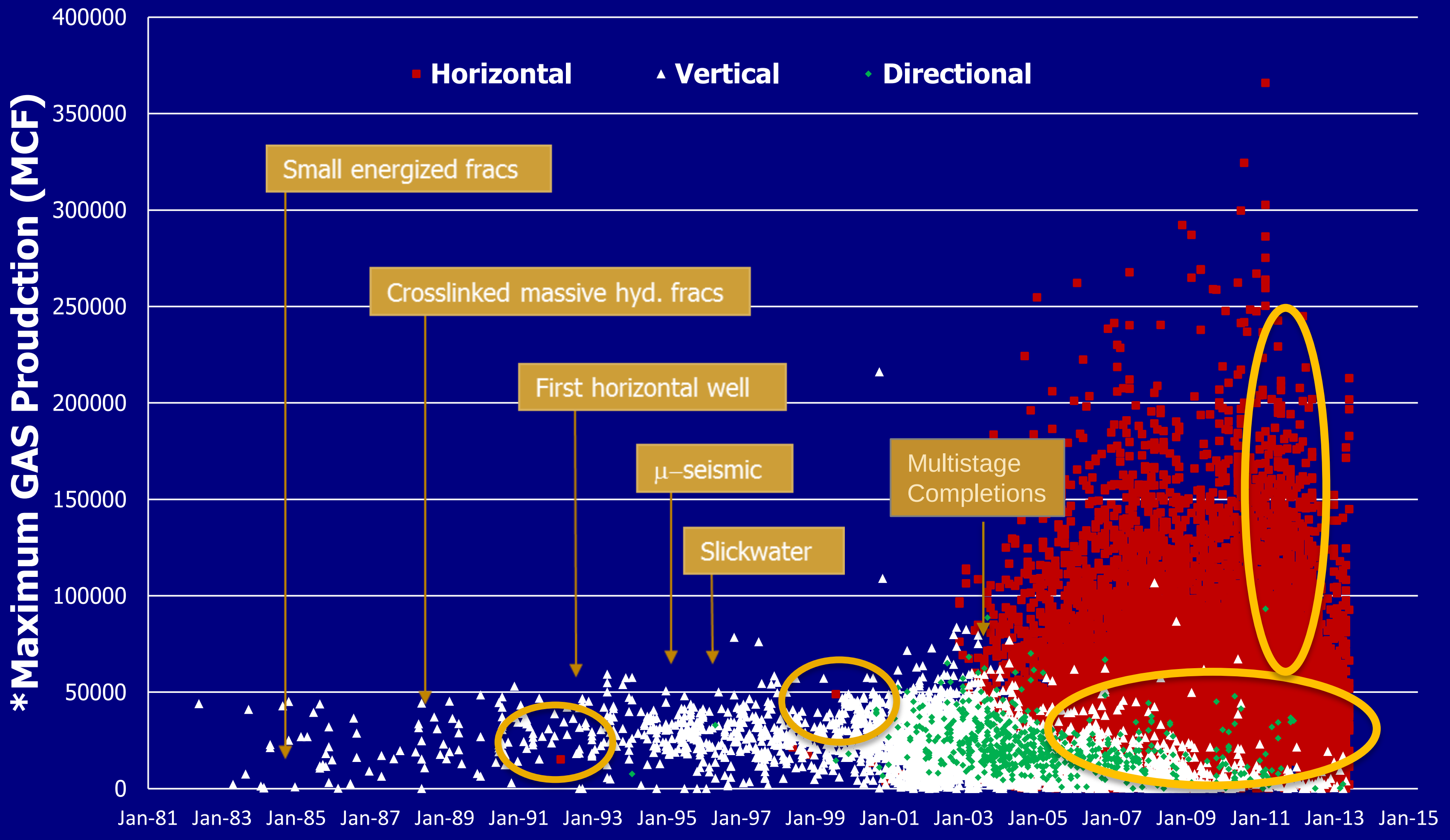
| Conventional | | Unconventional |
|---|---|---|
| | • Mapping | |
| • 3-35% | • Porosity | • 1- 10 % (nano-pores) |
| • 0.1 md to multi-darcy | • Permeability | • Nano-darcy |
| • Migration | • Source Rocks | • Insitu |
| • Lateral/vertical | • Seals | • Not required |
| • 1 – 3+ km $^2$ | • Drainage | • Dependant on horizontal drilling |
| • North Sea 20 to 70 BCF/well | • Productivity | • 2 to 10 BCF/well |

