Exploring for Tight Oil in the Pennsylvanian Cleveland Sandstone on the Nemaha Uplift Using High-Resolution 3D Seismic & Stratigraphic Analysis: A New "Resource" Play Model?*

Tony Lupo[1] and Lee Krystinik[2]

AND

Oil and Gas Outlook for 2017 and Beyond!*

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Abstract

Tight sands in the Upper Pennsylvanian Cleveland Fm. are an active development target in the panhandles of Texas and Oklahoma. However, since drilling started in the 1920s along the Nemaha Uplift (Ridge) of north-central Oklahoma and south-central Kansas the Cleveland has traditionally been viewed as a shallow (2500 feet-3000 feet), thin, tight-oil "teaser" or as a tertiary objective on the way down to other more economic objectives. By integrating high-resolution 3D seismic and detailed sequence stratigraphic analysis, thicker, productive Cleveland reservoir fairways can be identified and drilled economically on the Nemaha Ridge.

Cleveland depositional systems in the Nemaha Ridge area include river-dominated deltas and incised valleys, reservoirs of each with distinctive log and seismic characteristics. Deltaic reservoir successions occur in the upper two-thirds of the Cleveland interval and are usually the best reservoirs. The deltaic reservoir units are composed of very fine- to fine-grained "sanding upward" successions exhibiting dip-elongate behavior and rapid changes along strike. Cleveland-valley reservoirs in the study area are blocky to fining-upward, lower medium- to very fine-grained units that occur in the lower part of the Cleveland succession.

Optimal drilling locations are best identified by fine-scale correlations and seismic mapping, linked to subtle syn-sedimentary tectonics. High-resolution 3D seismic (up to 1.4 million traces per square mile) and multi-attribute analysis have proved a key tool in differentiating and

predicting optimal reservoir trends in this new play concept on the Nemaha Ridge and sets up an opportunity for focused horizontal exploitation. This type of analysis is broadly applicable to a number of other similar plays in old development areas.

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U.S. Energy Information Administration (EIA), OPEC net oil export revenues expected to fall in 2014 and 2015: Today in Energy: EIA December 17, 2014. Website accessed July 30, 2015, http://www.eia.gov/todayinenergy/detail.cfm?id=19231.,

Olson, B., 2015, 'God' of crude oil trading sees oil rally benefiting shale since this ins/t '86: World Oil, 2/5/2015. Website accessed July30, 2015, http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf.

Exploring for Tight Oil in the Pennsylvanian Cleveland Sandstone on the Nemaha Uplift Using High-Resolution 3D Seismic & Stratigraphic Analysis: A New "Resource" Play Model?

…and why independent oil and gas companies will not be able to pursue resources of this type

AND

Tony Lupo's Oil and Gas Outlook for 2017 and Beyond!

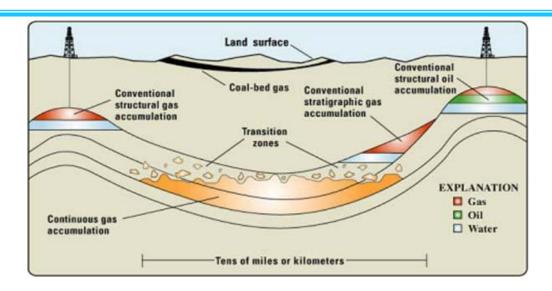**SM ENERGY**

Tony Lupo: Chief Geophysicist – SM Energy

Lee Krystinik: Principal – Fossil Creek Resources

What's Next?

There have been a progression of play types through time:
- Conventional Structural
- Conventional Stratigraphic
- Tight Gas
- Tight Oil
- Shale Gas
- Shale Oil
- "Halo" plays

Where can we apply all of this marvelous technology we've developed to open new play types?

What's Old is New Again

Bypassed Conventional/Tight Oil & Gas

- Those formations known to contain large amounts of HC but have traditionally been viewed as "tertiary" objectives due to:

  - Complex depositional environment
  - Unevenly distributed pay zone(s)
  - Low-resistivity pay
  - Unpredictable HC/water production (i.e., complex charge history)

  <u>In short, a seemingly randomly distributed reservoir with a highly variable Pg</u>

- Examples we've encountered:
  - Any number of Penn "stray" sands in the Anadarko Basin
  - Carbonate reservoirs, generally (Ordovician PDC in MI Basin, Trenton/Black River in NW Ohio, Big Valley Dolomite in AB, etc.)

Redefining a "Resource" Play?

An approach would be to reduce risk in a broad sense to create a set of opportunities with a similar Pg that could be pursued in a way that looks very much like a "resource" play:

"Resource" Play Characteristics (SPEE):
- Accumulation over large areal extent (>100 wells)
- A majority of the wells have a similar Pg
- Repeatable & Continuous
- HC not held in place by hydrodynamics

- We present a template we established at Fossil Creek in the Cleveland formation to regularize Pg through the judicious use of:

    - Exhaustive sequence stratigraphic analysis (Play identification)

    - 3D seismic reservoir characterization (i.e., delineating porous sand/pay zone)

    - Horizontal drilling and completion techniques (Factor of Safety)

Cleveland Play Characteristics

- Shallow (<6000', more generally between 2500'- 3500')

- Inexpensive drilling ($1.0 – $2.0 MM Horizontal CWC; 3500' lateral)

- Black oil (38-42 API)

- Large AOI (potential exists over several COUNTIES)

- Repeatable & Predictable (targeted locations via 3D; Factor of Safety with horizontal drilling)
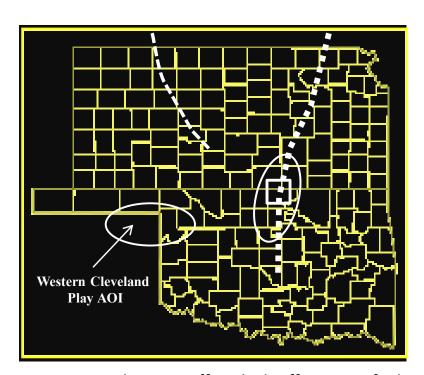
- SWD infrastructure in place

- Early entry/lack of industry focus or exposure

Cleveland Play Comparison

Western OK CLVD	Eastern OK CLVD
Lower CLVD Channel	Upper CLVD Deltaics
Φ: 0.08 – 0.12	Φ: 0.14 – 0.16
MD: 7000' – 9000'	MD: 2500' – 3500'
Thickness: up to 200'	Thickness: up to 100'
Phase: Gas/Wet Gas	Phase: Black Oil
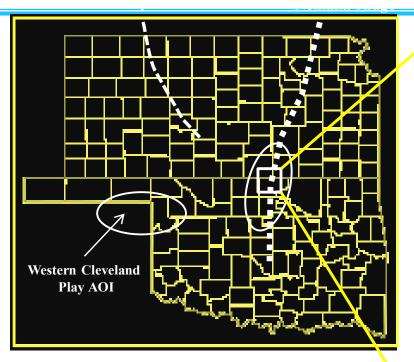
Western Cleveland Play AOI

Strategy: Utilize cost-effect, high-effort 3D to find stranded reserves near abandoned fields

April 28, 2015

Location Map

Strategy: Utilize cost-effect, high-effort 3D to find stranded reserves near abandoned fields

Western Cleveland Play AOI

N. Braman 3D

N. Braman Field (1926)
➤ **~25 MMBO Produced from ~ 640 ac**
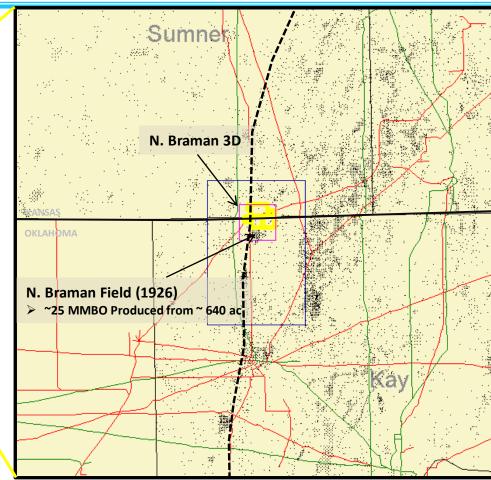
3D Parameters
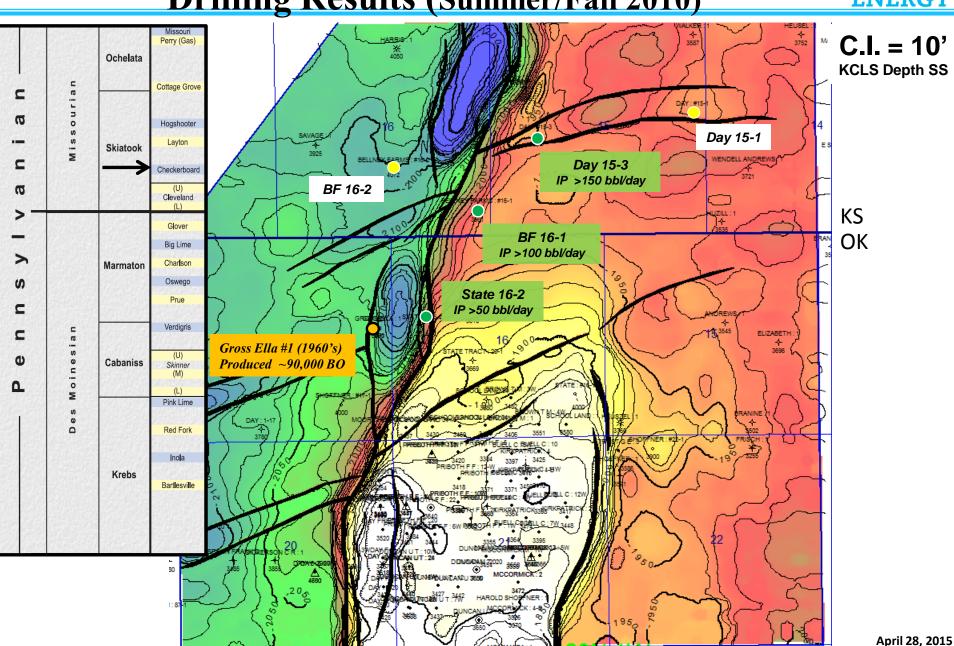
- 330' RL Spacing
- 440' SL Spacing
- 55'x55' Bin Size
- 250+ Nominal Fold
- 1.5+ Million Traces/Mi^2
- 65-70 Hz Dom Freq
- Low cost (~$25k/mi^2)*

