Source Rock Evaluation Technique: A Probabilistic Approach for Determining Hydrocarbon Generation Potential and In-Place Volume for Shale Plays*

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Abstract

The hydrocarbon generation potential of a source rock is a calculated volume that utilizes multiple rock properties including gross rock volume, total organic carbon, kerogen type, and pyrolysis parameters. Here we detail a probabilistic workflow to the generation potential calculation, using Monte Carlo simulation of the modified Schmoker (1994) equation with a distribution of values for each input parameter. This methodology can be an important component in identifying prospective shale plays for oil and gas production, and can be compared against traditionally calculated hydrocarbons-in-place as a screening tool for ranking prospects. Specifically, traditional oil-in-place calculations for shale plays, due to uncertainties in porosity and fluid saturation, may overestimate available resources that can be estimated independently by calculating oil generation potential. The comparison of the two calculations can provide valuable insight into the volume of oil that can be generated and stored within a source rock interval and adjacent reservoirs.

In a test of the probabilistic workflow, we use source rock data from the Upper Cretaceous Niobrara Formation and evaluate the results in comparison to horizontal Niobrara production at Silo Field, Wyoming, USA. The simulation outputs show that the Niobrara Formation in Silo Field has the potential to generate a mean resource of 29 million barrels of oil equivalent (MMBOE) of hydrocarbons per square mile, and store a mean of 21 MMBOE per square mile. A calculated net resource of 140 thousand barrels of oil equivalent per well closely approximates historical production for unstimulated, horizontal Niobrara wells at Silo Field.

We then apply the methodology to Ordovician and Silurian source rocks in Poland to determine source rock quality, and compare calculated generation potential against traditional volumetric in-place calculations. The results indicate the potential for significant resources in shale plays and can be used as screening criteria for ranking various acreage positions.

Determining generation potential provides a first step in understanding resource distribution by validating traditional in-place calculations. An integrated, probabilistic approach is crucial in areas where individual rock properties are inadequate indicators of source rock quality. To be truly robust, this method must incorporate resource preservation, migration, and flow characteristics to determine ultimate recoverability.

References

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SOURCE ROCK EVALUATION TECHNIQUE

A Probabilistic Approach for Determining Hydrocarbon Generation Potential and In-Place Volume for Shale Plays

Vitaly Kuchinskiy, Keith Gentry, Ron Hill

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Marathon Oil Corporation™

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…as well as everyone else in the Marathon Oil Poland and DJ Basin exploration teams.

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CONTENT

- Work scope/workflow
- Estimating hydrocarbon generation
- Retaining factor (from generated potential to in-place resource)
- Preservation chance (containment risk)
- Probabilistic modelling
- Case study: Early exploration, Poland unconventional
- Case study: Mature field, Silo Field Niobrara
- Summary & Conclusions

WORK SCOPE

The workflow integrates probabilistic calculations of hydrocarbon generation potential with in-place resource calculations and risking. It may serve for:

- **VALIDATION:** Source rock quality is adequate for generation of significant hydrocarbon volumes; requires integration of ALL available source rock data in to appropriate "prospect"-level maps and correlation panels
- **PRIORITIZATION:** Can be used as an "early" screening tool for assessment and/or ranking of acreage blocks; largely based on HC/acre yield in a given area

"Hard Data" Analysis

- **RESOURCE POTENTIAL ASSESEMENT:** Use estimates of reservoir quality (i.e. retaining factor) and apply recovery factor to develop potential in-place volumes and recoverable resources
- **RISKING:** Apply subjective factors such as "Tectonic history" and "Existing Field data" to further refine the "hard data" prioritization and assess containment risk

"Subjective Data" Analysis

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WORKFLOW

Log Analysis, Correlation, Mapping → Thickness, $TOC_{original}$

Source Rock Analysis → $TOC_{original}$, $(HI_{original} - HI_{present})$

Generated Hydrocarbon modified from Schmoker, 1994

$$M_{HC} = (Area * Thickness * \rho_{bulk}) * TOC_{original} * (HI_{original} - HI_{present})$$

$TOC_{original}$ = original total organic carbon

HI = hydrogen index (S2*100/TOC), mg of HC generated from gram of TOC

Storage Capacity Adsorbed Amount → Retaining Factor

Analog Data → Recovery Factor

Recoverable Resources

Recoverable Resources= V_{HC}* Retaining Factor * Recovery Factor

M_{HC} converted to volume (V_{HC})

oil system: use BOE to account for volume of gas generated at onset of oil generation (early maturity)

gas system: incorporate hydrogen-deficiency coefficient for oil-gas conversion (0.53 from Jarvie, 2010)

Retaining Factor: percentage of generated HC which is preserved inside of the source rock interval or adjacent reservoirs

Well Data → Seal Presence

Basin Modeling → Burial History

Regional Study → Existing Fields

Risking

Preservation Chance = Retaining Factor * Seal Presence * ((Burial History + Existing Fields)/2)

Preservation Chance: chance for generated HC to be preserved inside of the source rock interval or adjacent reservoirs

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Presenter's Notes: Mass to volume conversion: 6.58 bbl/tonne

