"Sweet Spot" Identification and Optimization in Unconventional Reservoirs

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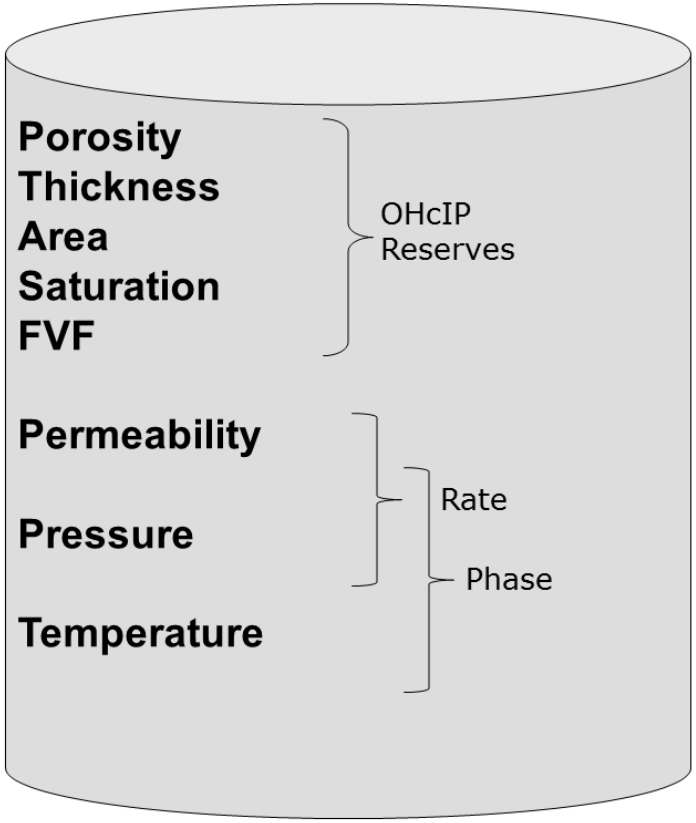
Fundamental Questions

- What is an Unconventional Reservoir?
- How are They Different from Conventional Reservoirs?
- What are the Characteristics that We can Measure?
- Which of Those Characteristics are Really Important?
- What Do We Mean by “Sweet Spot”?

The Difference Between Conventional and Unconventional Reservoirs

Producing Conventional Reservoirs

EARTH
(What can vary)



TOOLS
(What we can vary)

Wellbore Diameter

Well Spacing

Tubing Pressures

Artificial Lift

Enhanced Recovery Mechanisms

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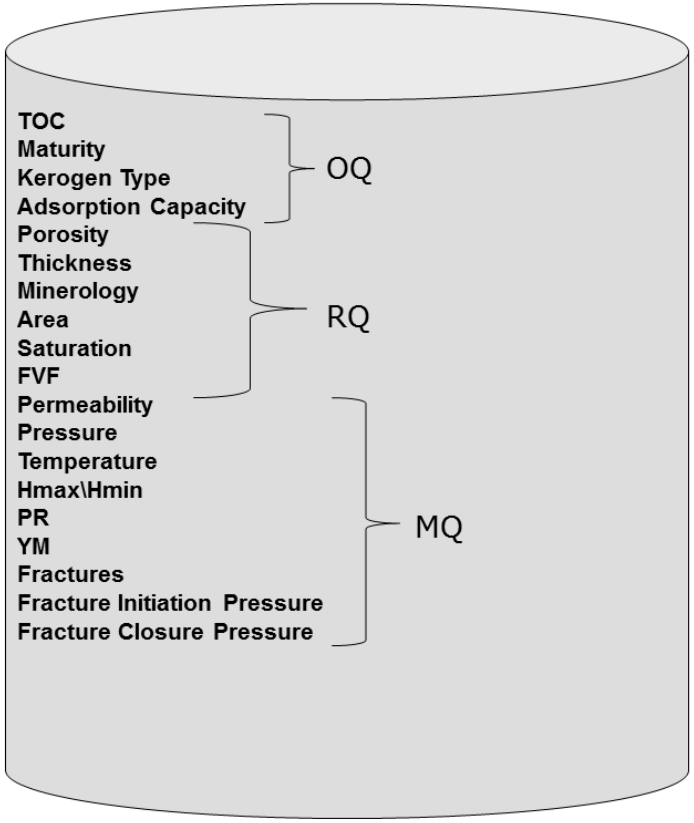
The Difference Between Conventional and Unconventional Reservoirs

Producing Unconventional Reservoirs

EARTH

(What can vary)



TOOLS

(What we can vary)

Horizontal Lateral Length
Perf size
# of perfs\ cluster
# of clusters \ stage
Stage length
Stage spacing
Frac Pressure [> FIP]
Frac Time
Fluid Viscosity
Fluid Slickness
Proppant Size
Amount of Proppant
Uniformity of Proppant
Strength of Proppant
Amount of Frac Fluid

STIMULATED ROCK VOLUME

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What are the Characteristics that We can Measure?

- Many Different Authors have tried to categorize the "productive" shale capabilities
- 2 Primary Approaches
  - Pre-Drill:
  - Post-Drill:
  - Methods vary from using as few as 2 parameters to as many as 14 parameters to define a "Sweet Spot"
- We reviewed papers from most active North American shale plays as well as advanced international shale plays.
- The major papers are summarized in the handout.

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THE 3 "QUALITIES"

ORGANIC QUALITY

TOC *Maturity* *Kerogen Type*
Storage Capacity

ROCK QUALITY

Thickness *Porosity* *Permeability*
Saturation *Mineralogy*

MECHANICAL QUALITY

Poisson's Ratio *Young's Modulus*
Mineralogical Brittleness *Stress* *Pressure*
Fractures

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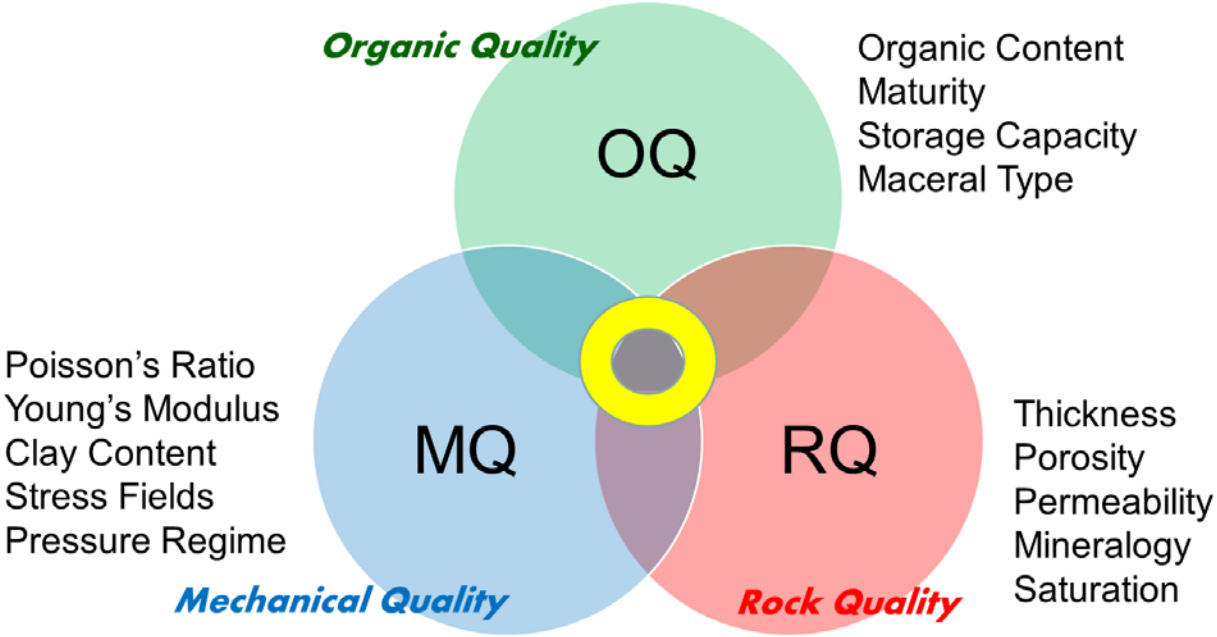
Factors that are needed for Sweet Spot Quantification