* Novel Sweep/Design Scheme

Kansas City Lime Depth Structure Map with Drilling Results (Summer/Fall 2010)

C.I. = 10'
KCLS Depth SS

Day 15-1

Day 15-3
IP >150 bbl/day

BF 16-2

BF 16-1
IP >100 bbl/day

State 16-2
IP >50 bbl/day

Gross Ella #1 (1960's)
Produced ~90,000 BO

KS
OK

Cleveland Regional Production

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Kay County Reported Cleveland Production (IHS):
Cum Oil: 4.95 MMBO
Cum Gas: 4.25 BCF
Black Oil Play (38-42 api) in this area

N. Braman 3D

Gas_Cum2
- 0 - 25000
- 25000 - 50000
- 51000 - 75000
- 75000 - 100000
- 100000 - 200000
- > 200000

3 County Cum Oil
Oil_Cum
- 0 - 25000
- 25000 - 50000
- 51000 - 75000
- 75000 - 100000
- 100000 - 200000
- > 200000

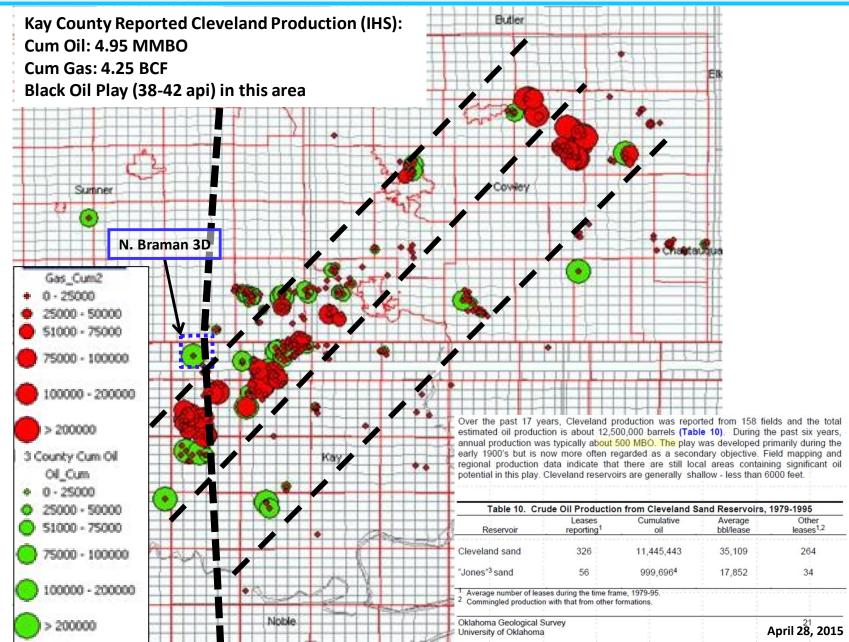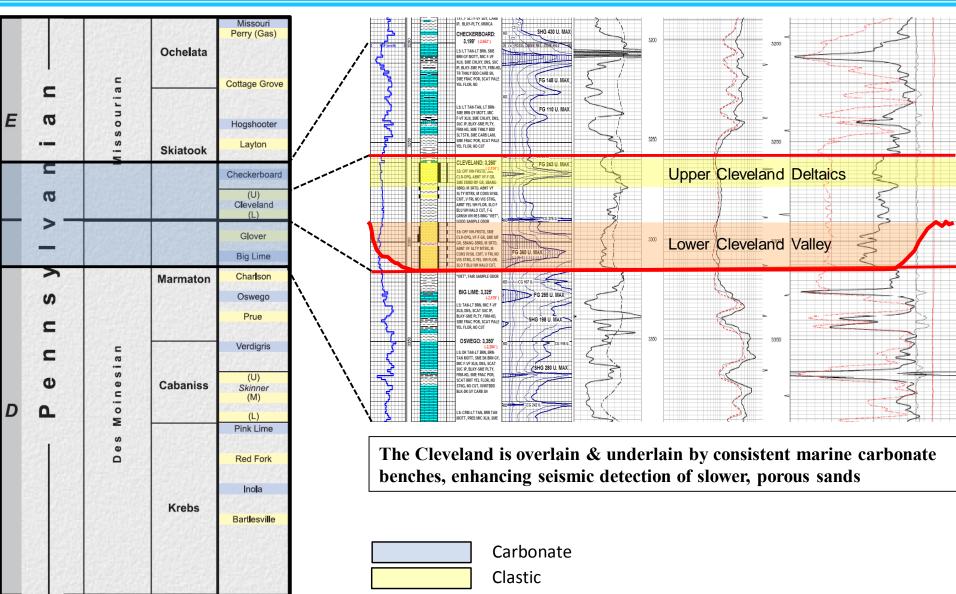Over the past 17 years, Cleveland production was reported from 158 fields and the total estimated oil production is about 12,500,000 barrels (Table 10). During the past six years, annual production was typically about 500 MBO. The play was developed primarily during the early 1900's but is now more often regarded as a secondary objective. Field mapping and regional production data indicate that there are still local areas containing significant oil potential in this play. Cleveland reservoirs are generally shallow - less than 6000 feet.

Table 10. Crude Oil Production from Cleveland Sand Reservoirs, 1979-1995				
Reservoir	Leases reporting[1]	Cumulative oil	Average bbl/lease	Other leases[1,2]
Cleveland sand	326	11,445,443	35,109	264
"Jones"[3] sand	56	999,696[4]	17,852	34

[1] Average number of leases during the time frame, 1979-95.
[2] Commingled production with that from other formations.

Oklahoma Geological Survey
University of Oklahoma

Nemaha Uplift Stratigraphic Column

Upper Cleveland Deltaics

Lower Cleveland Valley

The Cleveland is overlain & underlain by consistent marine carbonate benches, enhancing seismic detection of slower, porous sands

Carbonate

Clastic

N. Braman Type Log: Day #15-3

B. KCLM

U. CLVD

Φ: 0.16
R_t: 4.2 Ohm-m
S_w: 0.65 (calc)
S_w: 0.30 (obs)
Z: 20'- 40'

L. CLVD

Φ: 0.14
R_t: 3.6 Ohm-m
S_w: 0.75 (calc)
S_w: 0.65 (obs)
Z: 0'- 40'

T. BGLM

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N. Braman Type Log: Day #15-3

Wells completed with 70/30 nitrogen foam frac ~35,000 lbs. of sand
- DHC (2010): ~$190,000
- CWC (2010): ~$450,000

Lower Cleveland Isochore: Channelized Facies

N. Braman 3D

C.I. = 5.0'

Upper Cleveland Isochore: Deltaic Facies

N. Braman 3D
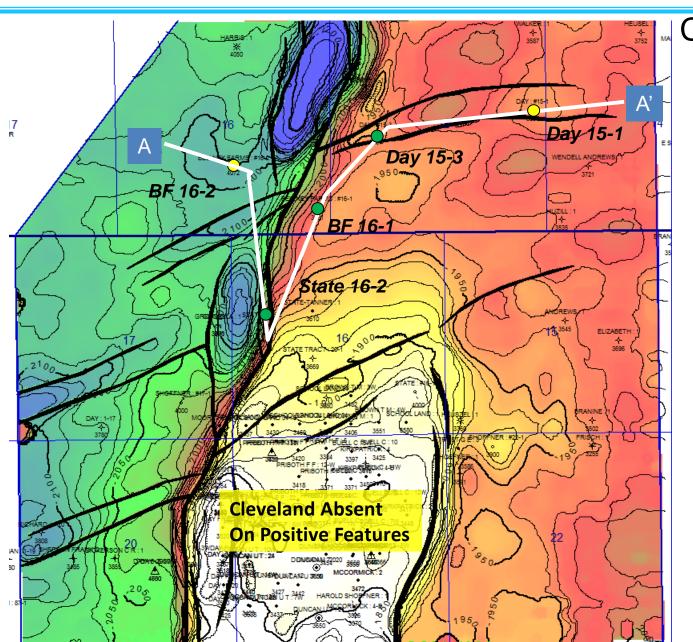
C.I. = 2.5'

KC Lime Depth Map w/ Cross Section

C.I. = 10'

Cleveland Absent
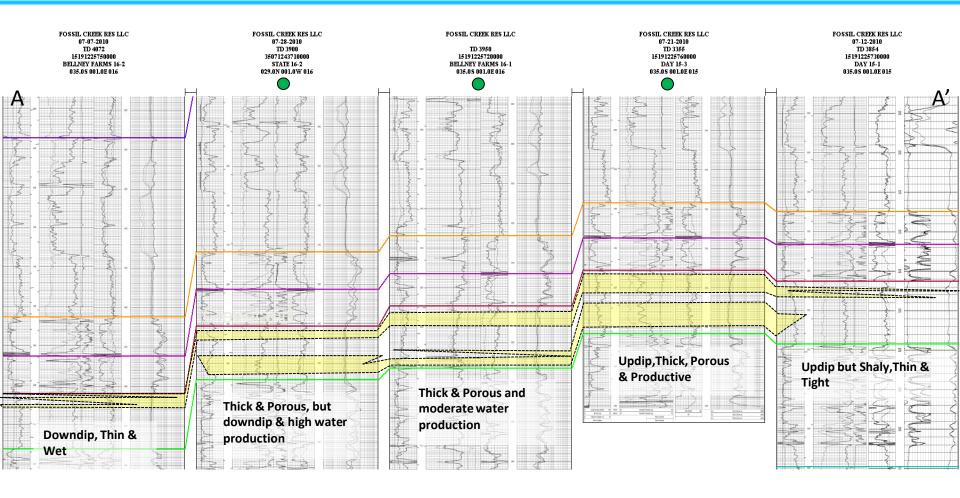On Positive Features

April 28, 2015

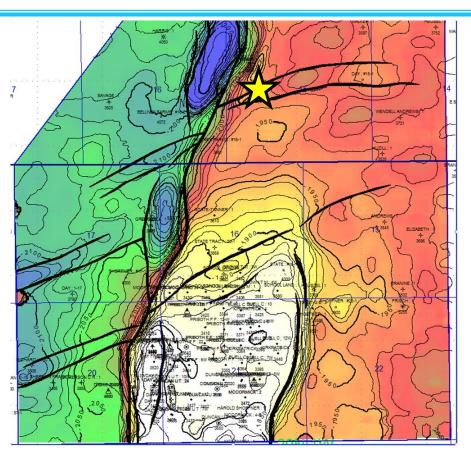# Nemaha Ridge Well Cross Section

Structural Cross Section showing the draping of Cleveland stratigraphy over the North Braman structure. This section follows the same line of section as the seismic image above.