GENERATED HYDROCARBON ESTIMATION

The Calculation Workflow

Generated Hydrocarbon from modified Schmoker equation, 1994

$$M_{HC} = (\text{Area} * \text{Thickness} * \rho_{bulk}) * TOC_{original} * (HI_{original} - HI_{present})$$

- **AREA:** license block, development area, area with specific maturity level, etc
- **THICKNESS**: identified source rock intervals; required to accurately average TOC data
- **BULK DENSITY (ρ_{bulk}):** has to be established for each of defined source rock intervals
- **$TOC_{original}$:** can be calculated from Peters (2005) or Jarvie (2007) formulas

$$TOC_{org} = \frac{83.33(HI_{pd})(TOC_{pd})}{HI_{org}(1-f)(83.33 - TOC_{pd}) + HI_{pd}(TOC_{pd})}$$

Peters, 2005

$$f = 1 - \frac{\mathrm{HI_{pd}}\left(1200 - \left(\frac{\mathrm{HI_{org}}}{1-\mathrm{PI_{org}}}\right)\right)}{\mathrm{HI_{org}}\left(1200 - \left(\frac{\mathrm{HI_{pd}}}{1-\mathrm{PI_{pd}}}\right)\right)}$$

f- transformation or conversion ratio calculated from HI_{org} and HI_{pd}

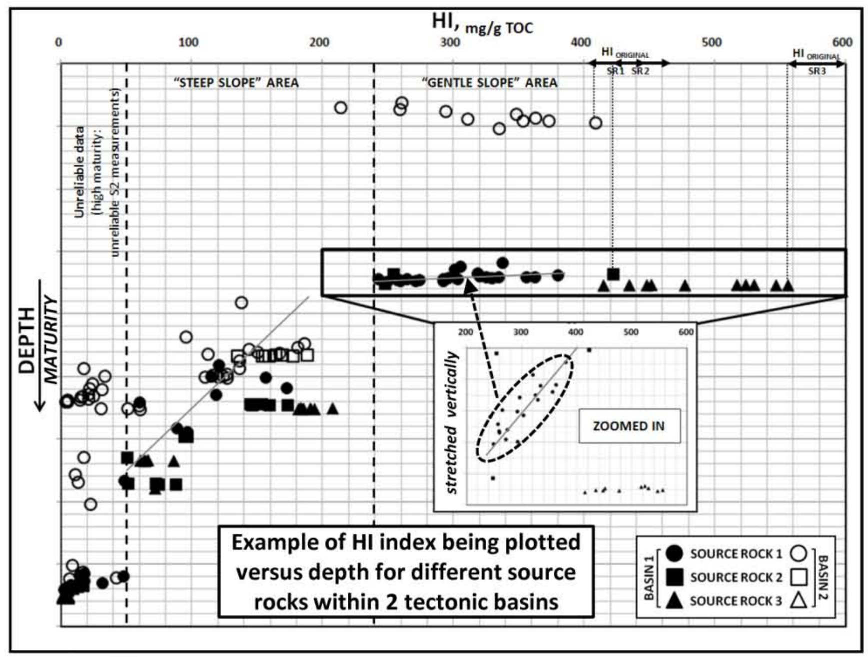
1200 is the maximum amount of hydrocarbons that could be formed assuming 83.33% carbon in hydrocarbons

83.33 is the average carbon content in hydrocarbons and *k* is a correction factor based on residual organic carbon being enriched in carbon over original values at high maturity (Burnham, 1989)

PI (production Index) – free HC content as measured by S_1 only divided by the sum of S_1 plus the remaining generation potential (S_2) or $S_1 / (S_1+S_2)$

PI_{org} (original production index) = 0.02

- **HYDROGEN INDEX "HI":**
  PRESENT DAY HI ($HI_{present}$); ORIGINAL HI ($HI_{original}$)
  - Derived from Pyrolysis Analysis: $S_2/TOC*100$ (mg/g TOC)
  - Depends on maturity and kerogen composition
  - HI can be defined from HI vs. Depth trend for the study area (depth intervals) when lacking actual HI data



Presenter's Notes: Mass to volume conversion: 6.58 bbl/tonne

RETAINING FACTOR

From Generated Hydrocarbon to In-Place Resources

<u>Retaining Factor</u> is defined as percentage of generated HC which can be preserved within the source rock interval or adjacent reservoirs

***Retaining Factor** = (**Storage Capacity Coefficient+ Retain Capacity Coefficient**)*

1. ***<u>Storage Capacity</u>*** *is defined as ability of source rocks and adjacent reservoirs to store some volume of hydrocarbon under defined thickness, porosity, saturation and pressure. Can be calculated using traditional volumetric formulas for oil and gas in-place calculations.*

$$GIIP=43560 * A * h * \Phi * Sg * Eg$$

$$OOIP=7758 * A * h * \Phi * So * Bo$$

***Storage Capacity Coefficient** can be calculated as ratio of In-Place Volume to Volume of generated HC*

2. ***<u>Retain Capacity</u>*** *is defined as amount of retained HC that can be trapped in organic matter due to adsorption (depends on maturity and kerogen type, e.g. for oil window adsorbed HC is ranged from 130-200 mgHC/g TOC, for gas is around 50 mgHC/g TOC , Pepper 1992)*