FIT FOR PURPOSE OPERATIONS

SUFFICIENT FISCAL ENVIRONMENT

PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT

When there are the optimum factors from all three Qualities then the reservoirs will be in the Sweet Spot

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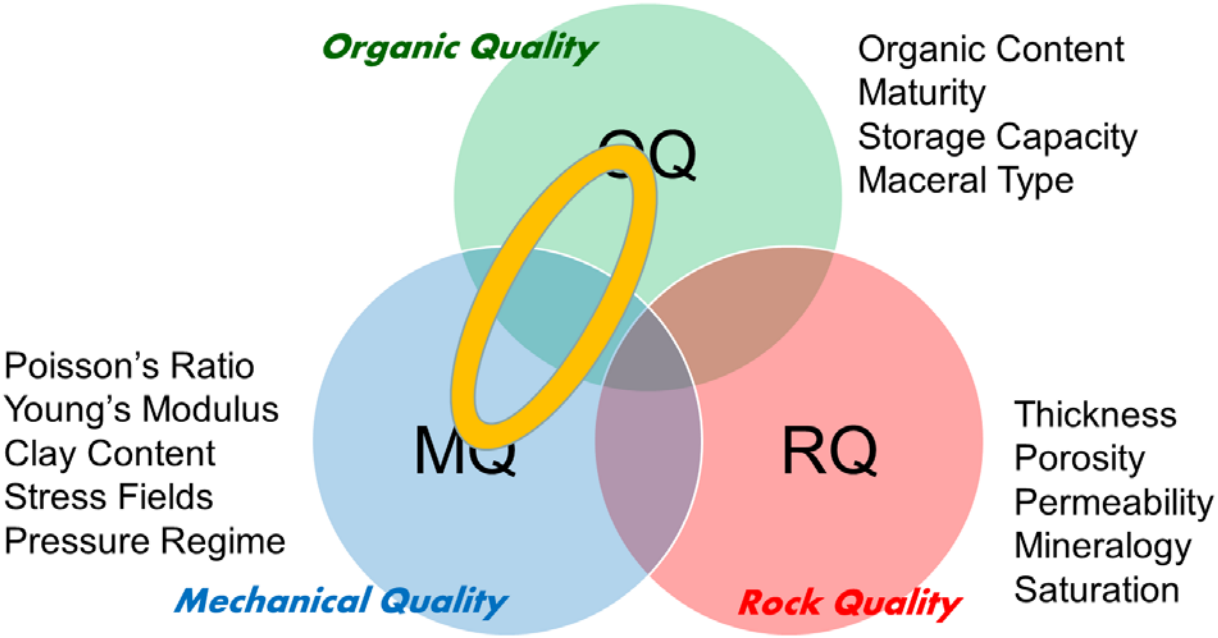
Factors that are needed for Sweet Spot Quantification



FIT FOR PURPOSE OPERATIONS

SUFFICIENT FISCAL ENVIRONMENT

PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT

With No "RQ" there is HC and the rock can be frac'd but it is just a source rock

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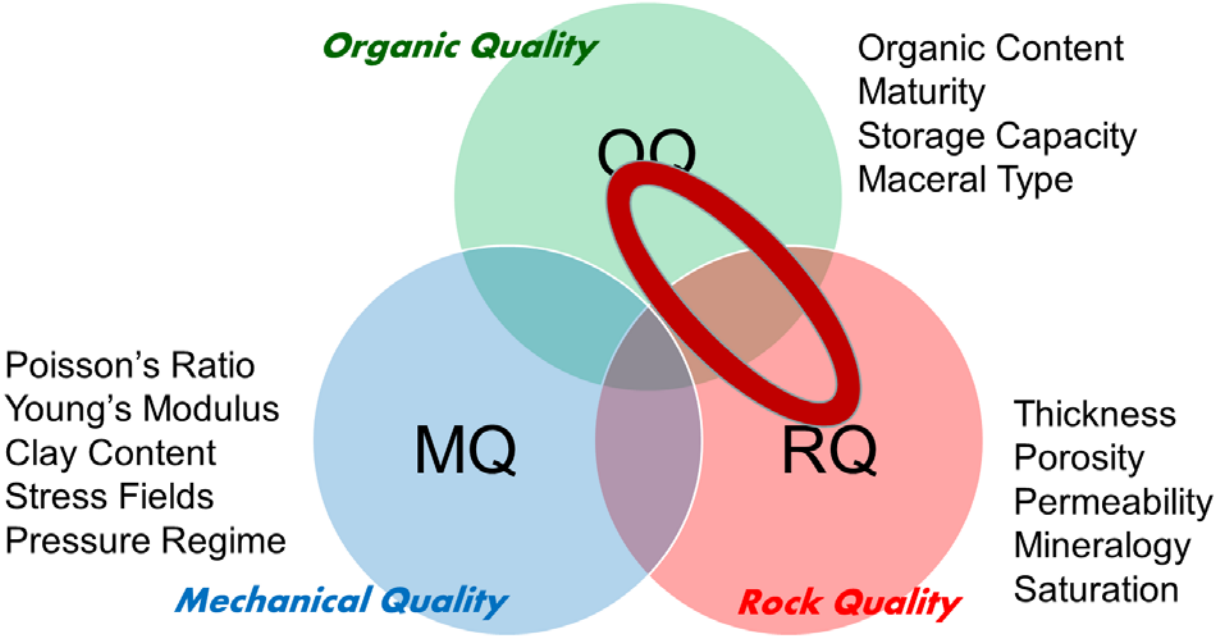
Factors that are needed for Sweet Spot Quantification



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PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT

With No "MQ" there is HC and storage but the rock can't be frac'd so no sustainable production

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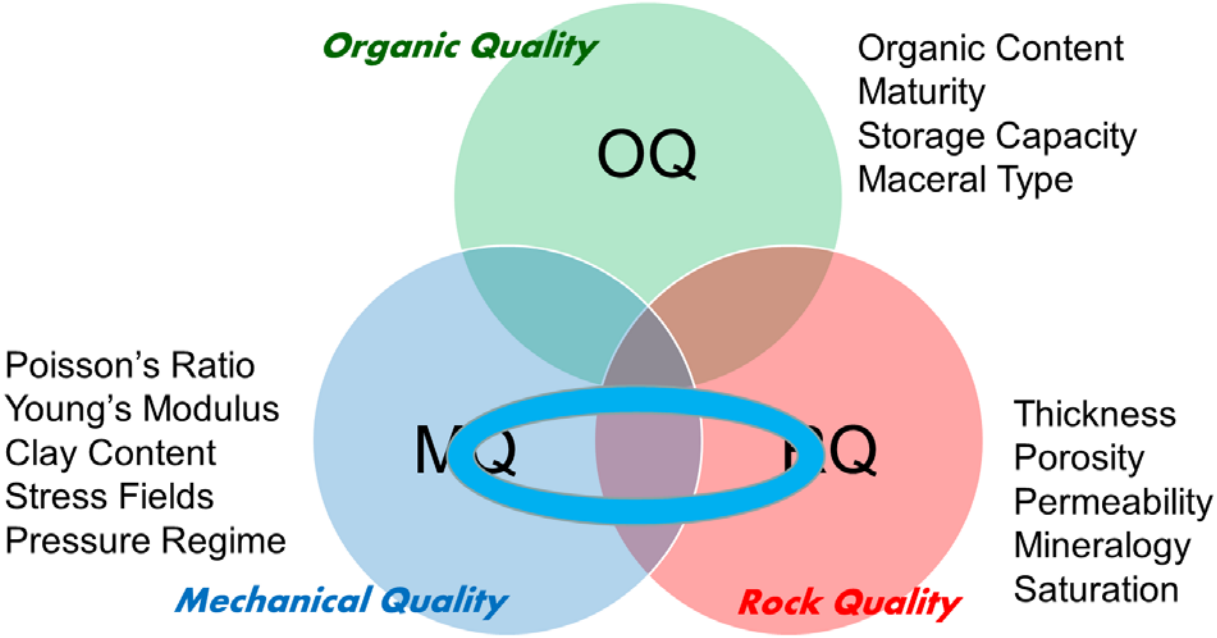
Factors that are needed for Sweet Spot Quantification