April 28, 2015
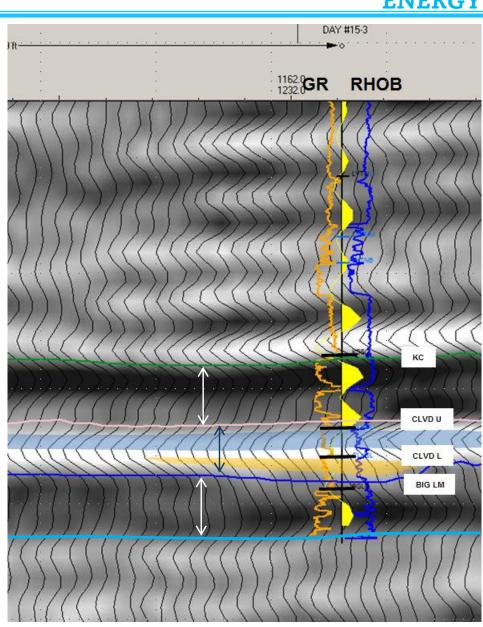
Cleveland Interval Well Tie and Data Quality
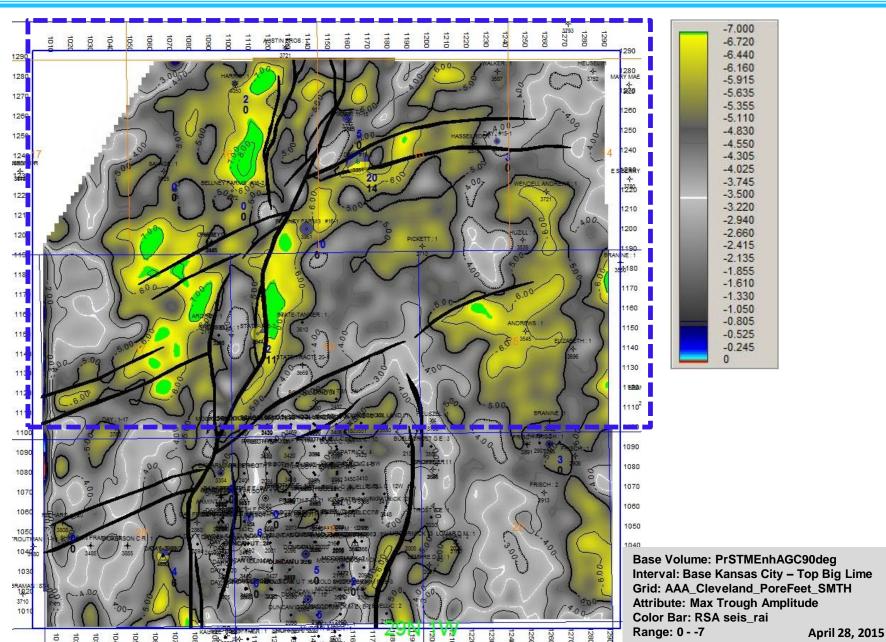
Presence of L. CLVD sand associated with changes in seismic character:

- *Increased amplitude*
- Overall change in waveshape
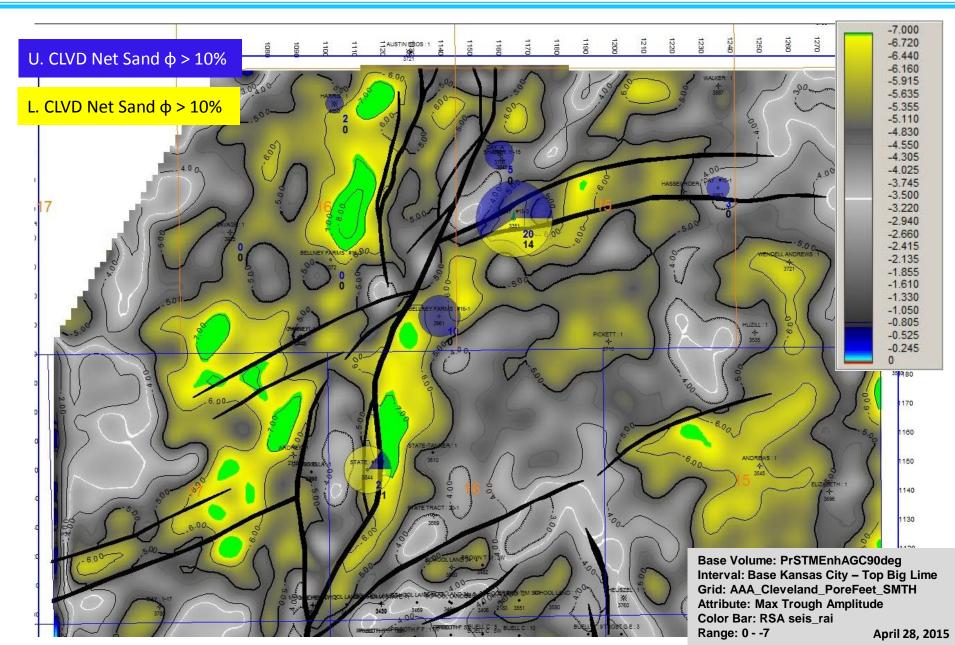
Max Trough Amplitude w/ Net Sand Bubble Overlay (>10%)

Base Volume: PrSTMEnhAGC90deg
Interval: Base Kansas City – Top Big Lime
Grid: AAA_Cleveland_PoreFeet_SMTH
Attribute: Max Trough Amplitude
Color Bar: RSA seis_rai
Range: 0 - -7   **April 28, 2015**

Max Trough Amp w/ Net Sand Bubble Overlay (φ > 10%)

U. CLVD Net Sand φ > 10%

L. CLVD Net Sand φ > 10%

Base Volume: PrSTMEnhAGC90deg
Interval: Base Kansas City – Top Big Lime
Grid: AAA_Cleveland_PoreFeet_SMTH
Attribute: Max Trough Amplitude
Color Bar: RSA seis_rai
Range: 0 - -7   April 28, 2015

How would the presence of POROUS sand affect amplitudes?

Cleveland Sand-Shale Modeled Response: Day #15-3

Thicker section of shale slightly attenuates the impedance contrast of the trough in the L. Cleveland sand body. As a result, the L. Cleveland sand trough is less well developed

1. Troughs within Cleveland zones are increased due to lower impedance of Cleveland sands

2. Both peaks associated with the overlying KC carbonate and underlying Big Lime carbonate are increased as more lower-impedance, porous Cleveland sand is introduced

Cleveland Sand-Shale Modeling Summary

1. Troughs within Cleveland zones are increased due to lower impedance of Cleveland sands

2. The reduced impedance is driven by increased porosity, as observed in density curve

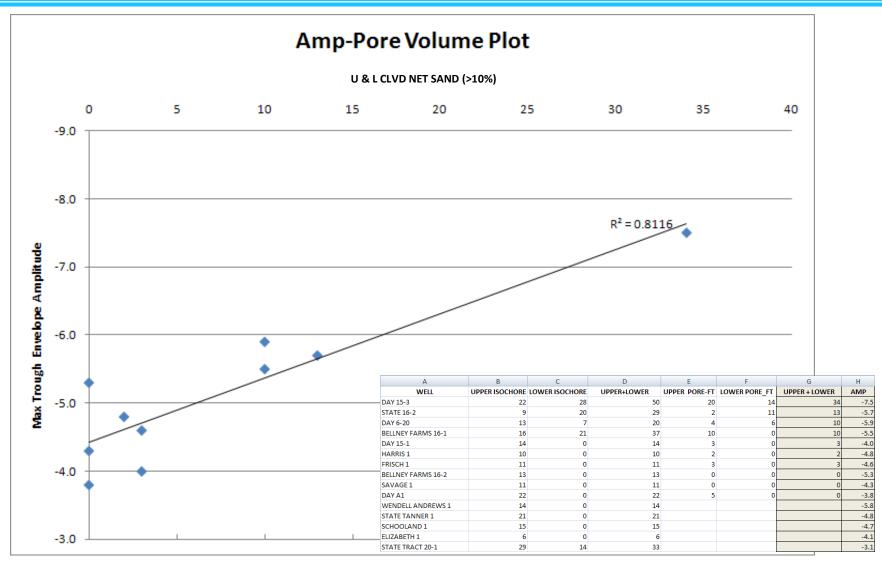3. Instantaneous attributes (e.g., maximum trough envelope) respond well to observed modeled response
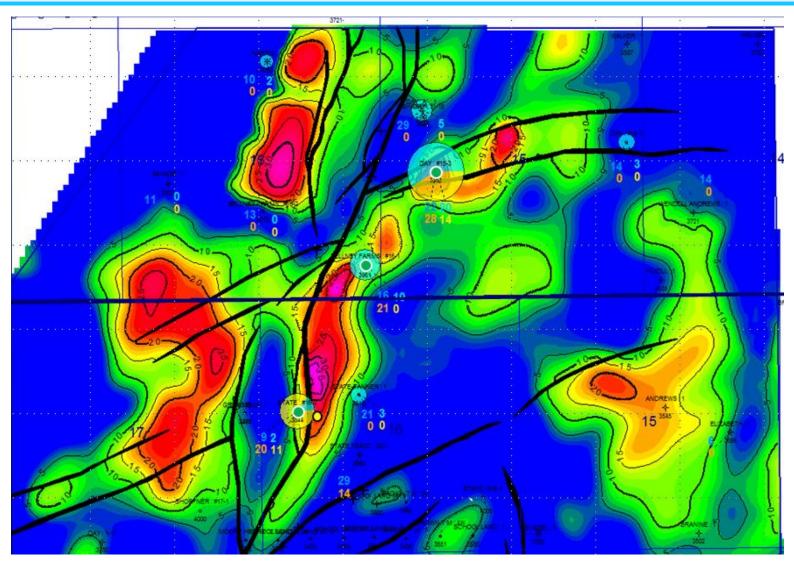
Cleveland Sand Porosity-Amp Cross Plot

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Amp-Pore Volume Plot

U & L CLVD NET SAND (>10%)

$R^2 = 0.8116$

Max Trough Envelope Amplitude

	A	B	C	D	E	F	G	H
	WELL	UPPER ISOCHORE	LOWER ISOCHORE	UPPER+LOWER	UPPER PORE-FT	LOWER PORE_FT	UPPER + LOWER	AMP
	DAY 15-3	22	28	50	20	14	34	-7.5
	STATE 16-2	9	20	29	2	11	13	-5.7
	DAY 6-20	13	7	20	4	6	10	-5.9
	BELLNEY FARMS 16-1	16	21	37	10	0	10	-5.5
	DAY 15-1	14	0	14	3	0	3	-4.0
	HARRIS 1	10	0	10	2	0	2	-4.8
	FRISCH 1	11	0	11	3	0	3	-4.6
	BELLNEY FARMS 16-2	13	0	13	0	0	0	-5.3
	SAVAGE 1	11	0	11	0	0	0	-4.3
	DAY A1	22	0	22	5	0	0	-3.8
	WENDELL ANDREWS 1	14	0	14				-5.8
	STATE TANNER 1	21	0	21				-4.8
	SCHOOLAND 1	15	0	15				-4.7
	ELIZABETH 1	6	0	6				-4.1
	STATE TRACT 20-1	29	14	33				-3.1

Cross-plot of Upper and Lower Cleveland net sand versus attribute values from key wells within the 3D survey.