***Retain Capacity Coefficient** can be calculated as ratio of retained HI to total generated HI*

***Retain Capacity Coefficient**= Adsorbed HI / Generated HI*
HI-Hydrogen Index, mg/g TOC

PRESERVATION CHANCE

Containment Risking at Early Exploration Stage

Preservation Chance is defined as the chance for generated HC to be preserved inside of the source rock interval or adjacent reservoirs

A subjective parameter, not measured directly, but it can be evaluated based on several input parameters:

Less Subjective Data:

1. - *Storage capacity of source rocks and adjacent reservoirs (if storage capacity is big enough to retain amount of generated HC without creating much overpressure then the chance of preservation is higher)*
   - *Amount of retained HC that can be trapped in organic matter due to adsorption*

Storage and Retained HC can be described by Retaining Factor

2. *Presence of a seal at the top of analyzed SR interval*

More Subjective Data:

3. *Basin Tectonic History (amount of uplifts, faulting occurred or currently present at the area of interest)*
4. *Presence of overlaying (underlying) producing fields sourced from analyzed source rocks*

***Preservation Chance** = Retaining Factor*Seal Presence*((Burial History + Existing Fields)/2)*

**Burial history and Existing fields parameters are weighted on 0.5 due to subjective nature*

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STOCHASTIC WORKFLOW: GENERIC SPREADSHEET EXAMPLE

Gas Model

AREA NAME

				A	B	C	D	E	TOTAL Deterministic	Probabilistic P10	Probabilistic Mean	Probabilistic P90
GENERAL INFO	Zone #			☑1	☑2	☑3	☑4	☑5				
	Depth	ft		9000-10000								
	HC Type			gas								
GAS GENERATED ESTIMATES	AREA, acres	determin.	lognorm	640	640	640	640	640				
		P10		320	320	320	320	320				
		P90		1280	1280	1280	1280	1280				
	THICKNESS, ft	determin.	normal	20.0	50.0	40.0	30.0	70.0	210.0			
		P10		15.0	45.0	35.0	25.0	65.0				
		P90		25.0	55.0	45.0	35.0	75.0				
	BULK DENSITY, g/cc	determin.	normal	2.35	2.45	2.4	2.45	2.6				
		P10		2.3	2.4	2.3	2.4	2.55				
		P90		2.4	2.5	2.5	2.5	2.65				
	TOC PRESENT, %	determin.	normal	4	2.5	3.5	2.8	1.9				
		P10		3	2	3	2.5	1.5				
		P90		5	3	4	3.1	2.3				
	HI PRESENT, mg/g	determin.	normal	20	20	20	50	50				
		P10		10	10	10	30	30				
		P90		30	30	30	70	70				
	HI ORIGINAL, mg/g	determin.	normal	400	400	400	550	550				
		P10		350	350	350	500	500				
		P90		450	450	450	600	600				
	PI PRESENT			0.3	0.3	0.3	0.3	0.3				
	TOC ORIGINAL, %			5.8	3.6	5.1	4.8	3.3				
	GAS GENERATED, TCF			19	31	34	33	55	172	129	182	241
	GAS YIELD GENERATED, MMCF/ACRE			30	49	53	51	86	269	235	271	309
☑ RECOVERABLE RESOURCES ESTIMATES	RETAINING FACTOR			0.3	0.5	0.3	0.2	0.2				
	RECOVERY FACTOR	determin.	normal	0.25	0.25	0.25	0.25	0.25				
		P10		0.20	0.20	0.20	0.20	0.20				
		P90		0.30	0.30	0.30	0.30	0.30				
	RECOVERABLE, BSCF			1	4	2	2	3	12	9	13	18
	ACRES PER WELL	determin.	triangular	160	160	160	160	160				
		MIN		80	80	80	80	80				
		MAX		240	240	240	240	240				
	RECOVERABLE PER WELL BSCF/WELL			0.3	0.9	0.6	0.5	0.8	3.1	2.5	3.1	3.8

INPUT	[green] - Deterministic
	P10 - P10 Value
	P90 - P90 Value
OUTPUT	[box] - Calculated Value