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SUFFICIENT FISCAL ENVIRONMENT

PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT

With No "OQ" there is no HC and the rock can be frac'd but it is non-productive

What Can Make a Sweet Spot "Sweet"?

Not Hard Rules – But Guidelines

	Variable	Range for Commercial Shales
OQ	Organic Content	>3% and <12% of correct macerals
	Maturity (Vr_o, Tmax, CAI)	Wet gas or dry gas windows
	Storage Capacity (Langmuir Isotherm, BCF/ac-ft, etc.)	Variable by shale and thickness
RQ	Thickness	>100' and bounded for Frac
	Porosity	>8% - can be much higher
	Permeability	>.001mD – not firm rule
MQ	Clay Content	<40%
	Poisson's Ratio	<.2
	Young's Modulus	>5x10e6
	Pressure	Generally – overpressure is positive

2.1

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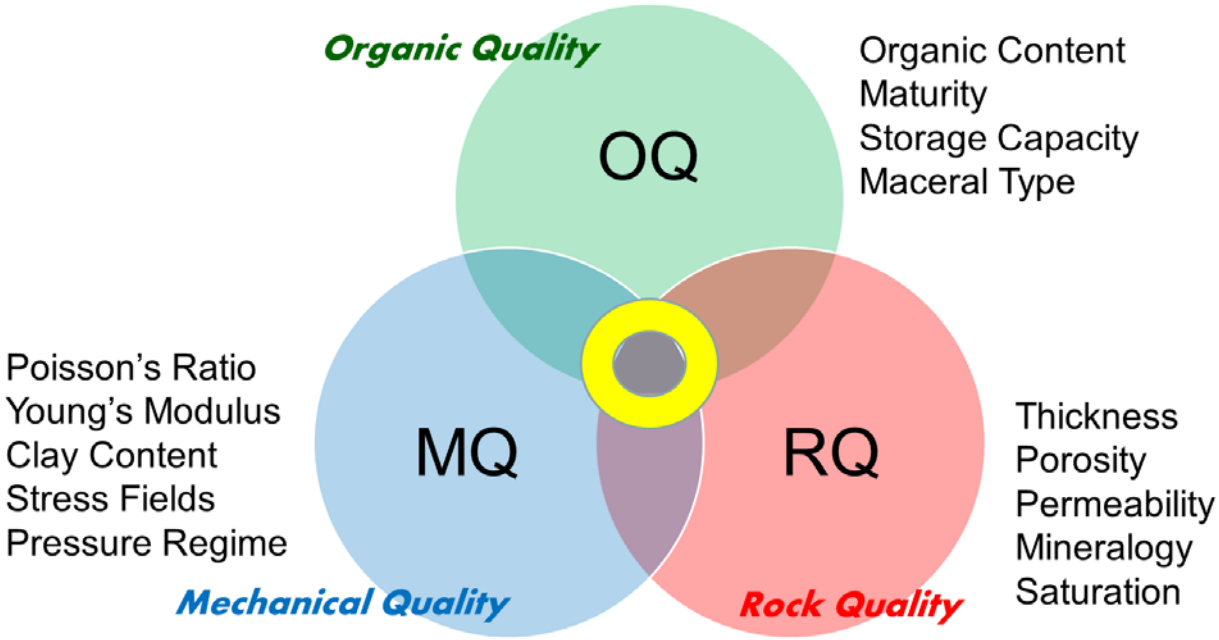
Factors that are needed for Sweet Spot Quantification



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How do we quantify these surface factors?

- If Proper Operations, Fiscal Environment, Regulations are also critical how do we measure or quantify them?
- Is there a Single System?
  - Organic Quality Rock Quality Mechanical Quality
  - Operations Fiscal Regulations

  - Can we get to Commerciality? Economics?

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THE USE OF THE PRMS

The PRMS has both a Commerciality and an Uncertainty measure built into the system. These measures can be used to quantify sweet spots in unconventional reservoirs.