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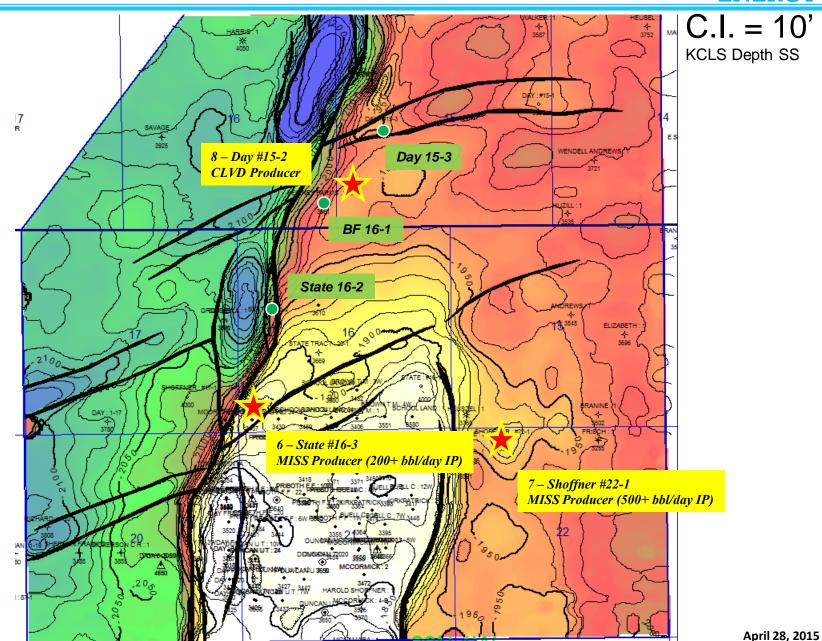# Cleveland Derived Net Sand Map

Net sand map established from relationship (see cross-plot) of log-observed net sand values with maximum trough envelope amplitude attribute from 3D data

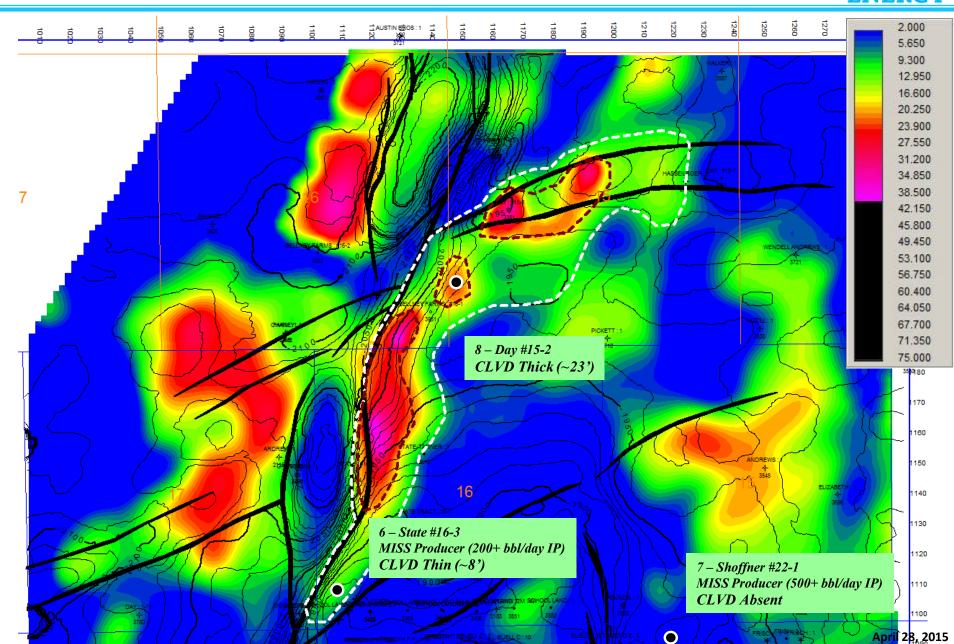# N. Braman Drilling Results: Summer/Fall 2011

C.I. = 10'
KCLS Depth SS

8 – Day #15-2 CLVD Producer

Day 15-3

BF 16-1

State 16-2

6 – State #16-3 MISS Producer (200+ bbl/day IP)

7 – Shoffner #22-1 MISS Producer (500+ bbl/day IP)

April 28, 2015
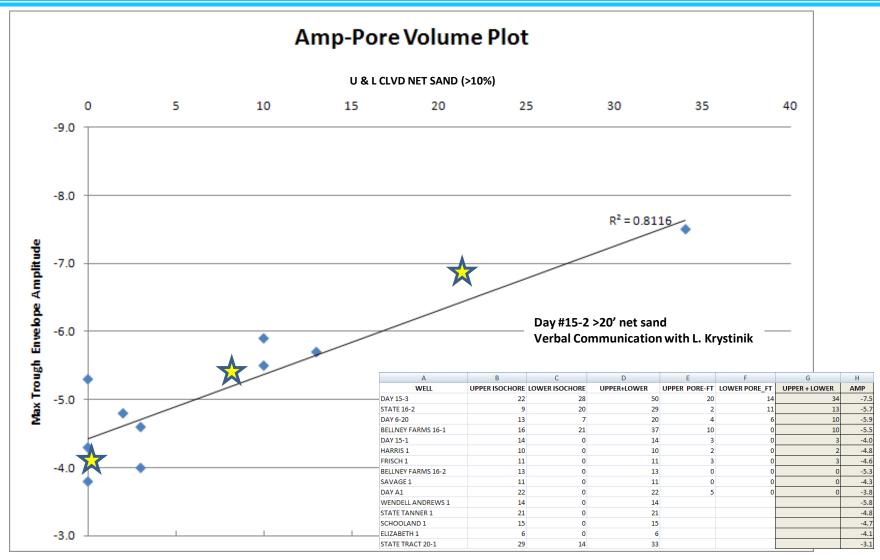
Cleveland Derived Net Sand Map (Porosity >10%)

8 – Day #15-2
CLVD Thick (~23')

6 – State #16-3
MISS Producer (200+ bbl/day IP)
CLVD Thin (~8')

7 – Shoffner #22-1
MISS Producer (500+ bbl/day IP)
CLVD Absent

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Cleveland Sand Porosity-Amp Cross Plot

Amp-Pore Volume Plot

U & L CLVD NET SAND (>10%)

$R^2 = 0.8116$

Day #15-2 >20' net sand
Verbal Communication with L. Krystinik

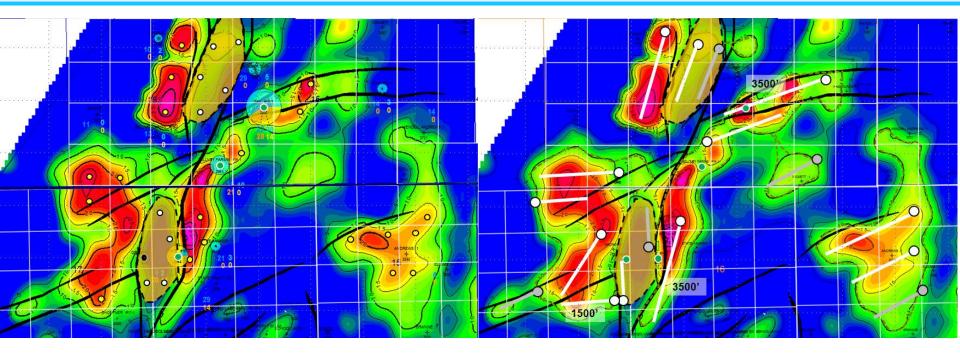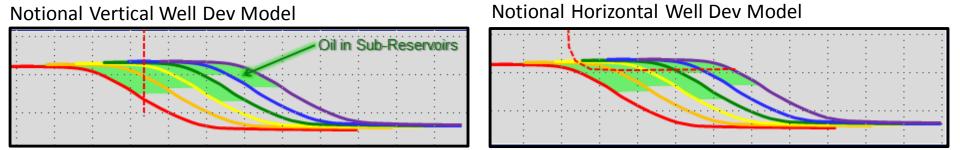|	A	B	C	D	E	F	G	H
	WELL	UPPER ISOCHORE	LOWER ISOCHORE	UPPER+LOWER	UPPER PORE-FT	LOWER PORE_FT	UPPER + LOWER	AMP
	DAY 15-3	22	28	50	20	14	34	-7.5
	STATE 16-2	9	20	29	2	11	13	-5.7
	DAY 6-20	13	7	20	4	6	10	-5.9
	BELLNEY FARMS 16-1	16	21	37	10	0	10	-5.5
	DAY 15-1	14	0	14	3	0	3	-4.0
	HARRIS 1	10	0	10	2	0	2	-4.8
	FRISCH 1	11	0	11	3	0	3	-4.6
	BELLNEY FARMS 16-2	13	0	13	0	0	0	-5.3
	SAVAGE 1	11	0	11	0	0	0	-4.3
	DAY A1	22	0	22	5	0	0	-3.8
	WENDELL ANDREWS 1	14	0	14				-5.8
	STATE TANNER 1	21	0	21				-4.8
	SCHOOLAND 1	15	0	15				-4.7
	ELIZABETH 1	6	0	6				-4.1
	STATE TRACT 20-1	29	14	33				-3.1

Cross-plot of Upper and Lower Cleveland net sand versus attribute values from key wells within the 3D survey.