RUN | VIEW CHARTS | ALLOW EDITING 'UNPROTECT SHEET' | CREATE REPORT | CLOSE CHARTS 'double click' | SAVE WORKBOOK

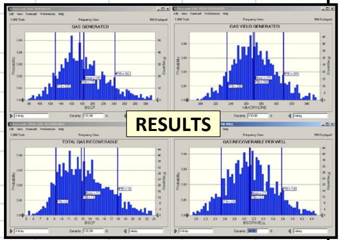
AREA NAME

GENERATION POTENTIAL TO IN-PLACE RESOURCES

				A	B	C	D	E	TOTAL / AVERAGE
GENERAL INFO	Zone #			☑1	☑2	☑3	☑4	☑5	
	Depth	ft		9000-10000					
	HC Type			gas					
STORAGE CAPACITY COEFFICIENT	AREA, acre			1	1	1	1	1	
	THICKNESS, ft	determin.	normal	20.0	50.0	30.0	40.0	70.0	210.0
		P10		15.0	45.0	25.0	35.0	65.0	
		P90		25.0	55.0	35.0	45.0	75.0	
	POROSITY, unit	determin.	normal	0.05	0.07	0.06	0.04	0.04	
		P10		0.04	0.06	0.05	0.03	0.03	
		P90		0.06	0.08	0.07	0.05	0.05	
	Sw, unit	determin.	normal	0.5	0.5	0.5	0.5	0.5	
		P10		0.4	0.4	0.4	0.4	0.4	
		P90		0.6	0.6	0.6	0.6	0.6	
	EXPANSION FACTOR Eg, scf/rcf	determin.	triangular	255	255	255	255	255	
		MIN		215	215	215	215	215	
		MAX		295	295	295	295	295	
	GIIP, MMCF/ACRE			5.6	19.4	10.0	8.9	15.6	TOTAL 59.4
	STORAGE CAPACITY COEFFICIENT			0.2	0.4	0.2	0.2	0.2	
RETAINING CAPACITY COEFFICIENT	ADSORBED HI, mg/g TOC	determin.	normal	30	30	30	30	30	
		P10		20	20	20	20	20	
		P90		40	40	40	40	40	
	GENERATED HI, mg/g TOC			380	380	380	500	500	
	RETAINING CAPACITY COEFFICIENT			0.08	0.08	0.08	0.06	0.06	
RETAINING FACTOR	MEAN			0.3	0.5	0.3	0.2	0.2	AVERAGE 0.3
	P10			0.2	0.3	0.2	0.2	0.2	
	P90			0.4	0.7	0.4	0.3	0.4	

RISKING

					P10	MEAN	P90
	RETAINING FACTOR			0.47			
PRESERVATION CHANCE	SEAL PRESENCE	determin.	normal	0.95			
		P10		0.90			
		P90		1.00			
	BURIAL HISTORY	determin.	normal	0.70			
		P10		0.60			
		P90		0.80			
	EXISTING FIELDS	determin.	normal	0.80			
		P10		0.70			
		P90		0.90			
	PRESERVATION CHANCE			0.33	0.27	0.37	0.48



✓Allows to evaluate and compare multiple source rock intervals/zones
✓The spreadsheet integrated with Crystal Ball for probabilistic estimates

ARBITRARY NUMBERS

STOCHASTIC WORKFLOW: GENERIC SPREADSHEET EXAMPLE

Oil Model

AREA NAME

				A	B	C	D	E	TOTAL: Deterministic	Probabilistic: P10	Probabilistic: Mean	Probabilistic: P90
				ZONE NAME								
GENERAL INFO	Zone #			☑1	☑2	☑3	☑4	☑5				
	Depth	ft		9000-10000								
	HC Type			oil								
GAS GENERATED ESTIMATES	AREA, acres	determin.	lognorm	640	640	640	640	640				
		P10		320	320	320	320	320				
		P90		1280	1280	1280	1280	1280				
	THICKNESS, ft	determin.	normal	15.0	50.0	10.0	30.0	70.0	175.0			
		P10		10.0	45.0	5.0	25.0	65.0				
		P90		20.0	55.0	15.0	35.0	75.0				
	BULK DENSITY, g/cc	determin.	normal	2.35	2.45	2.4	2.45	2.6				
		P10		2.3	2.4	2.3	2.4	2.55				
		P90		2.4	2.5	2.5	2.5	2.65				
	TOC PRESENT, %	determin.	normal	4	2.5	3.5	2.8	1.9				
		P10		3.0	2.0	3.0	2.5	1.5				
		P90		5.0	3.0	4.0	3.1	2.3				
	HI PRESENT, mg/g	determin.	normal	150	150	150	250	250				
		P10		125	125	125	200	200				
		P90		175	175	175	300	300				
	HI ORIGINAL, mg/g	determin.	normal	400	400	400	550	550				
		P10		350	350	350	500	500				
		P90		450	450	450	600	600				
	PI PRESENT			0.1	0.1	0.1	0.1	0.1				
	TOC ORIGINAL, %			5.1	3.2	4.5	4.0	2.7				
	OIL GENERATED, MMBOE			2	5	1	4	7	19	13	20	28
	OIL YIELD GENERATED, MBOE/ACRE			3.3	7.3	2.0	6.5	10.9	30	25	30	37
☑ RECOVERABLE RESOURCES ESTIMATES	RETAINING FACTOR			1.0	1.0	1.0	0.9	1.0				
	RECOVERY FACTOR	determin.	normal	0.10	0.10	0.10	0.10	0.10				
		P10		0.05	0.05	0.05	0.05	0.05				
		P90		0.15	0.15	0.15	0.15	0.15				
	RECOVERABLE, MMBOE			0.2	0.5	0.1	0.4	0.7	1.8	1.2	1.8	2.6
	ACRES PER WELL	determin.	triangular	160	160	160	160	160				
		MIN		80	80	80	80	80				
		MAX		240	240	240	240	240				
	RECOVERABLE PER WELL MBOE/WELL			53	115	32	90	173	462	305	434	574