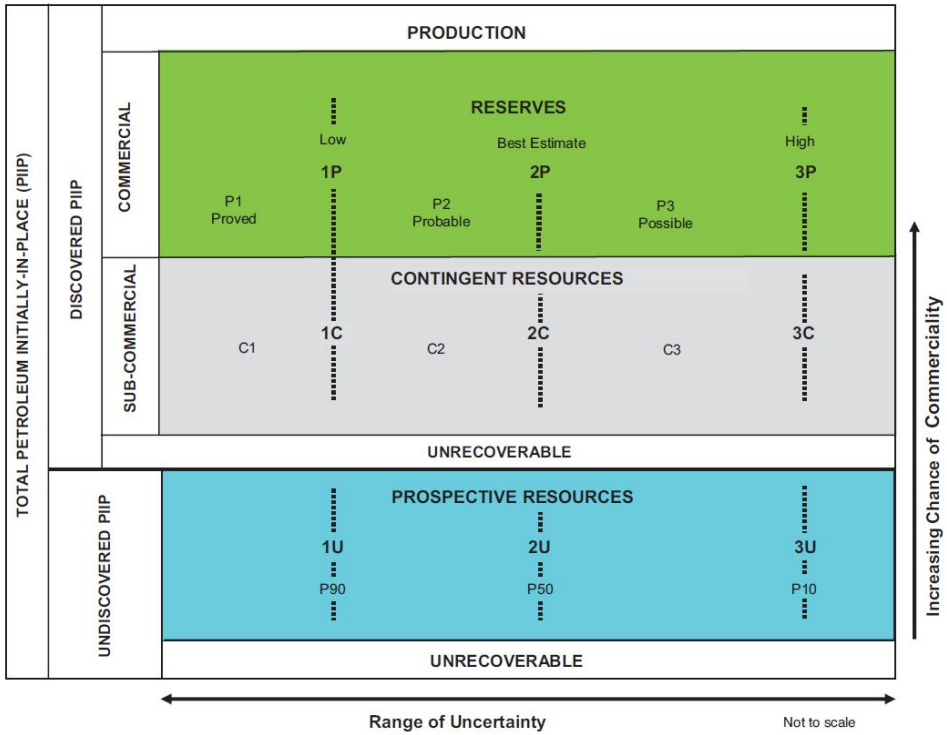

Figure 1.1—Resources classification framework

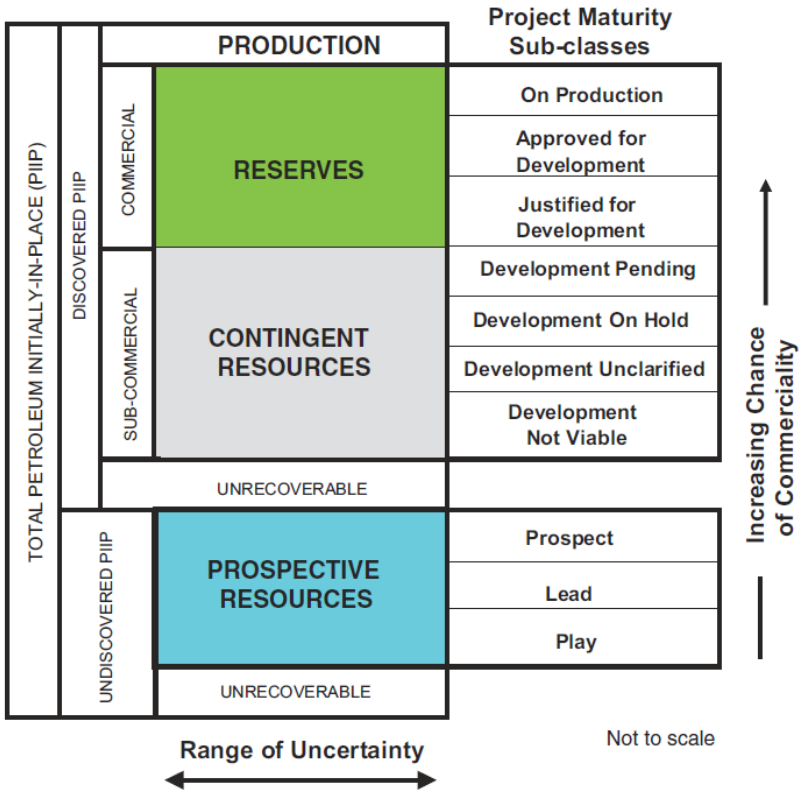

Figure 2.1—Sub-classes based on project maturity

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Reserve Definition for Shales

- Normally by decline curve analysis plus economic analysis to meet threshold values.
  - Commercial Rate
  - Commercial Gas Composition
  - Developable Gas Volume
  - Feasible Development Plan
  - Reasonable Time Frame
  - Viable Market
  - Existing or Imminent Approvals

(Facilities and Volumes and Rate align)

Notice that for Conventional – normally a well test will suffice!

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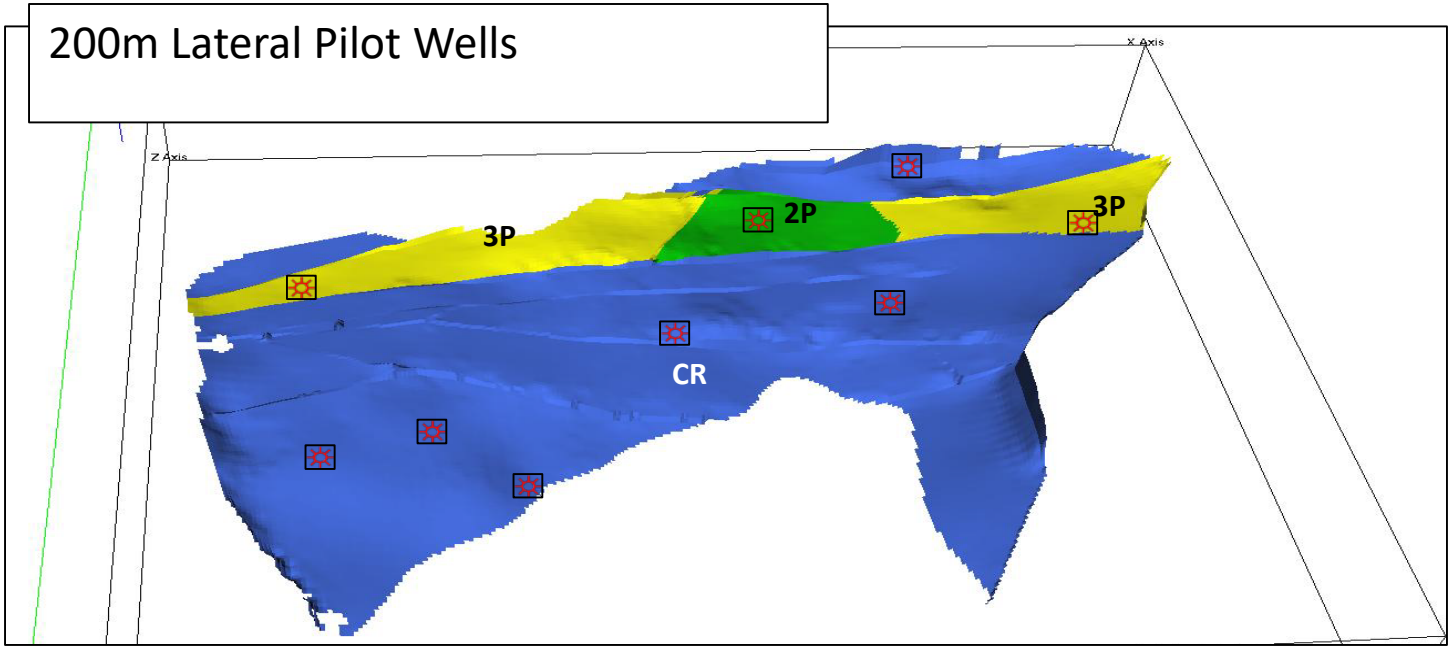
USING THE PRMS

Example where the PRMS can define the "Sweet Spot" on both Commerciality (Reserves) and Uncertainty (Probable vs Possible) within a field at an early stage of development.



Hower, Timothy L., Jeffrey B. Aldrich, Julianna Sipeki. SPE 168809/URTeC 1581734

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Examples of External Impacts on Sweet Spot Area from the Niobrara in the DJ Basin, Colorado

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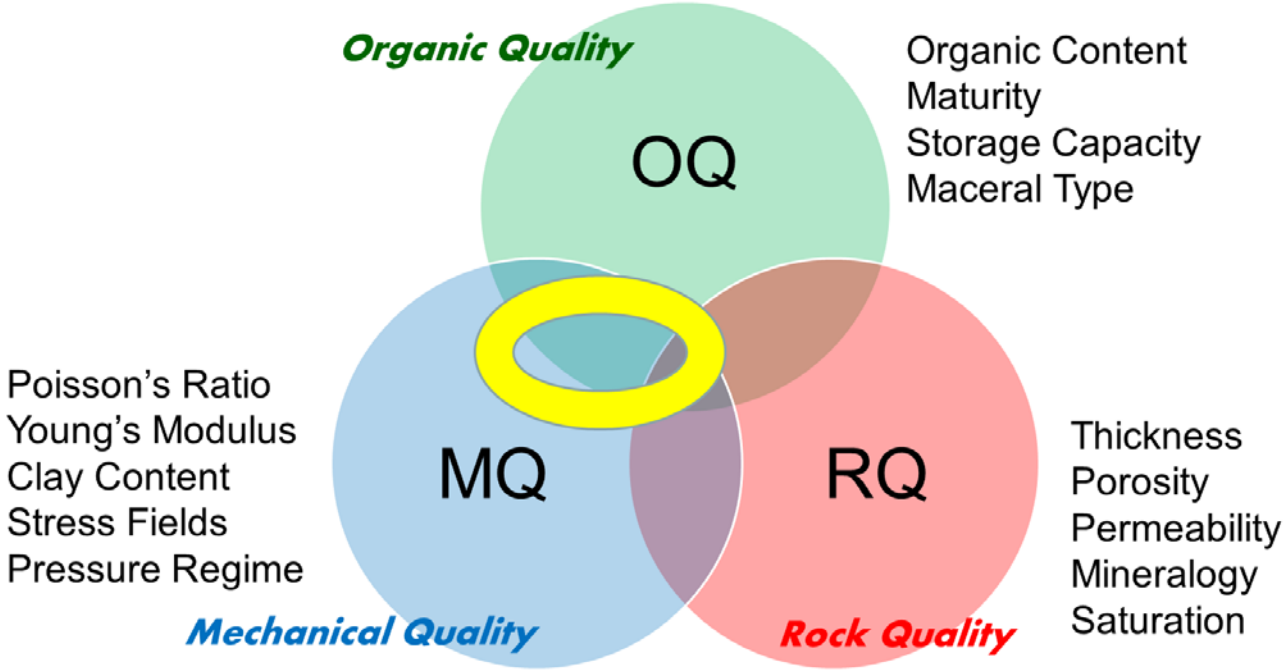
EFFECT OF TECHNOLOGY