Upper Cleveland Development Model (40 ac grid)

Notional Vertical Well Dev Model

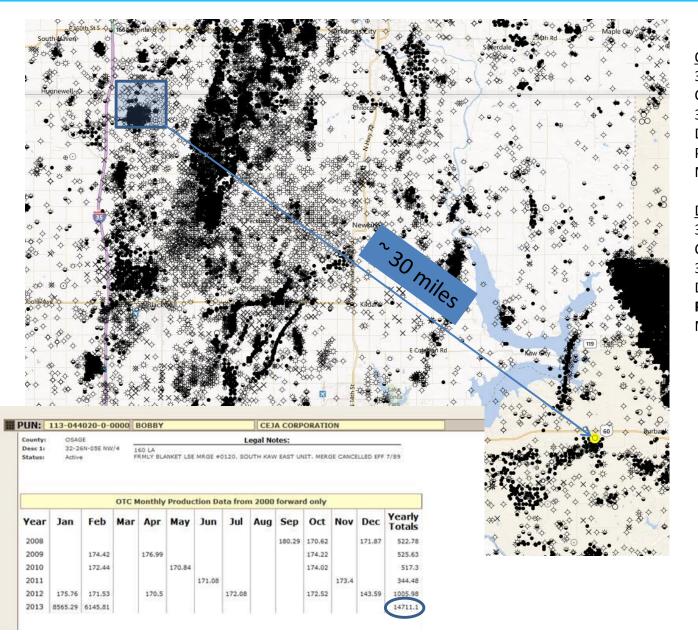Oil in Sub-Reservoirs

Notional Horizontal Well Dev Model

U. Cleveland River-Dominated Deltaic Sands - Heterogeneous Sub-Reservoirs: Oil saturated intervals shown as green fill. Vertical wells have inefficient recoveries vs. horizontal wells

Newly Drilled Horizontal in Cleveland?

Original Well
35113209620000
Ceja Bobby #1
32 26N-5E
Drilled in July, 1971
Produced ~3 MMBO from Miss Chat
MD: 3375'

Development Recompletion Well
35113209620001
Ceja Osage #1
32 26N-5E
Drilled in Fall 2012
Produced ~15 MBO from CLEVELAND
MD: 2763'

~30 miles

PUN: 113-044020-0-0000	BOBBY			CEJA CORPORATION			

County: OSAGE
Desc 1: 32-26N-05E NW/4 — 160 LA
Status: Active

Legal Notes:
FRMLY BLANKET LSE MRGE #0120, SOUTH KAW EAST UNIT. MERGE CANCELLED EFF 7/89

OTC Monthly Production Data from 2000 forward only

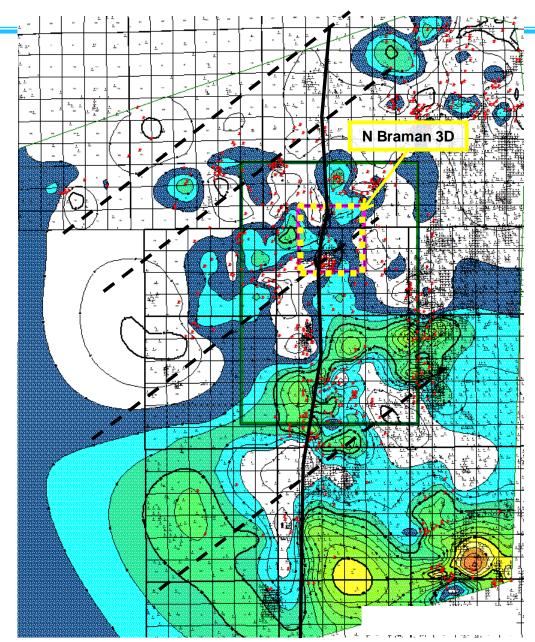| Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Totals
2008									180.29	170.62		171.87	522.78
2009		174.42		176.99						174.22			525.63
2010		172.44		170.84						174.02			517.3
2011					171.08						173.4		344.48
2012	175.76	171.53		170.5		172.08				172.52		143.59	1005.98
2013	8565.29	6145.81											14711.1

Play Extents

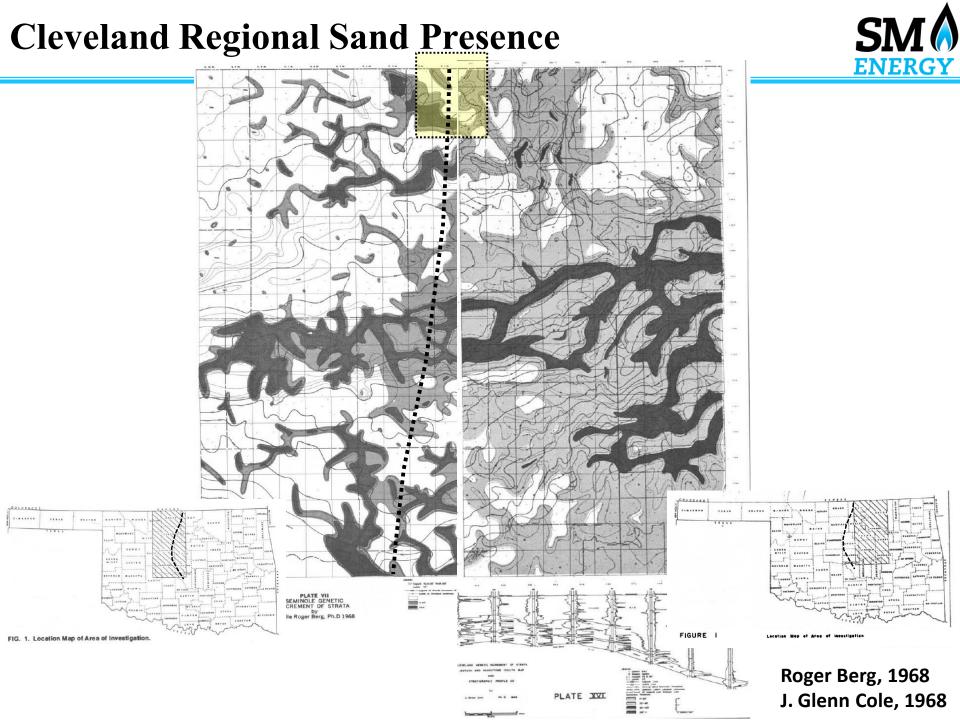# Upper Cleveland Regional Targets: U CLVD Net Sand Map

- Total map area represents
  ~10 Townships or ~230,00 acres

- Assume area with viable net sand
presence: ~75,000 acres

-Assume ½ of acreage has charge
 potential based on "blows and
 shows & petrophysics: ~35,000 ac
 ~55 sections

 4 hz wells/section: ~200 locations

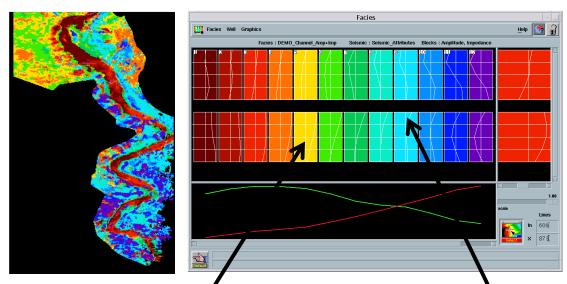N Braman 3D

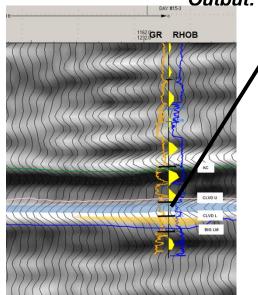Regional shears influence Cleveland deposition/preservation.

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Cleveland Regional Sand Presence

Roger Berg, 1968
J. Glenn Cole, 1968

Facies Modeling

Neural Net Facies Modeling
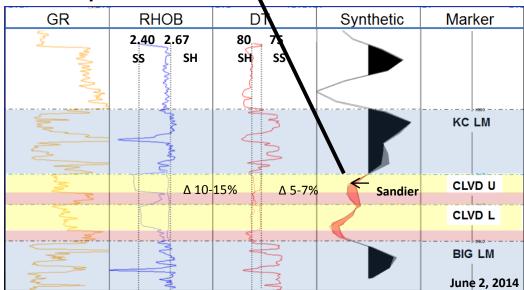
SEISMIC TRACE SHAPE CLASSIFICATION
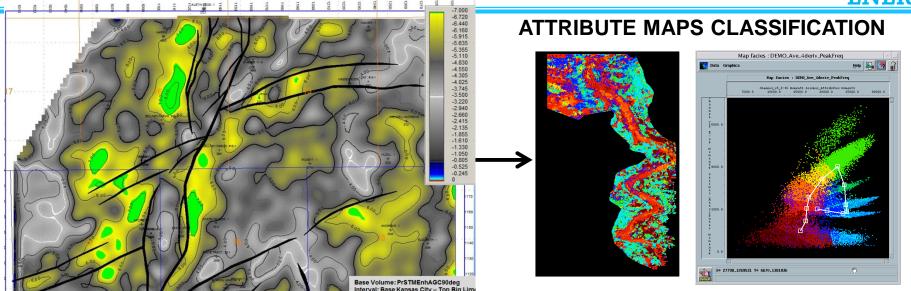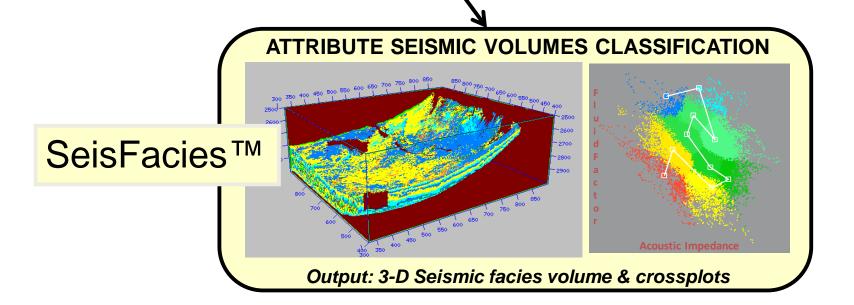

Output: Seismic facies map & model traces

June 2, 2014

Neural Net Facies Modeling

Base Volume: PrSTMEnhAGC90deg
Interval: Base Kansas City – Top Big Lime
Grid: AAA_Cleveland_PoreFeet_SMTH
Attribute: Max Trough Amplitude
Color Bar: RSA seis_rai
Range: 0 - -7