If Retaining Factor >1, then less hydrocarbon was generated than estimated from the storage capacity (ϕ,So)

INPUT	(green)	- Deterministic
	P10	- P10 Value
	P90	- P90 Value
OUTPUT	(blank box)	- Calculated Value

RUN | VIEW CHARTS | ALLOW EDITING 'UNPROTECT SHEET'

CREATE REPORT | CLOSE CHARTS 'double click'

SAVE WORKBOOK

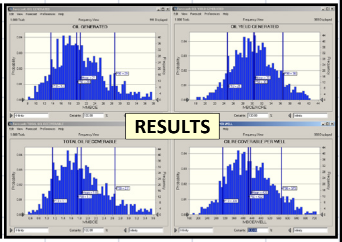
AREA NAME

GENERATION POTENTIAL TO IN-PLACE RESOURCES

				A	B	C	D	E	
				ZONE NAME					
GENERAL INFO	Zone #			☑1	☑2	☑3	☑4	☑5	
	Depth	ft		9000-10000					
	HC Type			oil					
STORAGE CAPACITY COEFFICIENT	AREA, acre			1	1	1	1	1	
	THICKNESS, ft	determin.	normal	15.0	50.0	10.0	30.0	70.0	175.0
		P10		10.0	45.0	5.0	25.0	65.0	
		P90		20.0	55.0	15.0	35.0	75.0	
	POROSITY, unit	determin.	normal	0.05	0.07	0.06	0.04	0.04	
		P10		0.04	0.06	0.05	0.03	0.03	
		P90		0.06	0.08	0.07	0.05	0.05	
	Sw, unit	determin.	normal	0.5	0.5	0.5	0.5	0.5	
		P10		0.4	0.4	0.4	0.4	0.4	
		P90		0.6	0.6	0.6	0.6	0.6	
	FORMATION VOLUME FACTOR Bo	determin.	triangular	1.35	1.35	1.35	1.35	1.35	
		MIN		1.2	1.2	1.2	1.2	1.2	
		MAX		1.5	1.5	1.5	1.5	1.5	TOTAL
	OIIP, MSBOE/ACRE			2.2	10.1	1.7	3.4	8.0	25.4
	STORAGE CAPACITY COEFFICIENT			0.6	1.4	0.9	0.5	0.7	
RETAINING CAPACITY COEFFICIENT	ADSORBED HI, mg/g TOC	determin.	normal	100	100	100	100	100	
		P10		75	75	75	75	75	
		P90		125	125	125	125	125	
	GENERATED HI, mg/g TOC			250	250	250	300	300	
	RETAINING CAPACITY COEFFICIENT			0.40	0.40	0.40	0.33	0.33	AVERAGE
RETAINING FACTOR	MEAN			1.0	1.0	1.0	0.9	1.0	0.97
	P10			0.7	1.0	0.7	0.6	0.7	
	P90			1.0	1.0	1.0	1.0	1.0	

RISKING

					P10	MEAN	P90
	RETAINING FACTOR			0.97			
PRESERVATION CHANCE	SEAL PRESENCE	determin.	normal	0.95			
		P10		0.90			
		P90		1.00			
	BURIAL HISTORY	determin.	normal	0.70			
		P10		0.60			
		P90		0.80			
	EXISTING FIELDS	determin.	normal	0.80			
		P10		0.70			
		P90		0.90			
	PRESERVATION CHANCE			0.69	0.56	0.64	0.73



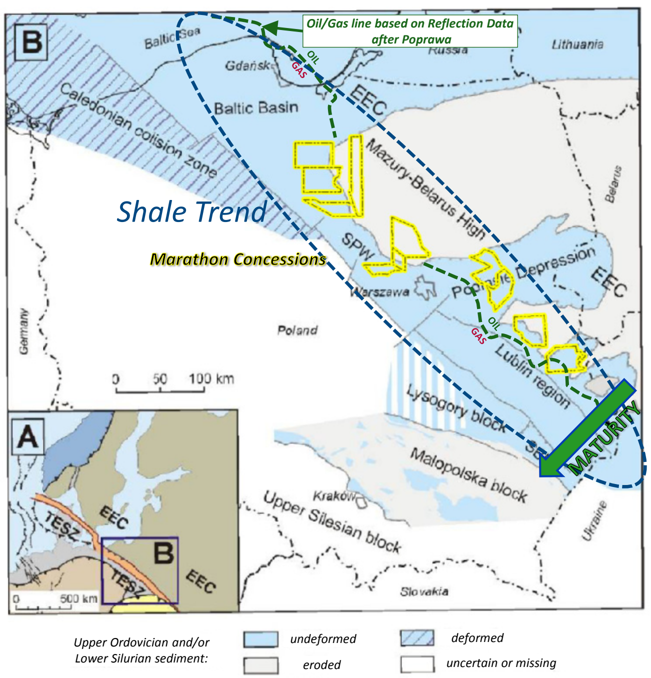
✓Allows to evaluate and compare multiple source rock intervals/zones
✓The spreadsheet integrated with Crystal Ball for probabilistic estimates