FIT FOR PURPOSE OPERATIONS

SUFFICIENT FISCAL ENVIRONMENT

PROPER REGULATIONS AND ENVIRONMENTAL MANAGEMENT

Advent of horizontal wells and MHF opened more rock volume to be commercial reservoir

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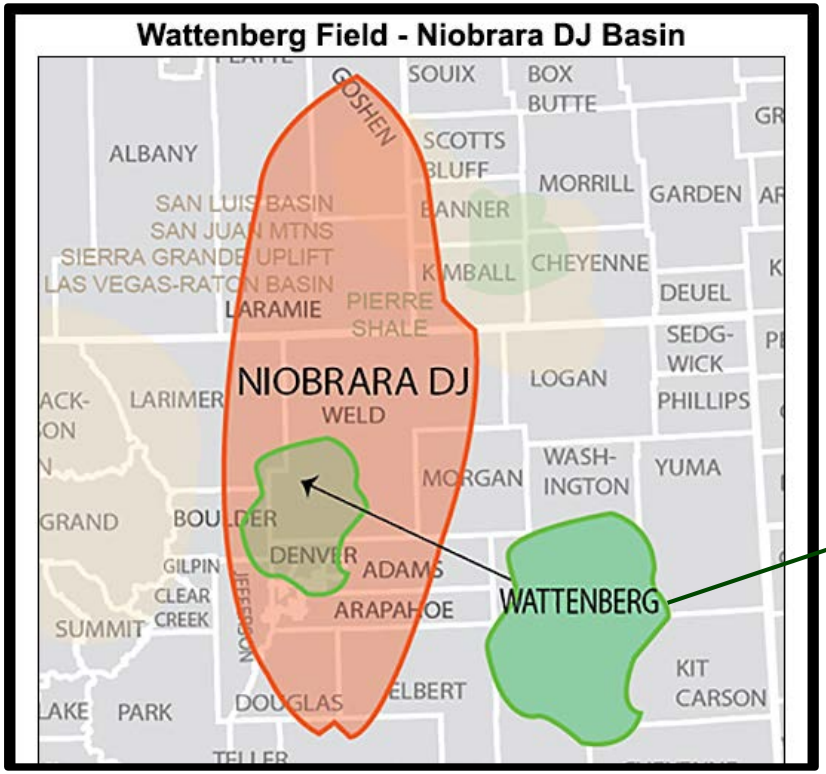
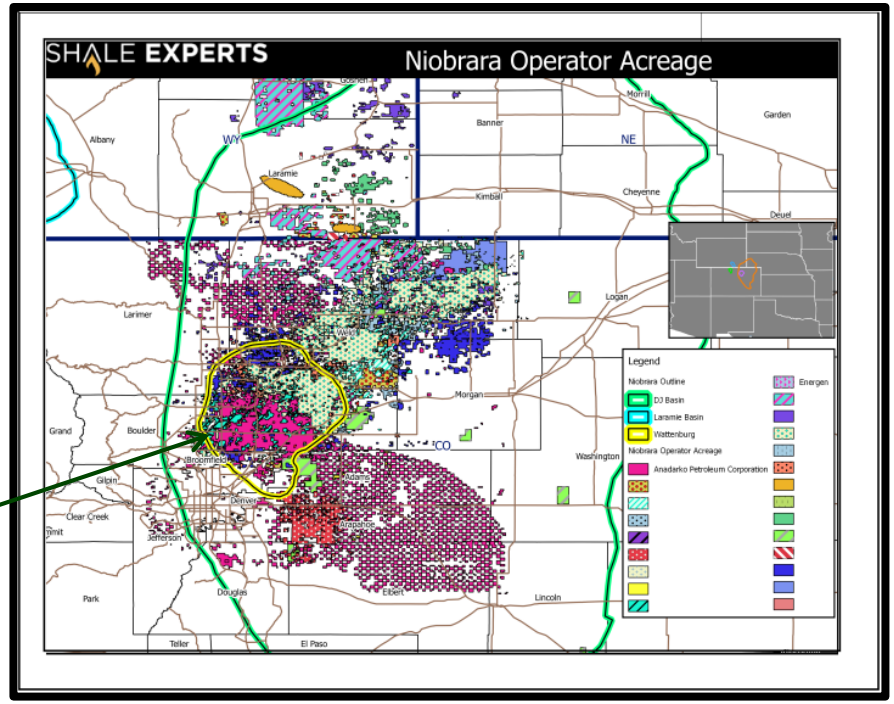
EFFECT OF TECHNOLOGY





NGI's Map of Shale/Resource Plays & North America Pipelines

Extent of Niobrara Production in Wattenberg Field in 1970 vs 2018, vertical vs MHF in horizontal wells

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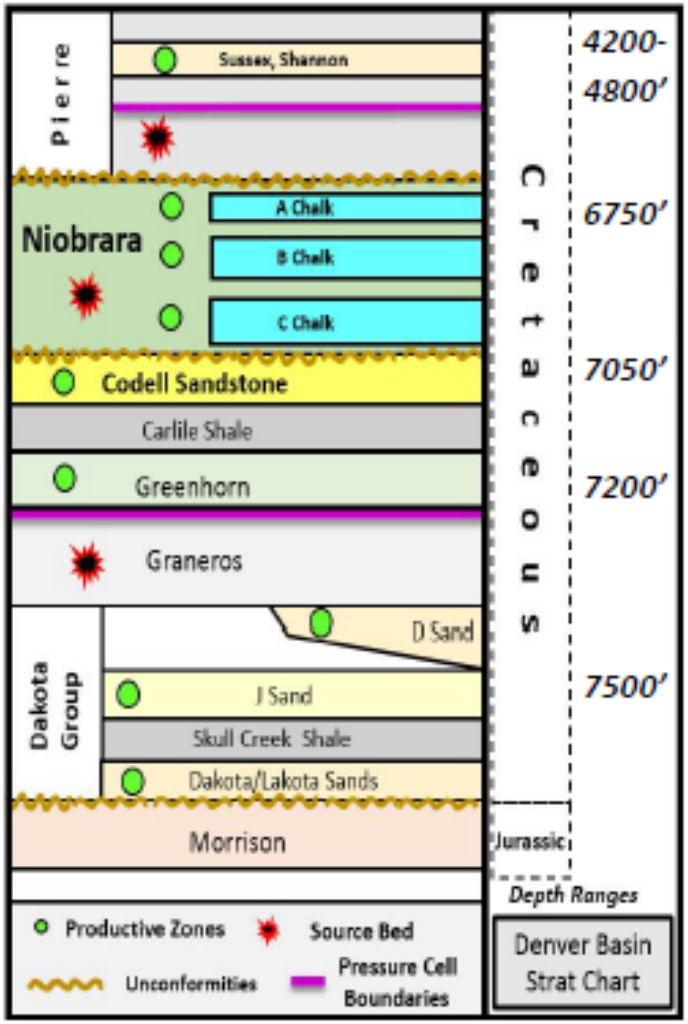
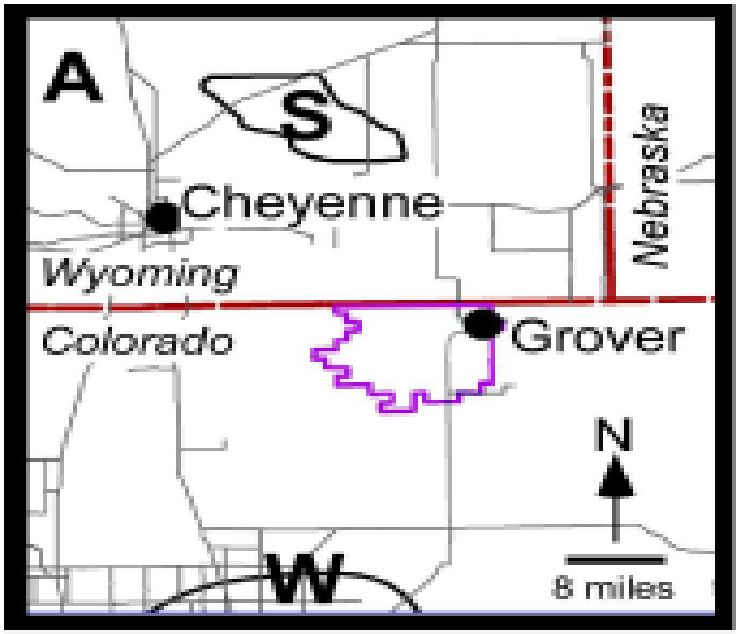
EFFECT OF PRICE