ATTRIBUTE MAPS CLASSIFICATION

Output: Seismic facies map & crossplots

ATTRIBUTE SEISMIC VOLUMES CLASSIFICATION

SeisFacies™

Output: 3-D Seismic facies volume & crossplots
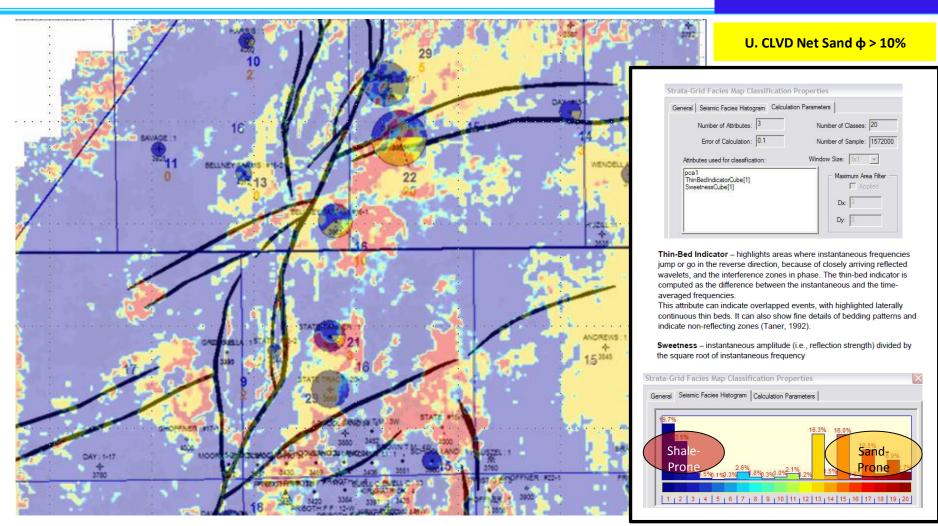
Upper Cleveland Facies Model

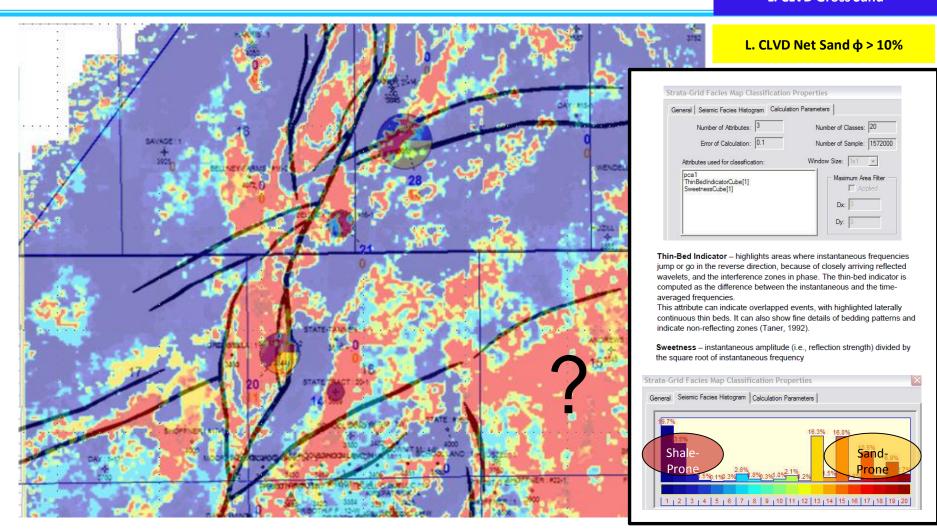**U. CLVD Gross Sand**

U. CLVD Net Sand φ > 10%

Facies map from stratal slice through the Upper Cleveland interval with gross/net sand bubble overlay.

Lower Cleveland Facies Model

L. CLVD Gross Sand

L. CLVD Net Sand φ > 10%

Facies map from stratal slice through the Lower Cleveland interval with gross/net sand bubble overlay.

June 2, 2014

Conclusions

- Rapidly evolving technology applied by aggressive independents helped create the most recent boom

- The trickle-down of this technology will enable smaller, lower cost, less dogmatic operators to create new opportunities in areas that have been largely ignored, when the price of oil rebounds and/or if D&C costs continue to deflate

- Critical risk elements of these play types could be reduced

  - **Complex depositional environment**: Better define play using a geologic model derived from sequence stratigraphic analysis
  - **Unevenly distributed reservoir facies:** Leverage cost-effective, fit-for-purpose 3D data to map better quality rock
  - **Low-resistivity pay**: Blows/shows/production trends, better petrophysical modeling and HZ drilling to increase likelihood of encountering pay
  - **Unpredictable HC/water production**: HZ drilling to penetrate multiple sub-reservoirs; piggy back on extensive SWD infrastructure that may already be in place from mudrock resource play development

ACQUISITION AND COST COMPARISON
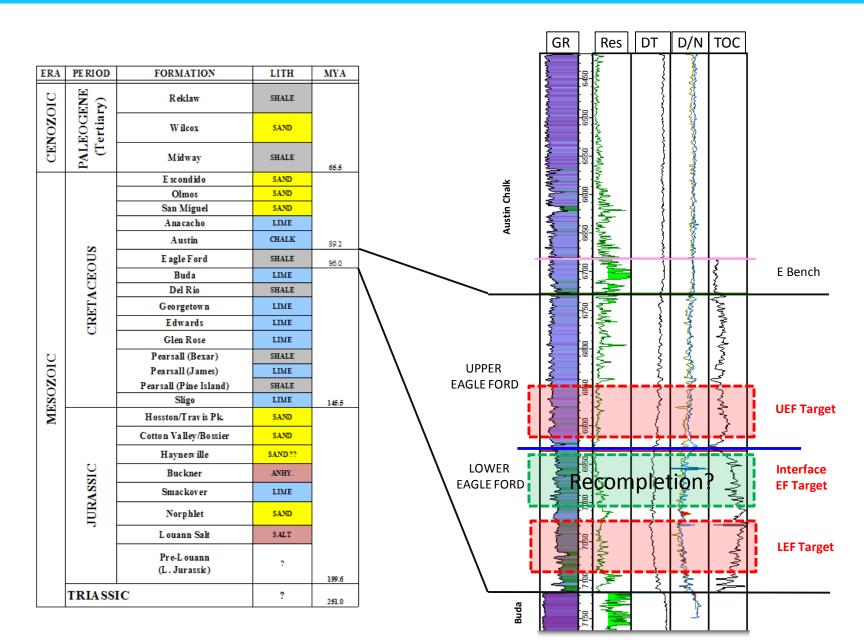# HARPER COUNTY, OKLAHOMA

	ACQUISITION - 2003	ACQUISITION - 2014	% CHANGE
SQ. MILES	66	72	
RLI	660 FEET	495 FEET	
RGI	220 FEET	165 FEET	
RCV PER SQ. MILE	194	343	176.80%
SLI	1,100 FEET	495 FEET	
SGI	220 FEET	165 FEET	
VP PER SQ. MILE	110	343	311.82%
SWEEPS PER VP	8	2	(75.00%)
BIN SIZE	110 FEET	82.5 FEET	
TOTAL BINS	148,860	296,720	
BINS PER SQ. MILE	2,255	4,121	182.72%
REC GEOMETRY	16 X 80	26 X120	
CHANNELS	1,280	3,120	243.75%
FOLD - ALL OFFSETS	64	260	406.25%
TOTAL TRACES	8,002,044	62,636,123	
TRACES PER SQ. MILE	121,243	869,946	717.52%
ACQUISITION COST			
PER SQ. MILE	$17,750.00	$27,725.00	156.20%
PER TRACE	$0.15	$0.03	(78.23%)
PER BIN	$7.87	$6.73	(14.51%)

Independents will not want, nor be able to pursue plays of this type
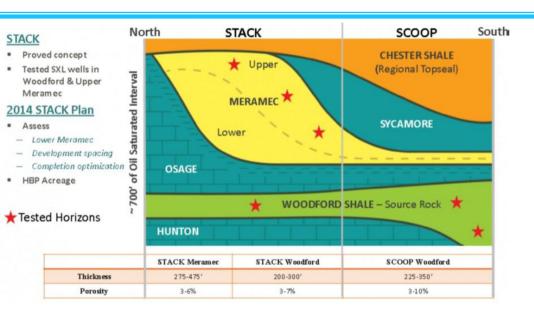
Independents may be Shackled to Their Assets

Independents may be Shackled to Their Assets

SM ENERGY

STACK
- Proved concept
- Tested SXL wells in Woodford & Upper Meramec

2014 STACK Plan
- Assess
  - *Lower Meramec*
  - *Development spacing*
  - *Completion optimization*
- HBP Acreage

★ Tested Horizons

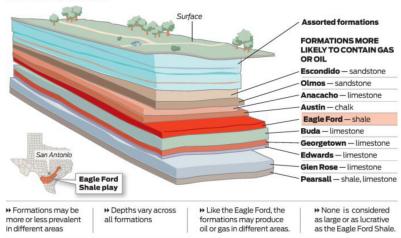|	STACK Meramec	STACK Woodford	SCOOP Woodford
Thickness	275-475'	200-300'	225-350'
Porosity	3-6%	3-7%	3-10%

Stacked plays are not the exception:
- SCOOP
- Permian
- Granite Wash
- Eagle Ford
- Niobrara
- Marcellus
- Bakken

Which play does NOT have stacked potential?

According to a research report from Wood Mackenzie, capital spending in the Wolfcamp and Bone Spring plays alone could top $22 billion by 2018. To put that number into perspective, operators are expected to invest $28 billion in the Eagle Ford this year (2013) which accounts for a quarter of oil CapEx in the lower 48 states.

These operators are NOT named Exxon and Shell!

South Texas' stacked oil and gas plays

The Eagle Ford Shale is nestled among various geologic layers, many of which also are producing oil and gas. Here's a look at how the various plays stack on top of each other.