ARBITRARY NUMBERS

CASE STUDY: POLAND UNCONVENTIONAL

Overview

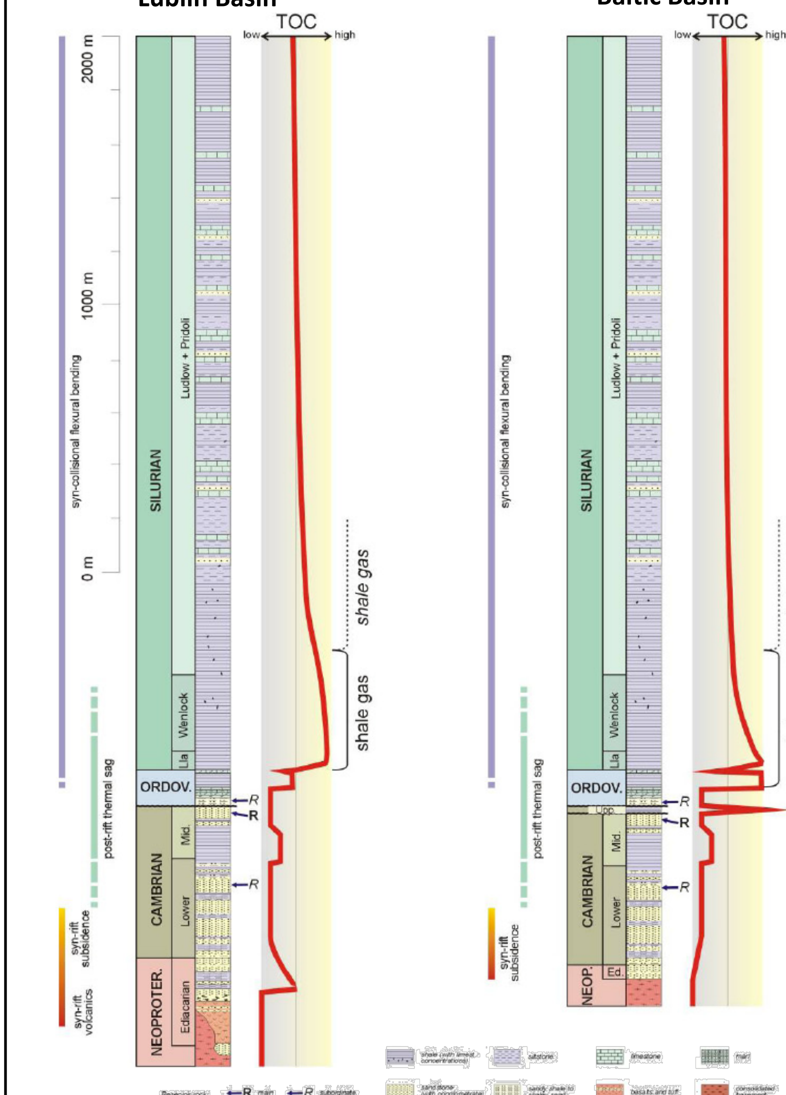
- The unconventional shale resource trend in Poland comprises three tectonic basins: Lublin, Podlasie, Baltic
- Most resource potential in the shale trend lies in Lower Silurian and Ordovician source rocks
- Variable TOC, source rock thickness, and maturity



Location of the Lower Paleozoic Baltic-Podlasie-Lublin Basin after Poprawa P, 2010 (PGI Resources Report, 2011)

SYSTEM	SERIES
SILURIAN	PRIDOLI
	LUDLOW
	WENLOCK
	LLANDOVERY
ORDOVICIAN	ASHGILL
	CARADOC
	LLANDEILO
	LLANVIRN

Targets are the regionally extensive mudstones of Ordovician – Silurian age containing organic-rich zones.



Simplified lithostratigraphic column of the Lower Paleozoic at the Lublin and Baltic basins after Poprawa P, 2010 (from PGI Resources Report, 2011)