# So What Changed the Game?



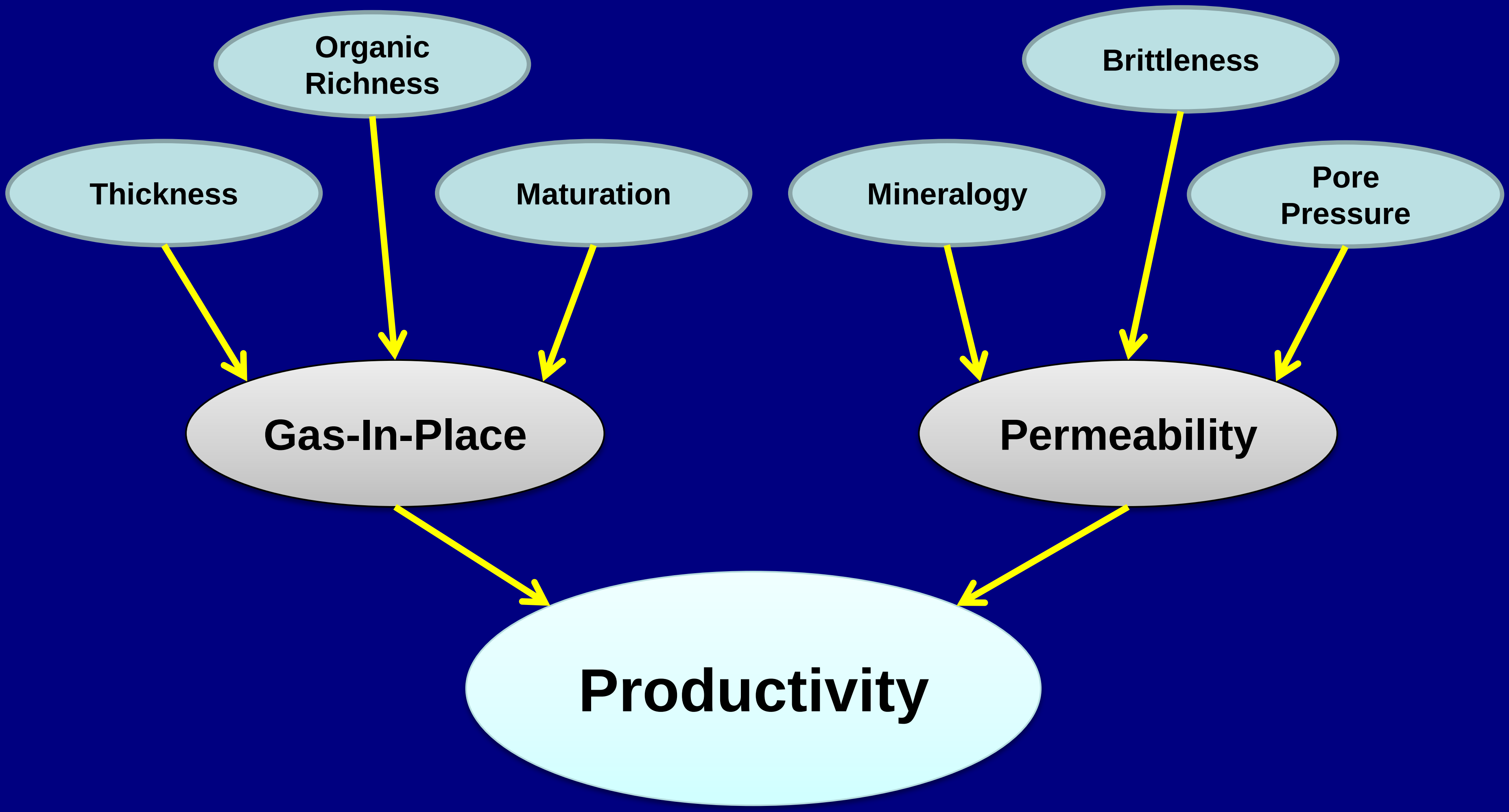
# Unconventional Development – Learning Curve

## Barnett Shale Development




* Individual well production during first 6 months

# Elements for a Successful Shale Gas Play



# So if shales are all different, what matters?

## Criteria for technically evaluating shale gas plays…

| PARAMETER | OPTIMAL TARGET |
| --- | --- |
| Source Rock Quality | TOC 2-5+% by weight<br>Minimum 15-20 m thick<br>Typically Type II/III Kerogen<br>Porosity 3- 10% |
| Source Maturity | Ro >1.4 for dry gas<br>Ro 1.1-1.4 for wet gas<br>Ro 0.6-1.1 for oil<br>T Max 450+ Deg C |
| Structural Complexity | Monocline <5 Degree dip<br>Simple structural architecture<br>Minimal faults, folds |