Diagram is for illustrative purposes and is not complete or to scale, given the complexity of mapping geologic layers across different parts of the state. But it gives a general idea of the shallow and deeper layers across the state's coastal plains region.
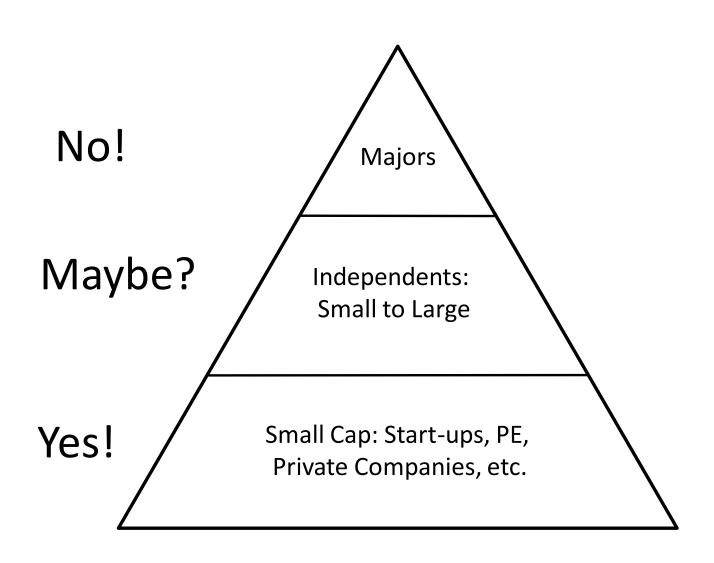
Assorted formations

FORMATIONS MORE LIKELY TO CONTAIN GAS OR OIL
- **Escondido** — sandstone
- **Olmos** — sandstone
- **Anacacho** — limestone
- **Austin** — chalk
- **Eagle Ford** — shale
- **Buda** — limestone
- **Georgetown** — limestone
- **Edwards** — limestone
- **Glen Rose** — limestone
- **Pearsall** — shale, limestone

▸ Formations may be more or less prevalent in different areas. ▸ Depths vary across all formations. ▸ Like the Eagle Ford, the formations may produce oil or gas in different areas. ▸ None is considered as large or as lucrative as the Eagle Ford Shale.

Source: University of Texas Bureau of Economic Geology   Research by Jennifer Hiller   Mike Fisher/San Antonio Express-News
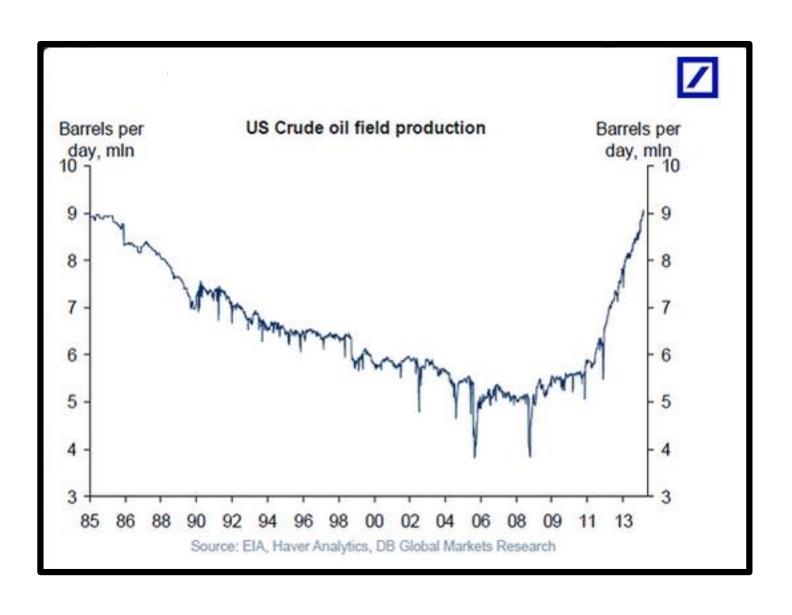
The Unusual Suspects…

No!

Maybe?

Yes!

Majors

Independents:
Small to Large

Small Cap: Start-ups, PE,
Private Companies, etc.

Tony Lupo's Oil and Gas Outlook for 2017 and Beyond!!!

The Shale Revolution in One Picture

Global Reserves to Production Ratios

Source: BP Statistical Review of World Energy 2014

Global Reserves to Production Ratios

Reserves-to-production (R/P) ratios
Years

2013 by region   200

History   800

- North America
- S. & Cent. America
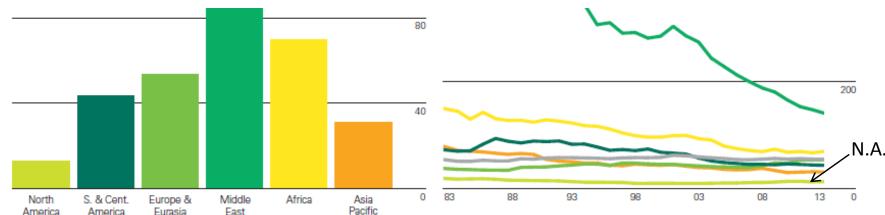- Middle East
- Asia Pacific

Different Times

Hall and several people close to him are taking different lessons from 1986. The most important difference for Hall, according to his letter, is that at the time **OPEC had about 25% of spare capacity. Today's surplus is only 2% higher than global oil consumption**, "and it will have dissipated by the end of the year, if not sooner," he said.

World Oil 2/5/2015

North America | S. & Cent. America | Europe & Eurasia | Middle East | Africa | Asia Pacific

N.A.
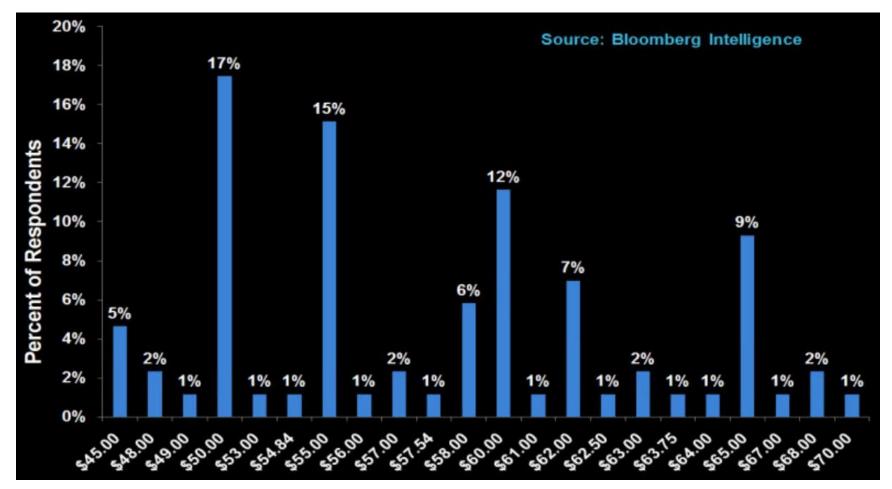
83   88   93   98   03   08   13

World proved natural gas reserves at end-2013 stood at 185.7 trillion cubic metres (tcm), sufficient to meet 55.1 years of global production. Proved reserves grew by 0.2% relative to end-2012 data. An increase in the US (+7.1%) accounted for all of the net growth in global proved reserves in 2013. Iran (33.8 tcm) and Russia (31.3 tcm) hold the largest proved reserves.

Source: BP Statistical Review of World Energy 2014

Volatility

QUOTE: "The outlook on oil prices is clear: Oil will crash. Unless prices surge. Definitely one or the other."
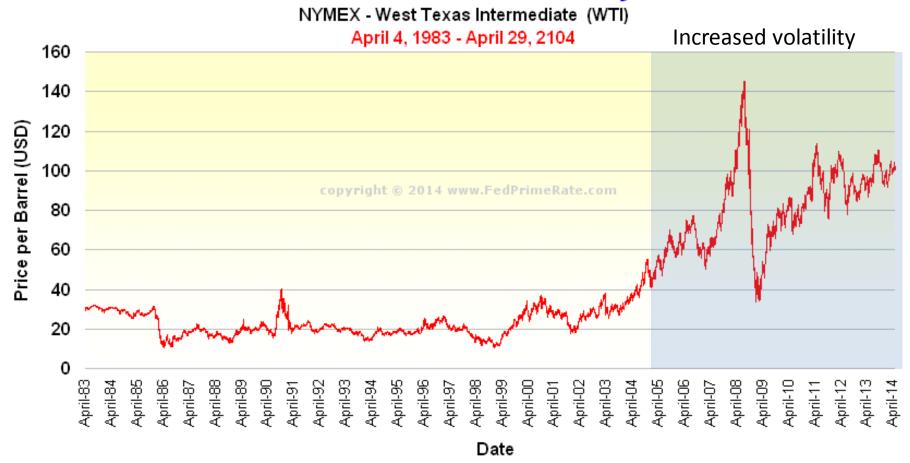

Price per barrel of WTI crude
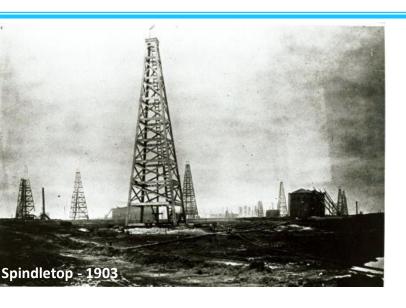
Bloomberg Business, Tom Randall 2/6/2015

Volatility

Crude Oil Price History
NYMEX - West Texas Intermediate (WTI)
April 4, 1983 - April 29, 2104

Increased volatility

Extracting Oil has Gotten Harder…

Spindletop - 1903

Vertical Completion - 1990's

Horizontal Completion Facility
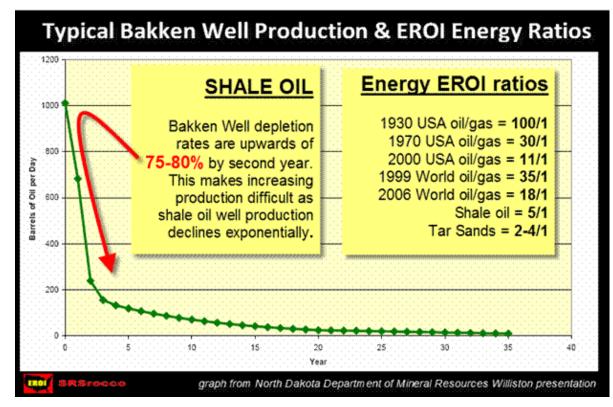
Cana Woodford Completion 2013

Extracting Oil has Gotten more Energy Intensive

In [physics](), [energy economics]() and [ecological energetics](), **energy returned on energy invested (EROEI or ERoEI); or energy return on investment (EROI)**, is the [ratio]() of the amount of usable [energy]() acquired from a particular energy resource to the amount of energy expended to obtain that energy resource.[1][2]

| EROI (for US) ▾	Fuel ⬍
100.0	Hydro
80.0	Coal
50-75[9][10]	Nuclear (with centrifuge enrichment)
35.0	Oil imports 1990
30.0	Oil and gas 1970
20.0	Oil production
18.0	Oil imports 2005
18.0	Wind
14.5	Oil and gas 2005
12.0	Oil imports 2007
10.0	Natural gas 2005
10.0	Nuclear (with diffusion enrichment)
8.0	Oil discoveries
6.8	Photovoltaic
5.0	Ethanol sugarcane
5.0	Shale oil
3.0	Bitumen tar sands
1.9	Solar flat plate
1.6	Solar collector
1.3	Biodiesel
1.3	Ethanol corn