Ref: Anderson, et al, Mountain Geologist, vol. 52, no. 3, July 2015, p 5

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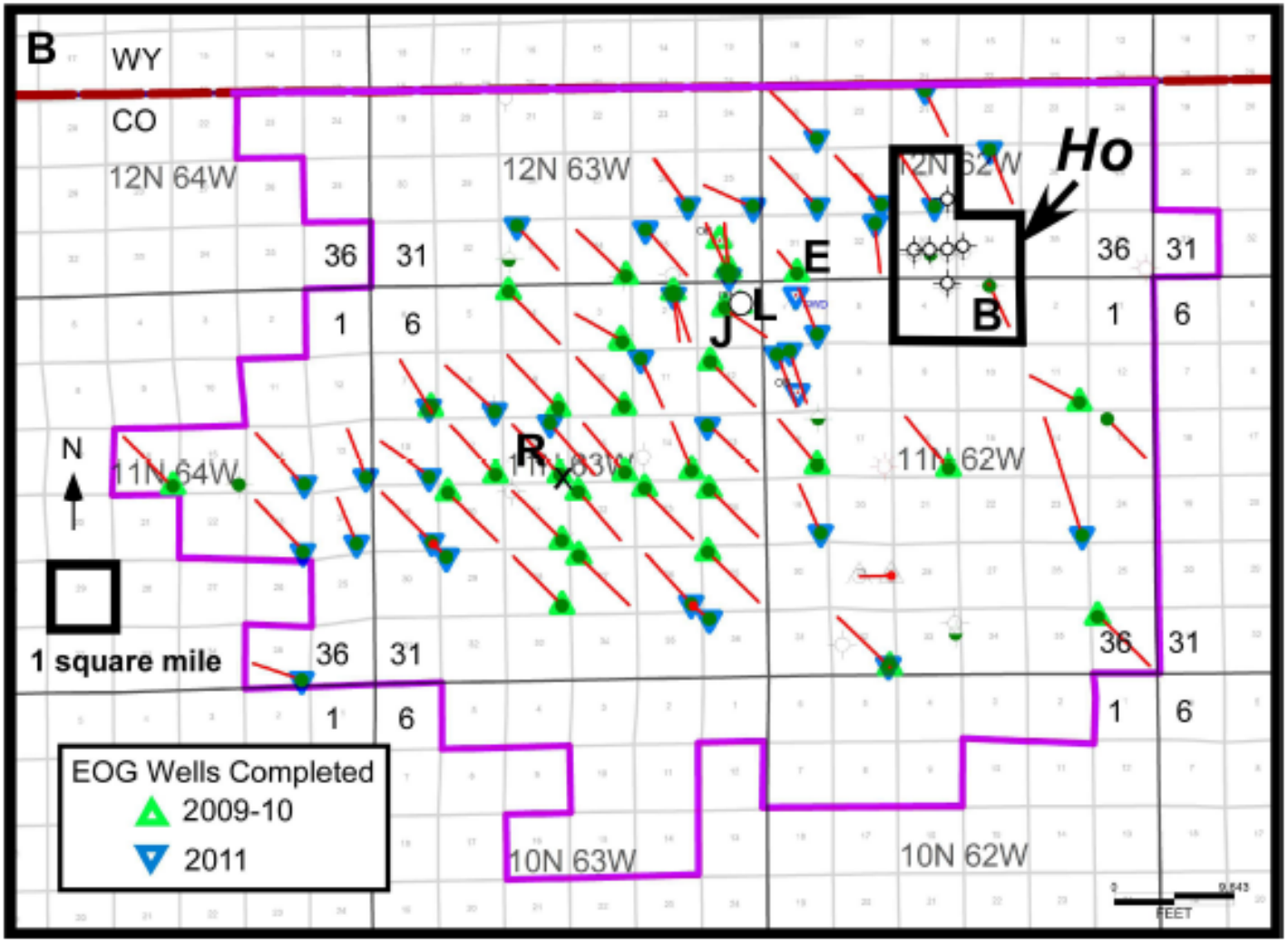
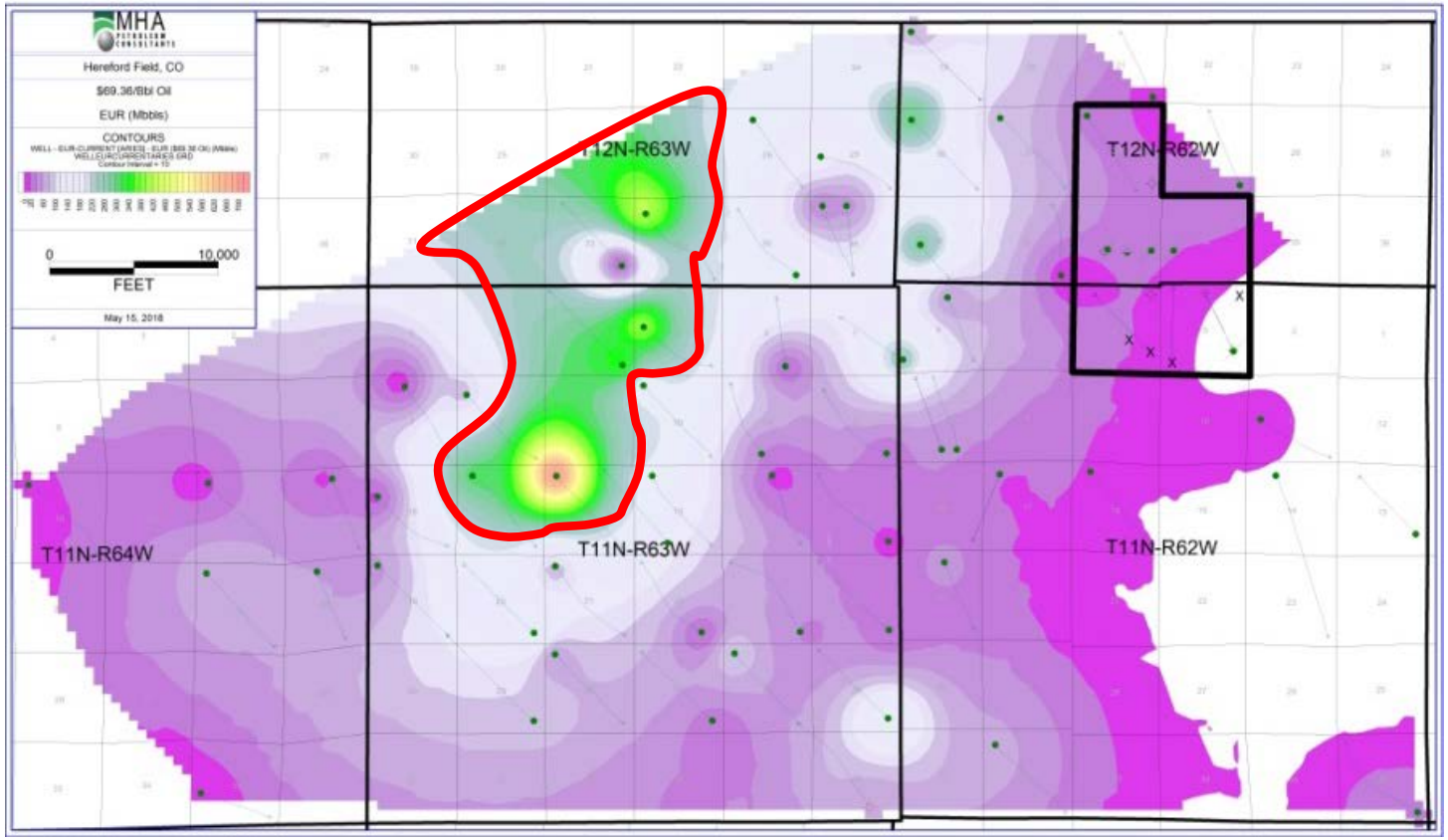
EFFECT OF PRICE