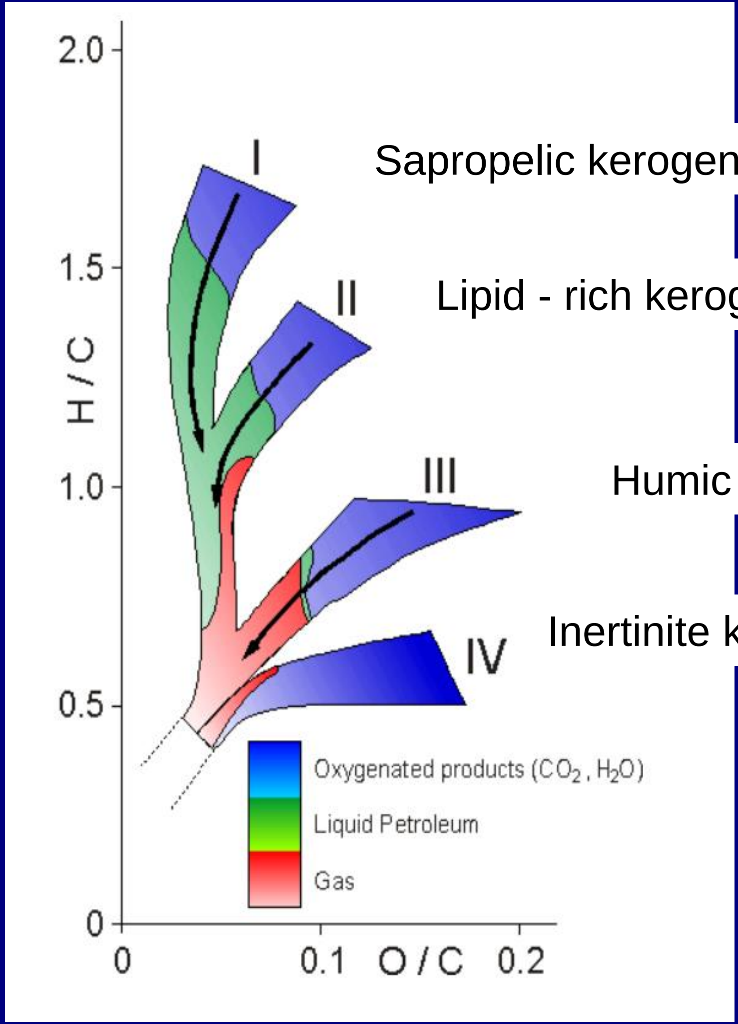
# So if shales are all different, what matters?

## Criteria for technically evaluating shale gas plays…

| PARAMETER | OPTIMAL TARGET |
|---|---|
| Clay content/ brittle index | <40% Vclay (XRD analysis),<br>Direct measurement of brittle index required |
| Presence of aquifers | Separated from target intervals by ductile barriers |
| Geomechanics | Knowledge required for orientation of laterals |
| Pore Pressure | Knowledge required to select frac fluids and proppants |
| | |

# Land and Marine Kerogens Evolve Differently

## Van Krevelen diagram



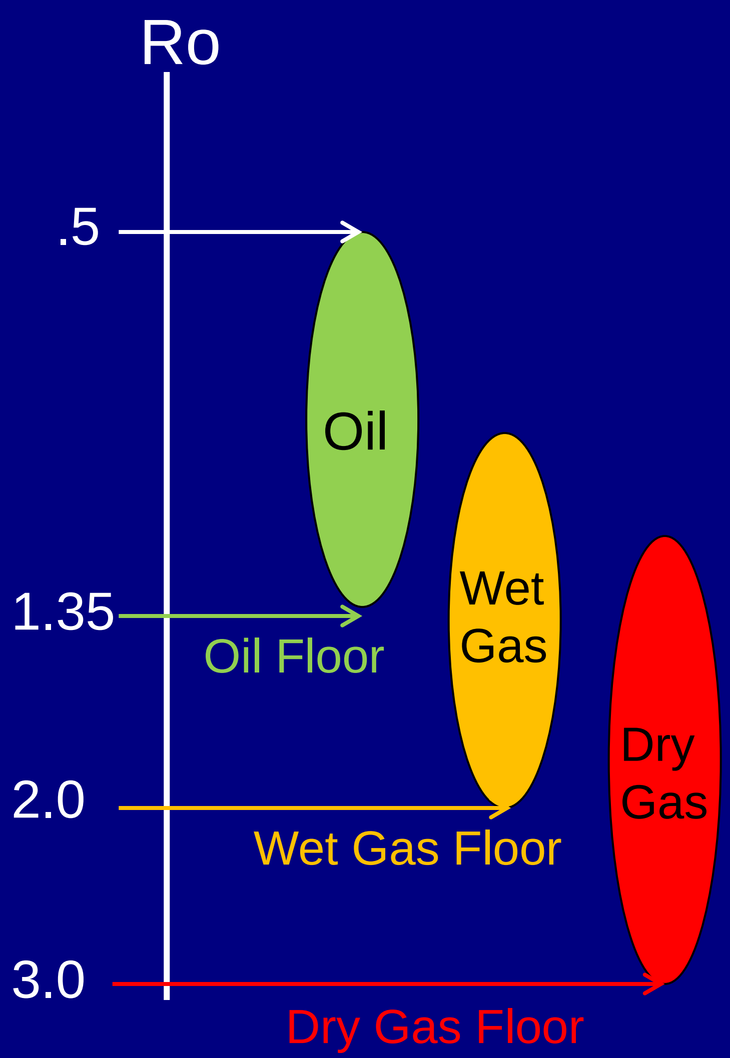

Sapropelic kerogen (algal)