CASE STUDY: POLAND UNCONVENTIONAL

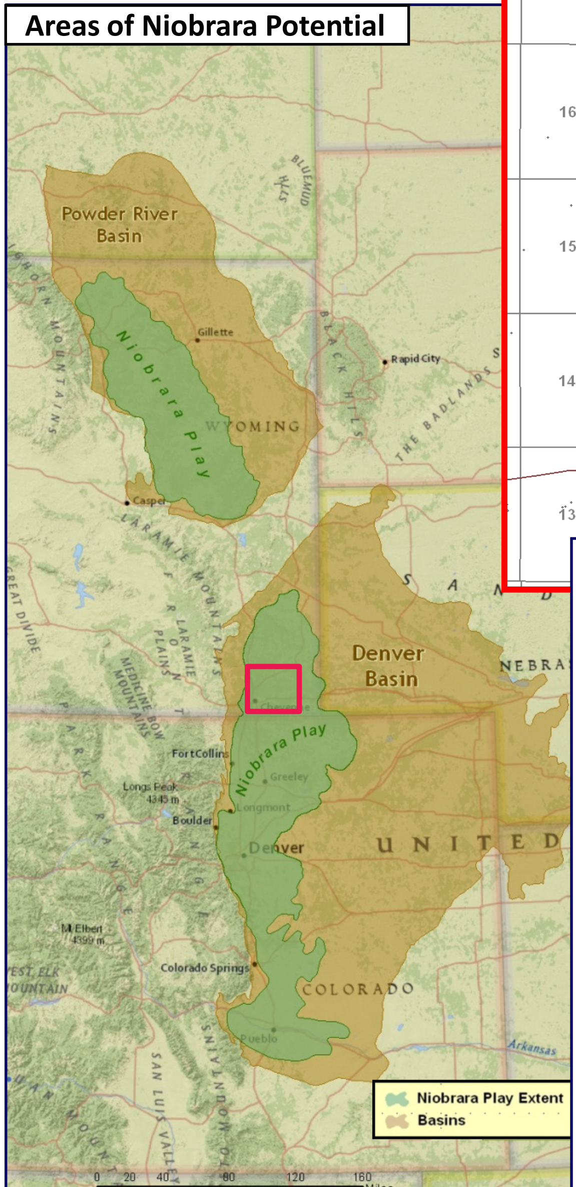
Results

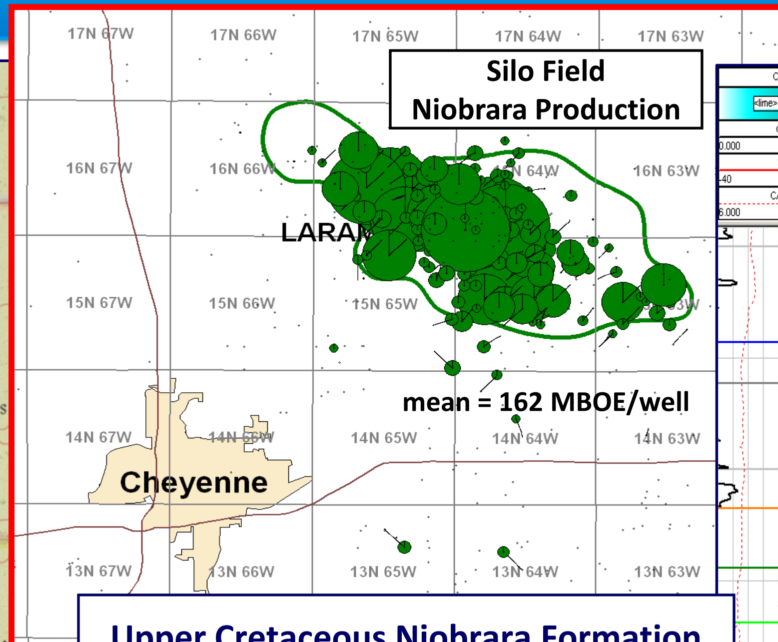
- **Data Set Available for Evaluation:**
  - Extensive geochemical data: TOC and kerogen pyrolysis analyses
  - Regional well data: well logs and core data from legacy wells
  - No production, test data are available
- **Generation Potential**: The evaluation confirmed adequate source rock quality, generated hydrocarbon yields were defined for each study area
- **In-Place Resources**: The results indicate the potential for hydrocarbon resources in Lower Silurian/ Ordovician source rocks
- **Risking**: Containment risk was evaluated suggesting high chance for large fraction of generated hydrocarbon to be preserved
- **Results:** Used as one of the screening criteria for ranking various study areas