Map of EOG's original field development

EFFECT OF PRICE



EUR's of the original wells

Sweet Spot based on EUR

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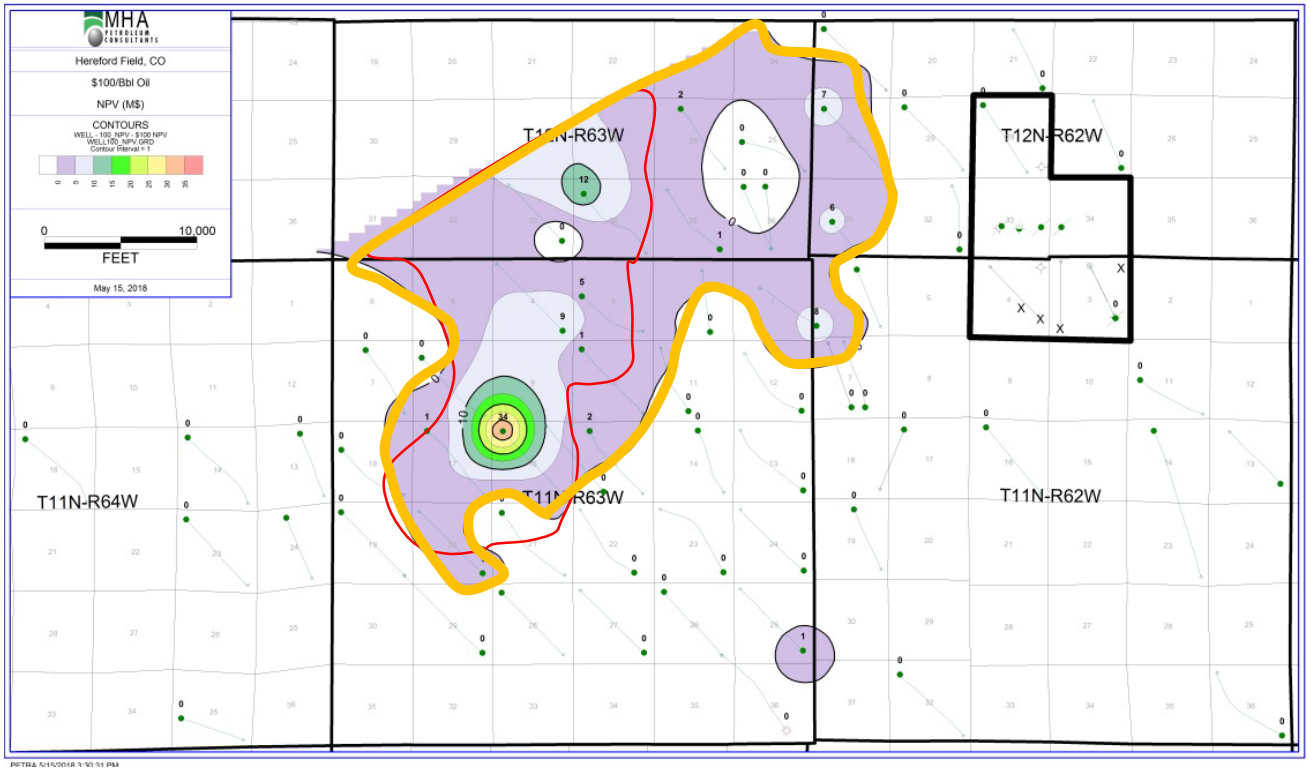
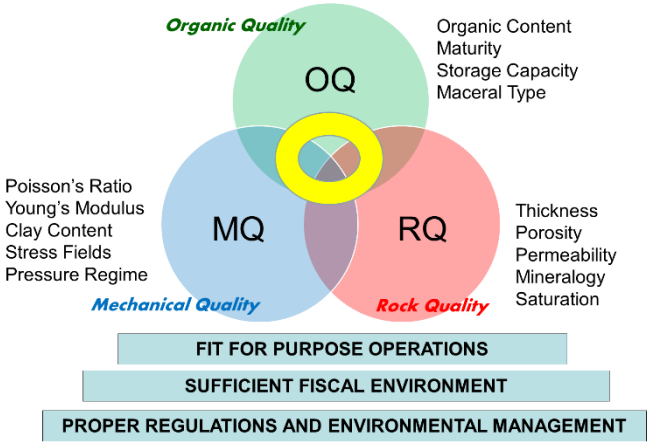
INCREASE IN $$ INCREASES SWEET SPOT