Lipid - rich kerogen (phyto and zooplankton)

Humic kerogen (land plants)

Inertinite kerogen (oxidized/hydrogen poor)

# Thermal Maturity – Vitrinite Scalar (Ro)

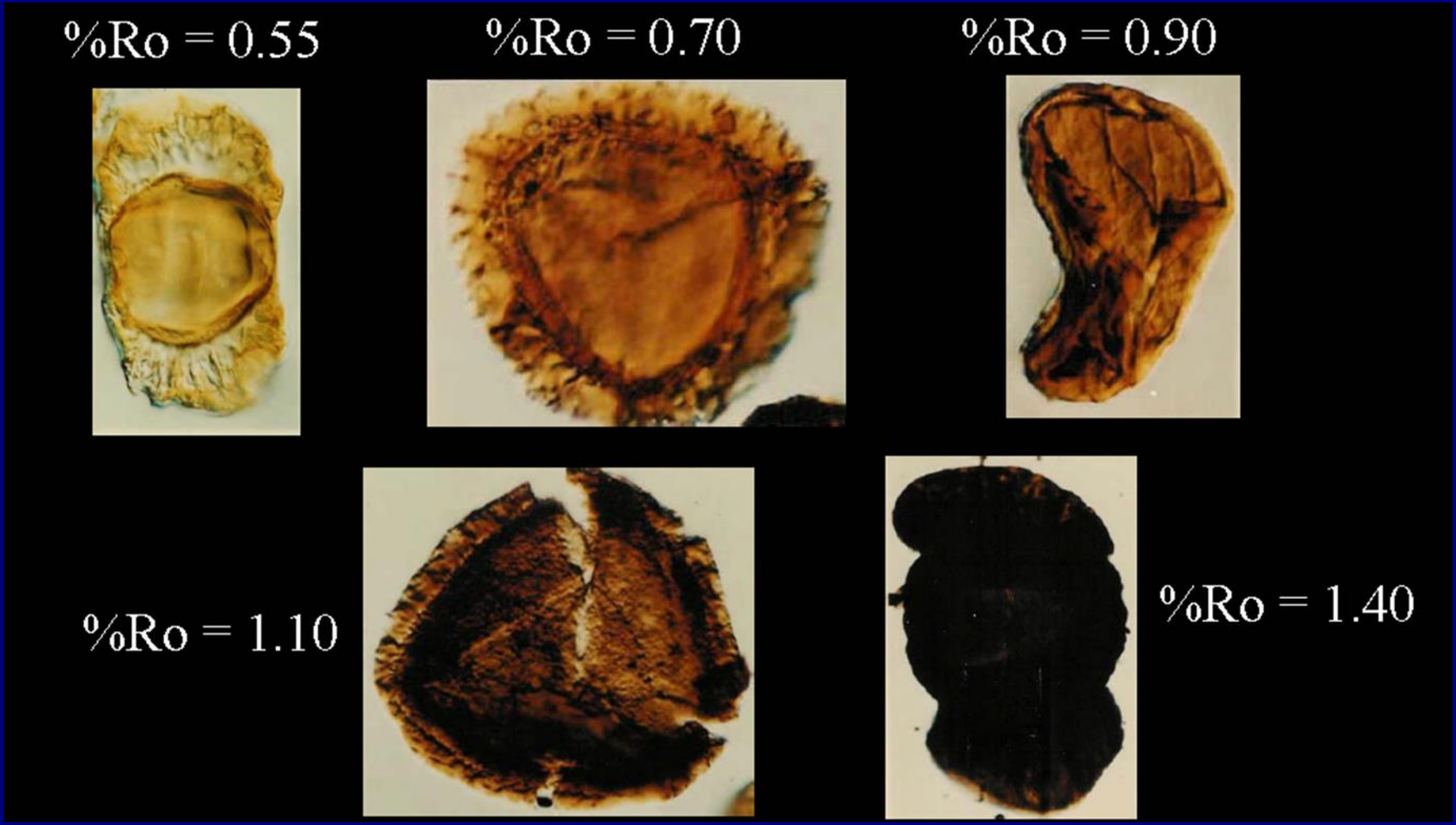



| Oil/Gas Generation |
|---|
| 0.2 – 0.5 Immature |
| 0.5 – 0.7 Early Mature Oil |
| 0.7 – 1.0 Mature Oil |
| 1.0-1.3 Late Mature Oil |
| 1.3 -2.2 Main Gas |
| 2.2 – 3.0 Late Gas |