CASE STUDY: SILO FIELD NIOBRARA

Overview

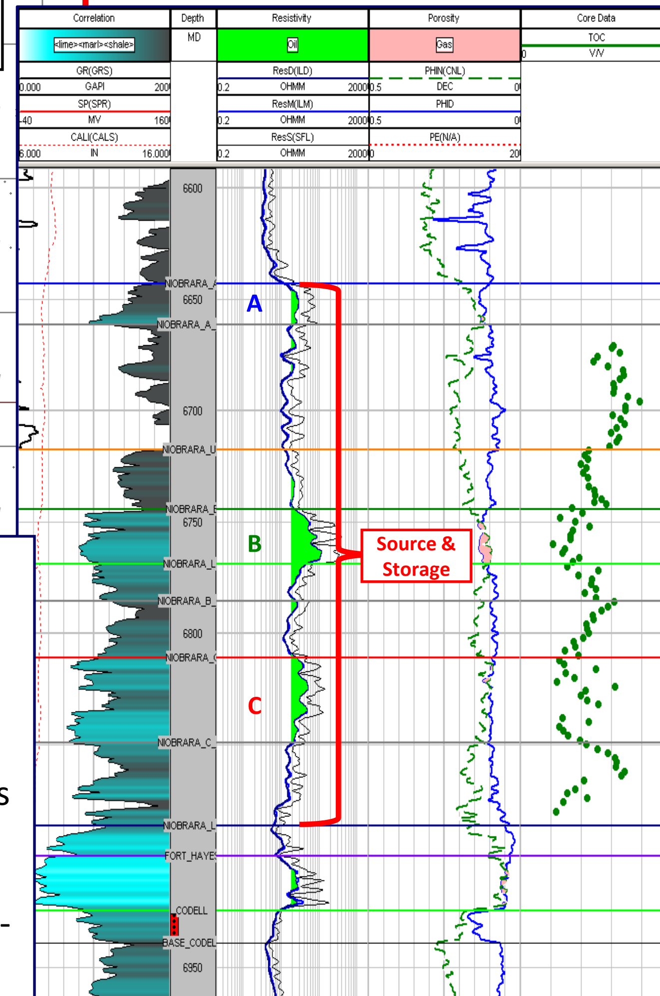
Areas of Niobrara Potential





Upper Cretaceous Niobrara Formation

- Self-sourced reservoir, interbedded series of chalks and marls
- Model assumes combined interval is simultaneous source and storage
- Variable TOC (1-5%) and porosity (8-12%) between chalks and marls
- Silo Field case study draws on historical data from 68 horizontal wells produced from naturally fractured Niobrara in the 1990s



Stratigraphic Type Log

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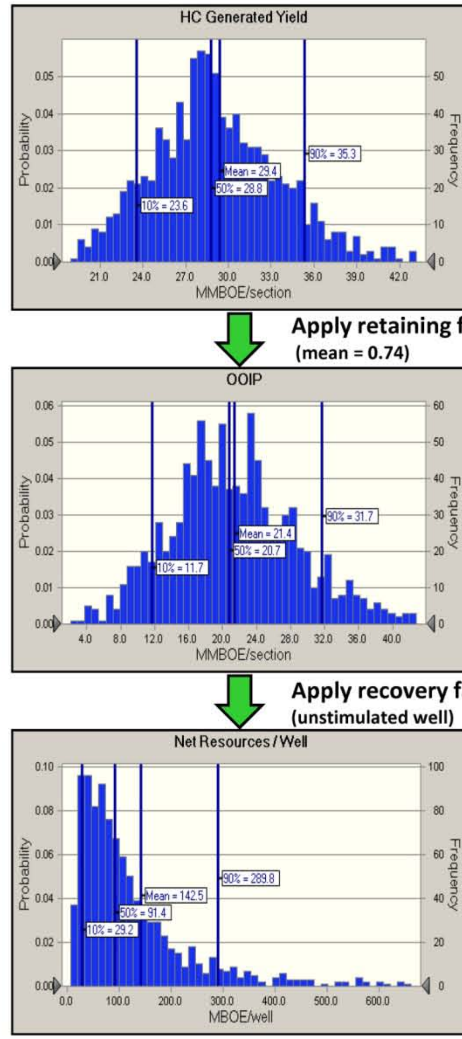
CASE STUDY: SILO FIELD NIOBRARA

Results

Model Inputs

- Niobrara broken out into 4 chalks and 4 marls with rock properties characterized separately for each
  - Thickness, RhoB, porosity, and S_W averaged for each interval from wireline logs, and TOC and HI derived from nearby core data
  - Storage capacity determined from standard OOIP calculation using thickness, porosity, Archie-derived water saturation, and formation volume factor (B_O)
- Multi-zone breakout allows flexible application for multiple targets
  - Can be isolated to individual target zones
  - Silo Field case study assumes only the B interval and adjacent marls

Model Outputs



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Presenter's Notes: B zone and adjacent marls (source-reservoir-source)

CASE STUDY: SILO FIELD NIOBRARA

Conclusions

- The net recoverable resource of 143 MBOE/well approximates the mean cumulative horizontal production at Silo Field of 162 MBOE/well (lognormal mean, source: IHS) and helps validate this methodology. This determination assumes unstimulated horizontal production from a single zone and does not take artificial fracturing into account.

- As an assumption of determining the retaining factor, the reservoir is filled to spill by the generated hydrocarbon volume with the remainder expelled from the reservoir.
  - Silo Field is a relatively mature source area, in the early oil window, where the retaining factor is less than 1 and retained hydrocarbon volume is equal to storage capacity.
  - Use of this method in other, less mature areas yields generated hydrocarbon volumes that are much smaller than calculated storage capacity, resulting in retaining factors greater than 1.
  - **Use of OOIP calculations alone in areas of low maturity carries the risk of overestimating recoverable resources.**

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Presenter's Notes: Net recoverable resource has tighter distribution than that for cumulative well production at Silo. Altering inputs can bring these numbers much closer together.

SUMMARY/CONCLUSION

- This workflow can be utilized in the early exploration stage:
  - to validate adequate source rock quality
  - to use as an “early” screening tool for area prioritization and risking
  - to incorporate uncertainty of the input data into probabilistic results
- Used to validate the traditional in-place calculation for mature fields
- **For cases where calculated storage capacity exceeds generated volume, conventional in-place calculations may lead to overestimation of recoverable resources**
- Key uncertainties: lateral and vertical migration, original HI, adsorption HI, fluid saturation (storage capacity)
- The results can be represented in map view as a key component of play fairway analysis for unconventional plays

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