- NPV of the wells at $100/Bbl WTI Price

Sweet Spot based on $100/Bbl



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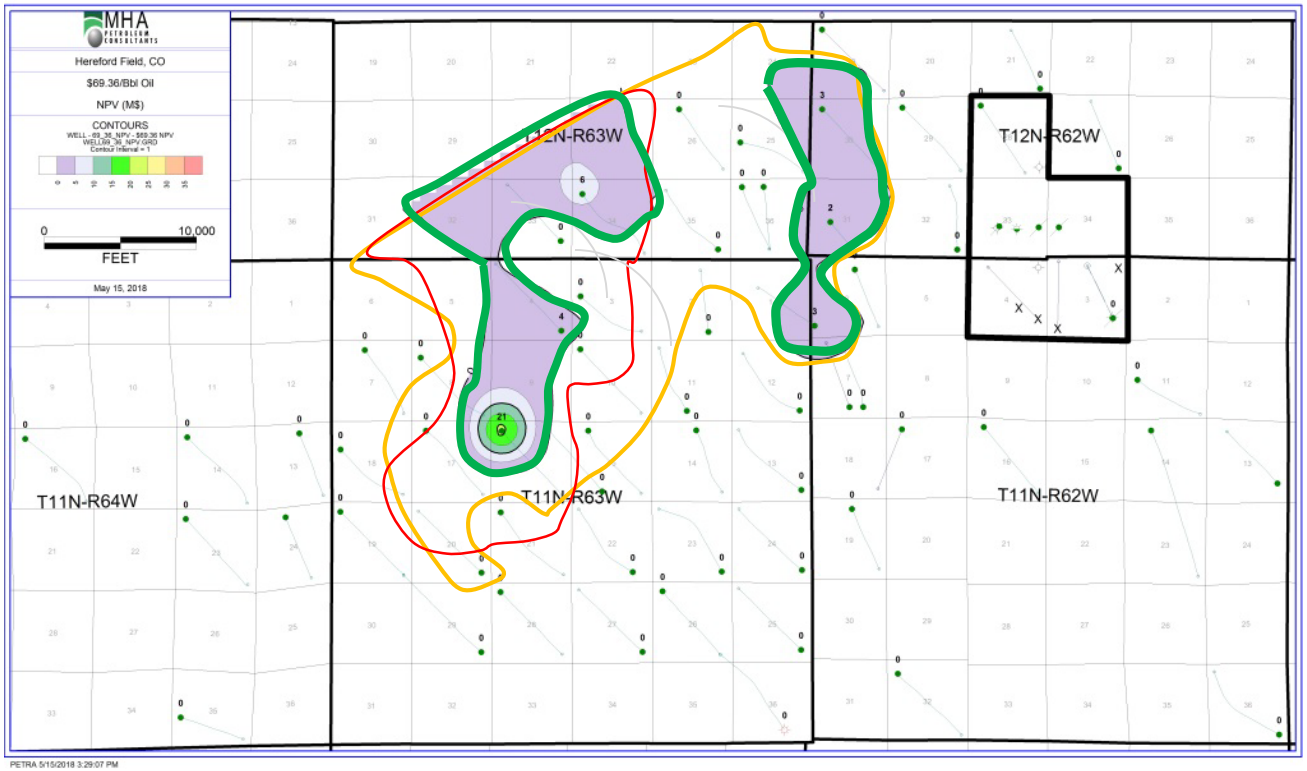
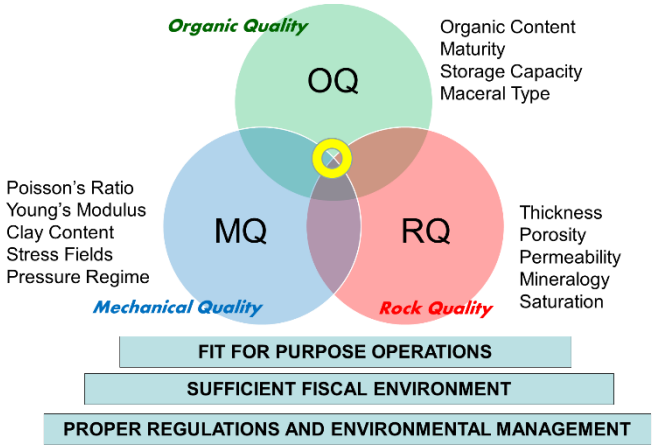
DECREASE IN $$ DECREASES SWEET SPOT



- NPV of the same wells at $69.36 WTI Price

Sweet Spot based on $69.36/Bbl



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KEY TAKE AWAYS

- **Key Take Away #1**
  - **Sub-Surface Productivity Factors (PF) can vary by basin, shale or field but can be subdivided into:**
    - **Organic Quality Factors (OQ)**
    - **Rock Quality Factors (RQ) and**
    - **Mechanical Quality Factors (MQ).**

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Key Take Aways

- **Key Take Away #2**
  - **Sweet Spot quantification needs to include commercial terms:**
    - **Operations**
    - **Fiscal**
    - **Regulations**

    and the AAPG-SPE PRMS has the built-in tools for quantification of both commerciality and uncertainty.

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Key Take Aways

- **Key Take Away #3**
  - **Due to above ground factors of:**
    - **commodity price**
    - **Drilling and Completion efficiency**
    - **Regulations and**
    - **Societal challenges**

    "Sweet Spots" are not static but change over time.

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ACKNOWLEGEMENTS

Appreciation goes to MHA Petroleum Consultants for the time and material used in this presentation.

The authors would like to offer special thanks to Mrs. Shawna Harrison, Jessica Davey, and Traci Paine for their hard work in helping us prepare this presentation.

MAY I MAKE A RECOMMENDATION?

- **DENVER INTERNATIONAL PETROLEUM SOCIETY (DIPS)**
  - Meets the 2nd Friday of every month at the Wyncoop Brewery
    - September – May
  - **You will not always work your current basin for the rest of your career!**
  - The lowest cost geoscience lunch, the most fascinating geology!
  - Walk-ins welcome
  - Contact Kurt.Reisser@gmail.com to get on mailing list

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"Sweet Spot" Identification and Optimization in Unconventional Reservoirs

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Literature Review

			Organic Quality					Rock Quality				Mechanical Quality						
			TOC	Maturity	Kerogen Type	Storage Capacity	Height	Porosity	Permeability	Saturation	Mineralogy	Mechanical Brittleness		Mineralogical Brittleness	Brittleness	Stress Fields	Pressure	Fractures
												Poisson's Ratio	Young's Modulus	Clay Content				
Sena, et.al.	Seismic Reservoir Characterization in Resource Shale Plays: "Sweet Spot" Discrimination and Optimization of Horizontal Well Placement	SEG 2011 Annual Meeting, San Antonio						X		X	X	X	X			X	X	
Van Hoeve, Meyer, Preusser, Makowitz	Basinwide Delineation of Gas-shale "Sweet Spots" Using Density and Neutron Logs: Implications for Qualitative and Quantitative Assessment of Gas-shale Resources	AAPG Memoir 103: Critical Assessment of Shale Resource Plays, Chapter 9, PP 151-165, 2013					X	X										
Glaser, et. Al.	Seeking the Sweet Spot: Reservoir and Completion Quality in Organic Shales	Olfield Review, Winter 2013/2014 pp16-29	X	X			X	X		X	X	X	X	X	X	X		X
Algarhy, Soliman, Bateman, Asquith	Shale Gas Plays Screening Criteria, "A Sweet Spot Evaluation Methodology"	Fracturing Impacts & Technologies Conference, Texas Tech Univ, 2014	X	X		X	X	X									X	
Brian Toelle	Shale Sweet Spot Detection with Surface Seismic	SPE Distingushed Lecturer Program (2014?)	X	X				X										X
Kormaksson, Vieira, Zadrozny	A Data Driven Method for Sweet Spot Identification in Shale Plays using Well Log Data	SPE-173455-MS, 2015										X	X			X		X
Altamar and Marfurt	Identification of Brittle/Ductile Areas in Unconventional Reservoirs using Seismic and Microseismic Data: Application to the Barnett Shale	SEG Interpretation, Nov, 2015 T233								X				X	X			X
Renfang, Qin, Jie, Jineng	Elements and Gas Enrichment Laws of Sweet Spots in Shale Gas Reservoir: Case Study of the Longmaxi Fm in Changning Block, Sichuan Basin	Natural Gas Industry, B3, 2016, pp 196-201	X	X	X	X	X	X	X		X				X		X	X
Dotsey	Logs Reveal Marcellus Sweet Spots	AOGR, 3-3M, T1, A2	X				X	X										
Naizehen Liu, Guoyang Wang	Shale Gas Sweet Spot Identification and Precise Geo-steering drilling in Weiyuan Block of Sichuan Basin, SW China	Petroleum Exploration and Development V43, Is 6, Dec 2016	X				X	X	X						X			X
Chopram Sharma, Nemati and Keay	Organically Rich Sweet Spot Determination in Utica Shale	Search and Discovery, Article #42137, 2017	X					X							X			
Tahmasebi, Javadpour, Sahimi	Data Mining and Machine Learning for Identifying Sweet Spots in Shale Reservoirs	Expert Systems with Applications, Vol 88, Issue C, Dec 2017, pp 435-447.	X												X			

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