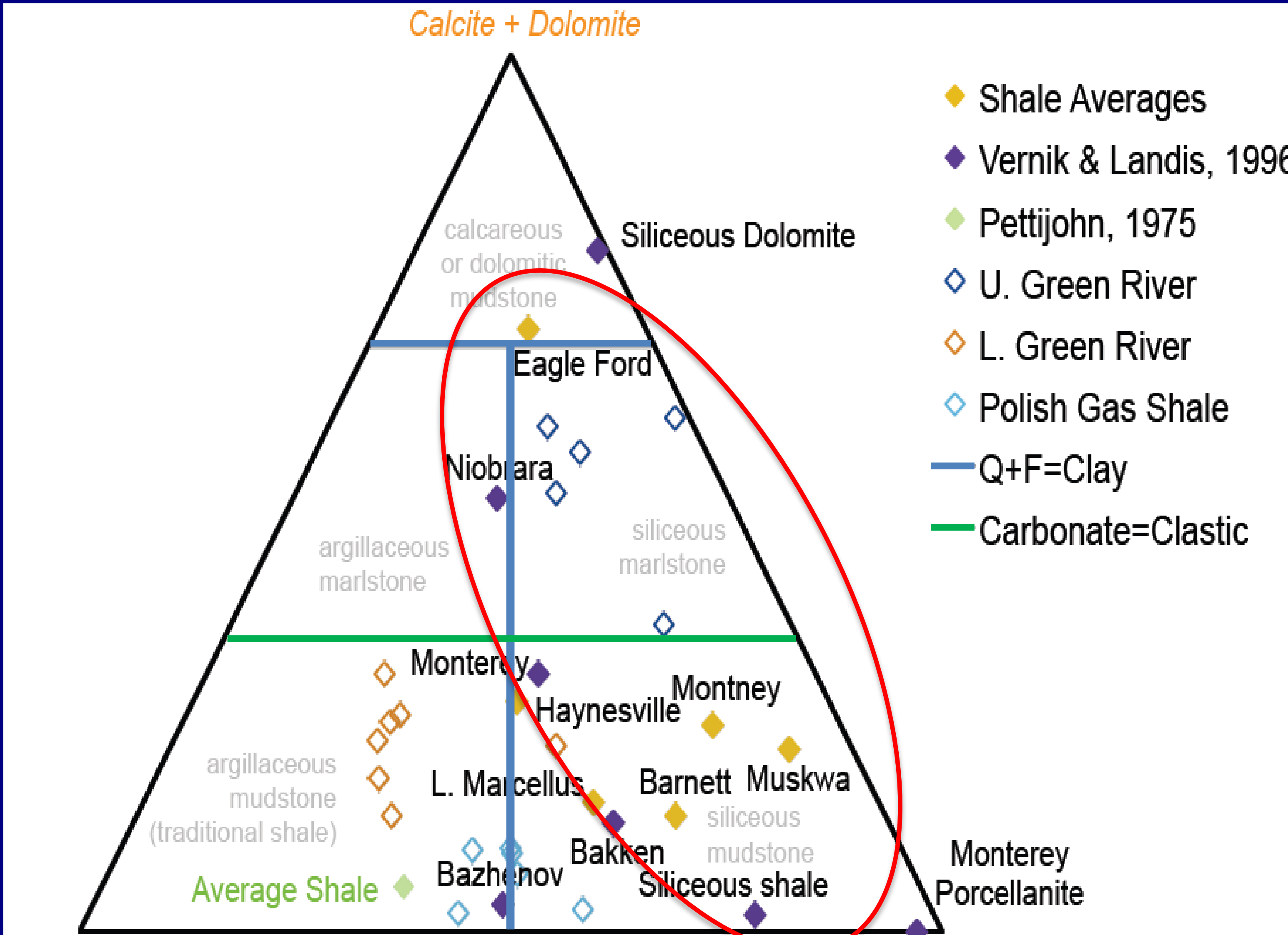
Increased burial depth

# Organic Matter Maturation

## Examples of Vitrinite Reflectivity



# Inorganic Mineralogy
# Ternary diagram of selected shales

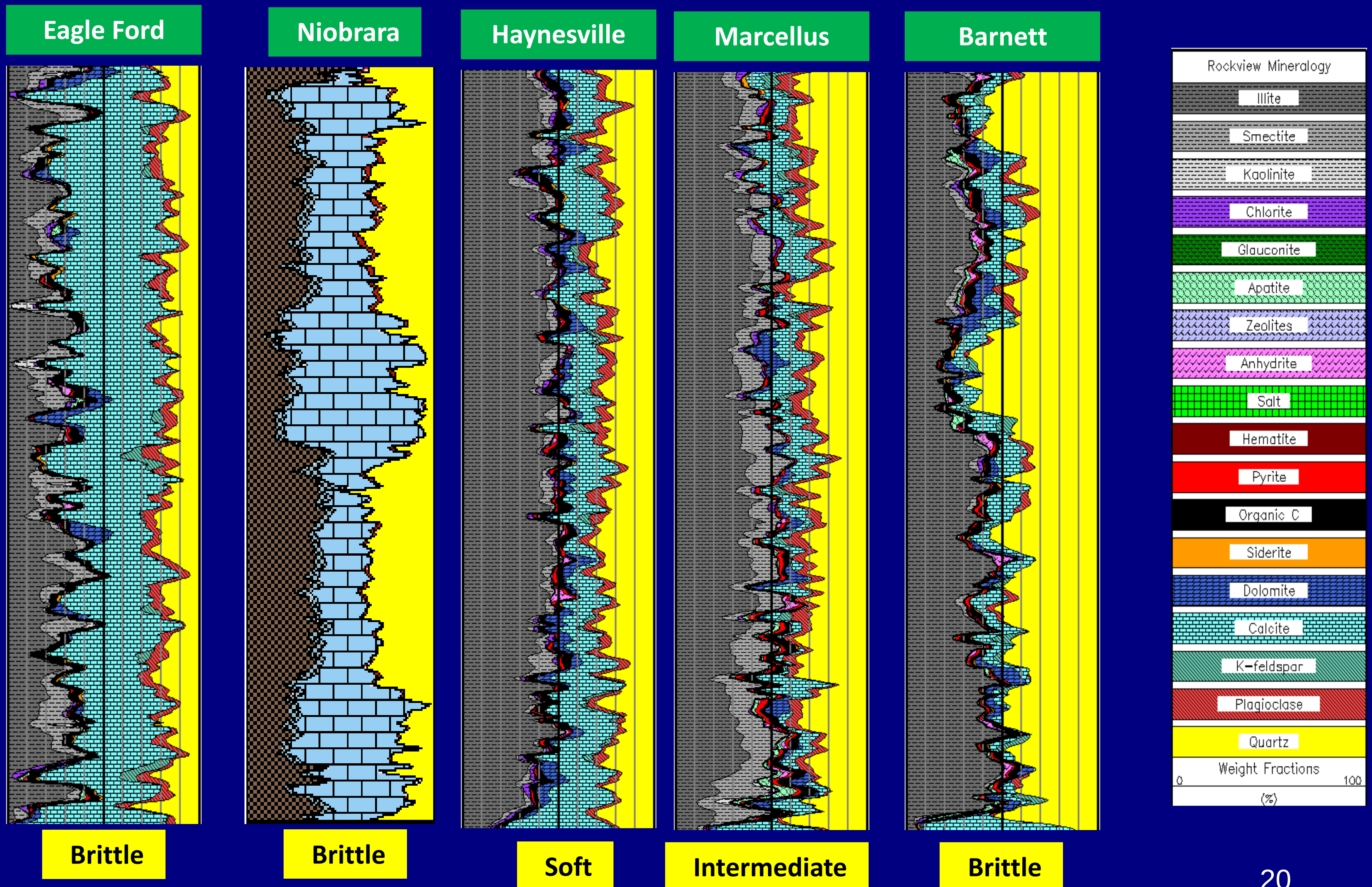



Jeremy Boak, February 2011

# Comparison of Key Geologic Factors

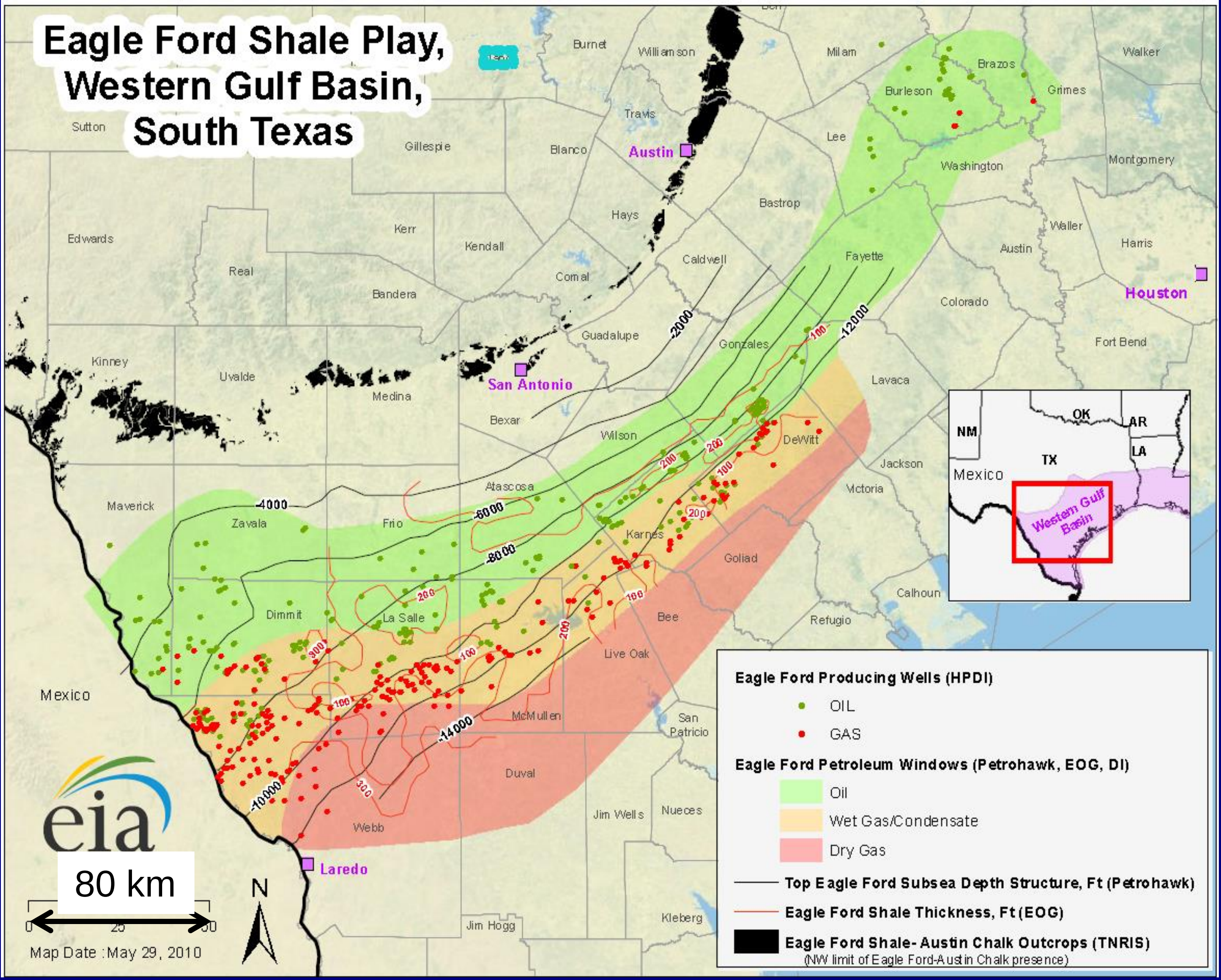
| Shale | Barnett | Eagle Ford | Marcellus |