Source: Murphy & Hall (2010)
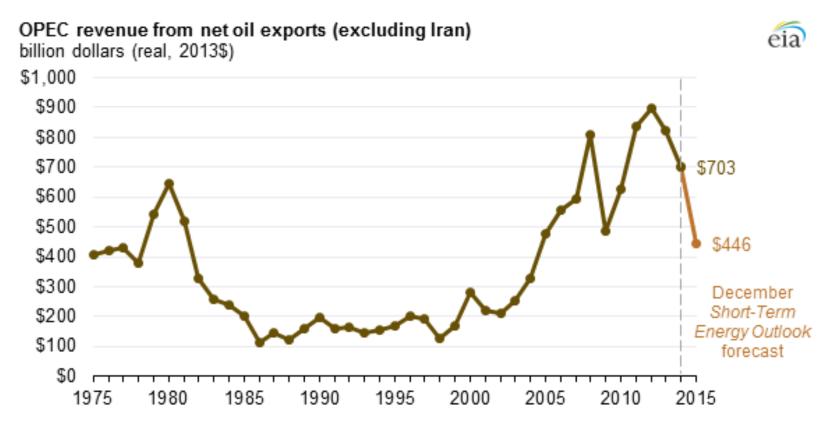
Note: not just on due to production, but refining as well. Since 1985, crude have become 5.5% heavier and contains 54% more sulfur (source: EIA)

Typical Bakken Well Production & EROI Energy Ratios

SHALE OIL

Bakken Well depletion rates are upwards of 75-80% by second year. This makes increasing production difficult as shale oil well production declines exponentially.

Energy EROI ratios

1930 USA oil/gas = 100/1
1970 USA oil/gas = 30/1
2000 USA oil/gas = 11/1
1999 World oil/gas = 35/1
2006 World oil/gas = 18/1
Shale oil = 5/1
Tar Sands = 2-4/1

graph from North Dakota Department of Mineral Resources Williston presentation

OPEC is Squeezed

OPEC revenue from net oil exports (excluding Iran)
billion dollars (real, 2013$)

eia

$703

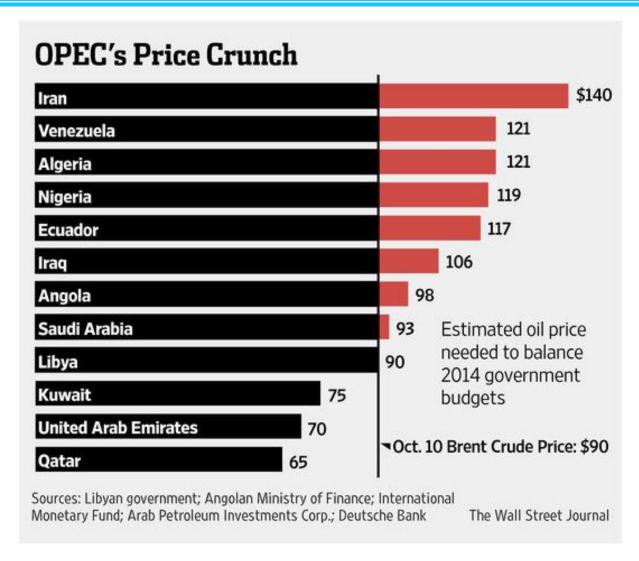$446

December
Short-Term
Energy Outlook
forecast

Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*
Note: OPEC is the Organization of the Petroleum Exporting Countries. Iran is excluded because current sanctions make it difficult to estimate revenues. The 2014 revenue estimates are subject to revision as historical production and consumption data are updated.

OPEC has to do More With its OIL Revenue

OPEC's Price Crunch

Country	Estimated oil price needed to balance 2014 government budgets
Iran	$140
Venezuela	121
Algeria	121
Nigeria	119
Ecuador	117
Iraq	106
Angola	98
Saudi Arabia	93
Libya	90
Kuwait	75
United Arab Emirates	70
Qatar	65

Oct. 10 Brent Crude Price: $90

Sources: Libyan government; Angolan Ministry of Finance; International Monetary Fund; Arab Petroleum Investments Corp.; Deutsche Bank

The Wall Street Journal

- OPEC needs money for budgets to positively engage a large, young and increasingly disaffected population
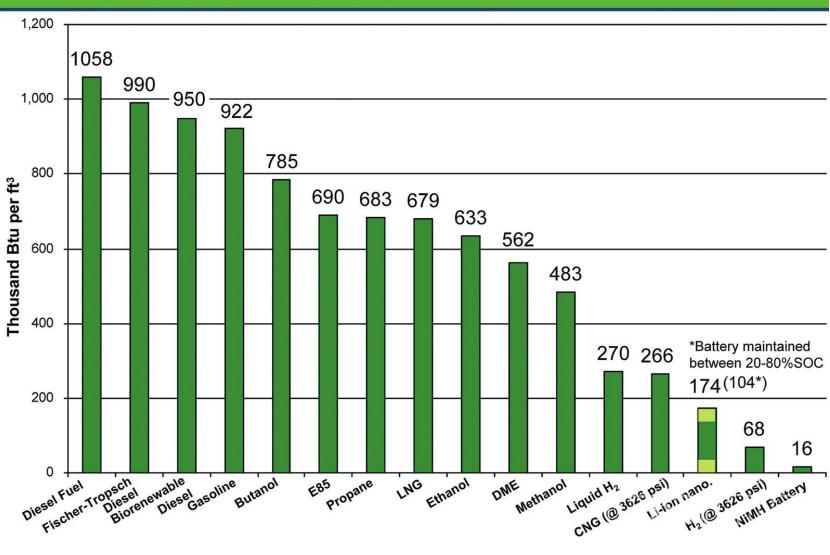
Conclusions

- Most agree that an oil glut has been created by an increase in supply and reduced demand stemming from slower economic growth and increased efficiencies

- However, newer sources of oil are getting more expensive to find and extract, and are of lower quality, require more energy to produce, and decline faster

- The amount of oil being discovered is not keeping pace with consumption (i.e., R/P ratios)

- OPEC needs money for budgets to positively engage a large, young and increasingly disaffected population

- The net effect is a long-term, positive pressure on the price of oil with more volatility
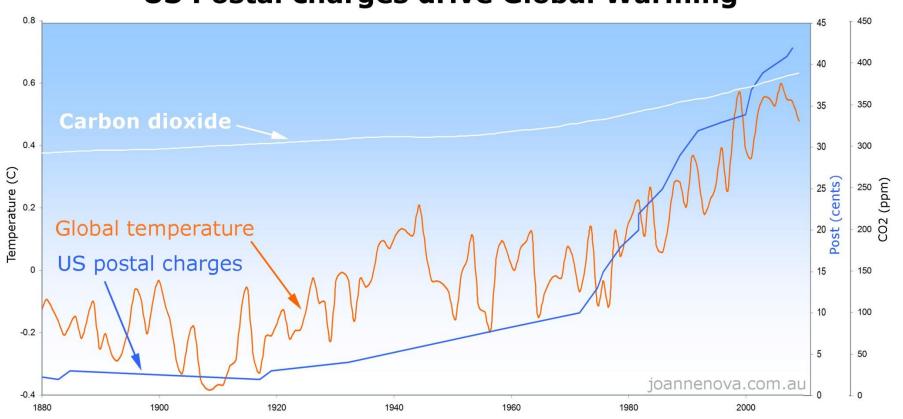
Energy Density

The Power of Statistics
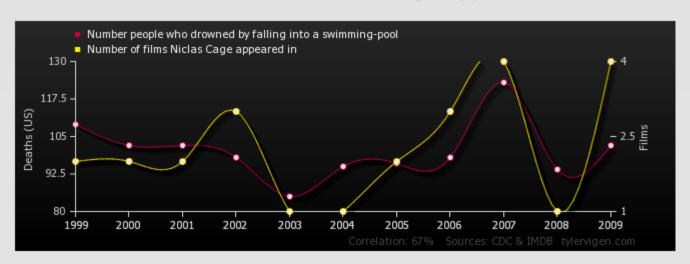

US Postal charges drive Global Warming

The Power of Statistics

Number people who drowned by falling into a swimming-pool correlates with Number of films Nicolas Cage appeared in
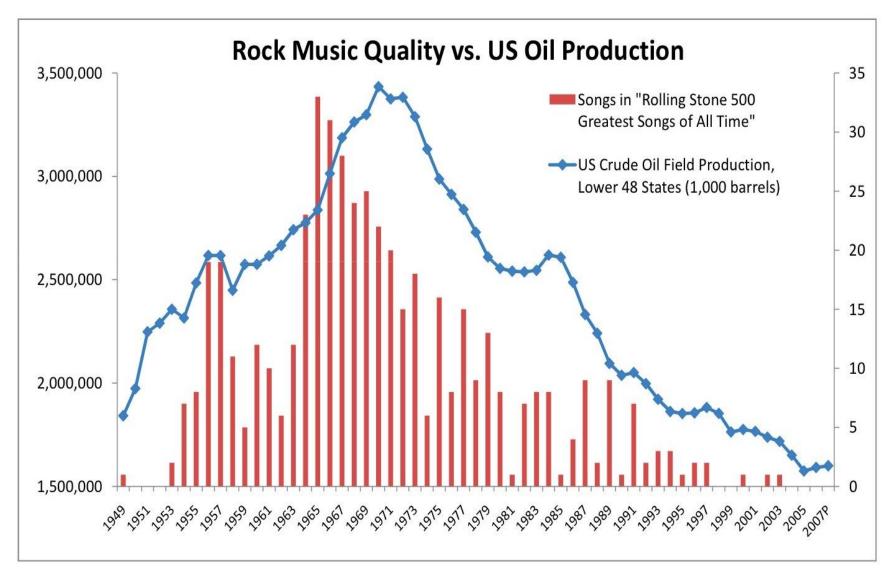
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number people who drowned by falling into a swimming-pool Deaths (US) (CDC)	109	102	102	98	85	95	96	98	123	94	102
Number of films Nicolas Cage appeared in Films (IMDB)	2	2	2	3	1	1	2	3	4	1	4

Correlation: 0.666004

The Power of Statistics

Rock Music Quality vs. US Oil Production

Songs in "Rolling Stone 500 Greatest Songs of All Time"

US Crude Oil Field Production, Lower 48 States (1,000 barrels)

Source: Rick Fritz DPA Presentation