|---|---|---|---|
| Basin | Ft. Worth | Maverick | Appalachian |
| Age | Miss | U. Cret | Dev |
| Area ($kms^2$) | 13,000 | 9,800 | 245,000 |
| Depth (m) | 1,900-2,500 | 1,200 – 4,500 | 1200 - 2,500 |
| Gross Thickness (m) | 30-180 | 90-145 | 15 -60 |
| Quartz Content % | 41 | 20 | 25 |
| Carbonate Content % | 13 | 67 | 15 |
| Clay Content % | 23 | 7.5 | 45 |
| TOC % | 3.0 - 7.5 | 2.0 - 6.5 | 3 - 12 |
| Ro % | 1.0 - 1.74 | 1.0 - 1.27 | 1.0 -2.5 |
| Porosity % | 4.0 - 9.0 | 3.4 - 14.6 | 10 |
| Pressure Gradient (psi/m) | 1.41 - 1.48 | 1.41 - 1.77 | 1.41 - 1.48 |
| Original GIIP (TCF) | 327 | ND | 1500 |
| IP Rate MMCFD | 2.5 | 7.0 & cond | 3.5 |
| Well Cost $MM | 2.8 | 7.5 | 3.5 |
| Est. EUR/well (BCF) | 2.4 - 3.5 | ~5 | 0.6 - 3.5 |

# Lithologies Vary



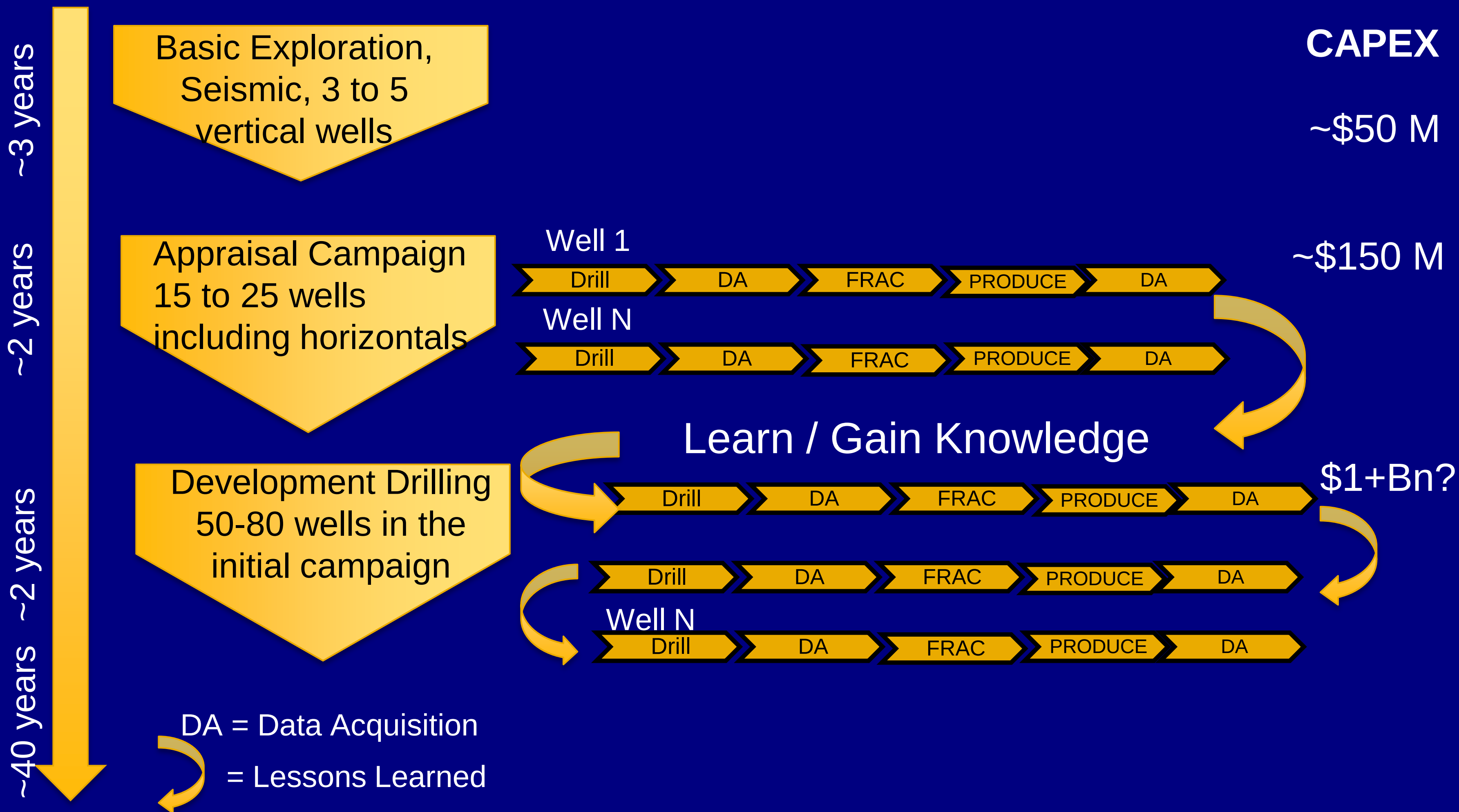
# Eagle Ford shale play

Not only are all shales different but hydrocarbons can also vary



# Unconventional Plays Require Time & Investment

Example Development , $1-2 Bn over 5-7 years for initial campaign




400 km² = 1000 wells = $4 billion = ~$300 MM/yr (15 year program)

# What Else Matters?

It takes more than the right geology to make a shale gas play work

- **Environment**
  - These are long term projects
    - Being a good neighbor is important
- **Water**
  - Each “frac” job requires millions of gallons of water
  - Produced water must be properly recycled / re-used
- **Proppant**
  - Many Tons of proppant are required for each well
  - Logistics

# What Else Matters? continued

- **Infrastructure**
  - Both roads for exploitation activity and pipelines for egress
- **Manpower and Equipment**
  - Requires a large number of trained personnel and
  - A large amount of very specialized equipment
- **Community Support**
  - Long term project requires acceptance by community

# Key Take-aways

- **Shale Gas in North Americas has caused a paradigm shift**
  - Large resource base
  - Low geologic risk
  - Technologically driven
- **Shale Gas is very different from conventional gas plays**
  - Lower geologic risk
  - Requires different exploitation methods
  - Production curves are very different
    - Shale Gas production tends to fall dramatically and then produce for tens of years

# Key Take-aways

- **Shale Gas plays are all different**
  - Lithologic variations
  - Paleo-histories
  - Present environment
- **Variations within a play**
  - Many shale plays have "sweet spots"
    - Data mining is important in defining the most productive areas
- **Evaluation techniques are evolving**
- **But one thing we know:**

**"SHALE GAS PLAYS ARE ALL DIFFERENT"**

# THANK YOU

Typical "Hydraulic Fracturing" treatment in South Texas

• Multiple wells being fracked simultaneously on location
• 4, 4, 5 stages
• 55,200 HHP
• 14.7MM gals fluid (56,000 $m^3$)
• 5.5MM lbs prop (2.5 million kg)

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