

Stratigraphy and Oil Resource Potential of the Mississippian Heath Formation, Central Montana, USA*

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Abstract

The Heath Formation of central Montana is an emerging tight oil play. Historically studied for oil shale mining potential, these organic-rich beds are the primary source rocks for more than 100 MMBO of oil produced from the Tyler Sandstone and other reservoirs in central Montana. The late Mississippian Heath Formation is the highest stratigraphic unit in the Big Snowy Group and is unconformably overlain by the Pennsylvanian (and/or latest Mississippian) Tyler Formation. The Heath exceeds 450 feet in thickness in areas of little basal Tyler erosion. Internally the Heath can be informally subdivided into, in ascending order, a lower 'shale', the Van Dusen Zone, Potter Creek Coal, Forest Grove Limestone, Cox Ranch Oil Shale, Heath Limestone, and an upper 'shale'. Oil shows and saturations are present throughout the entire Heath Formation. The Potter Creek and several other thin coals indicate humid conditions were present in near shore areas in older parts of the Heath. Intertidal to supratidal dolomites with up to 18 percent porosity interbedded with nodular anhydrites in the Heath Limestone indicate hot, arid conditions dominated near shore areas in the middle part of the Heath. Oil production from the Heath Formation was discovered in 1919 at Devil's Basin Anticline. Recent horizontal and vertical completions in the Heath Formation have initial potentials up to 447 BOPD and demonstrate the economic potential of the Heath. With Oil-In-Place estimates ranging from 6.6 to 22.4 MMBO/section and total Oil-In-Place of more than 14.0 BBO there is sufficient oil potential to warrant additional drilling and testing.

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AAPG Rocky Mountain Section

September 24, 2013

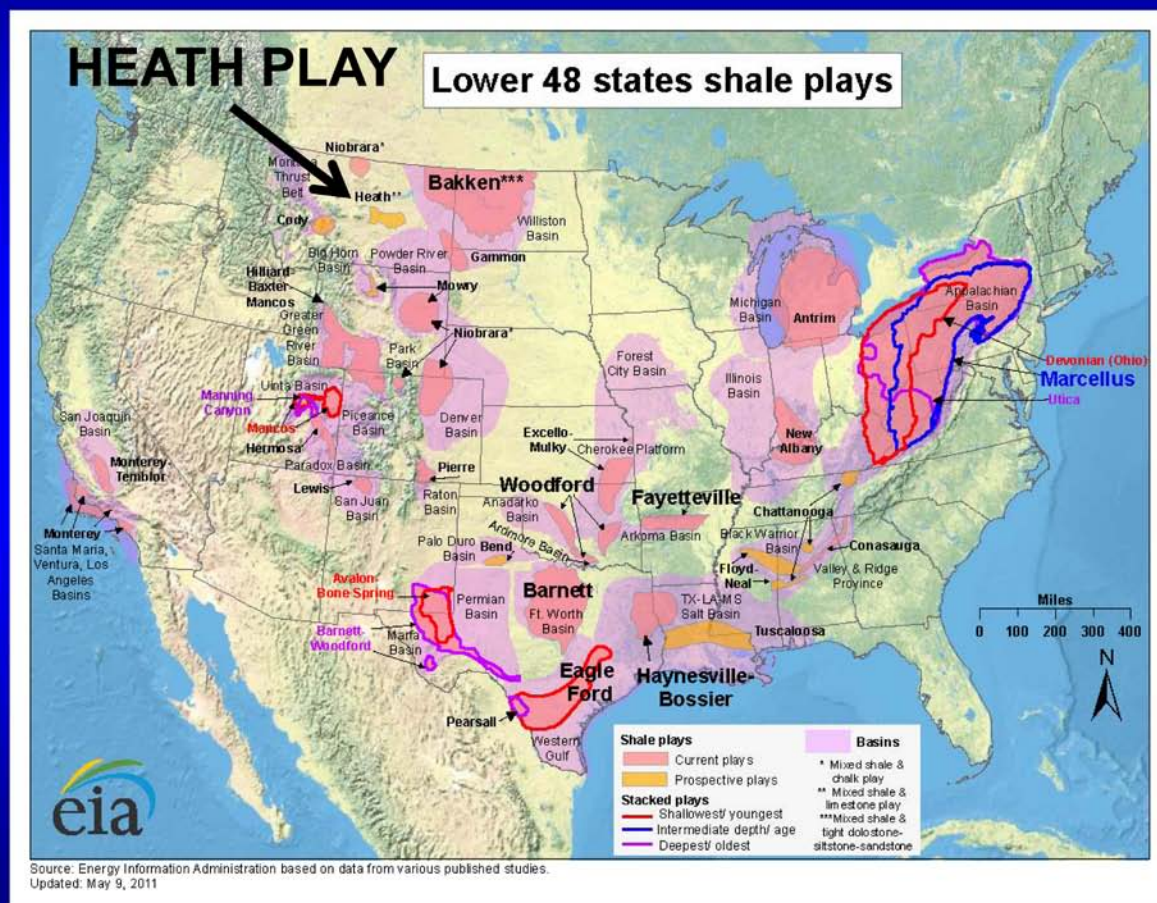
**Stratigraphy And Oil Resource
Potential of the Mississippian Heath
Formation, Central Montana, USA**

Richard Bottjer

Cirque Resources, LP



EIA Shale Plays, Lower 48 States, USA 2011



- “Prospective” in 2011
- Heath is a Proven Oil Producer in 2013
- 15 Horizontal Heath Wells Drilled 2010-2012; 14 Completions
- 8 of Last 9 Horizontal Wells IP > 90 BOPD
- Peak IP 447 BOPD
- Play in Early Phase of Development

Presenter’s notes: EIA Shale Plays Map of North America from 2011. The Heath was prospective in 2011 and is a proven oil-producing “shale” at this time in 2013.

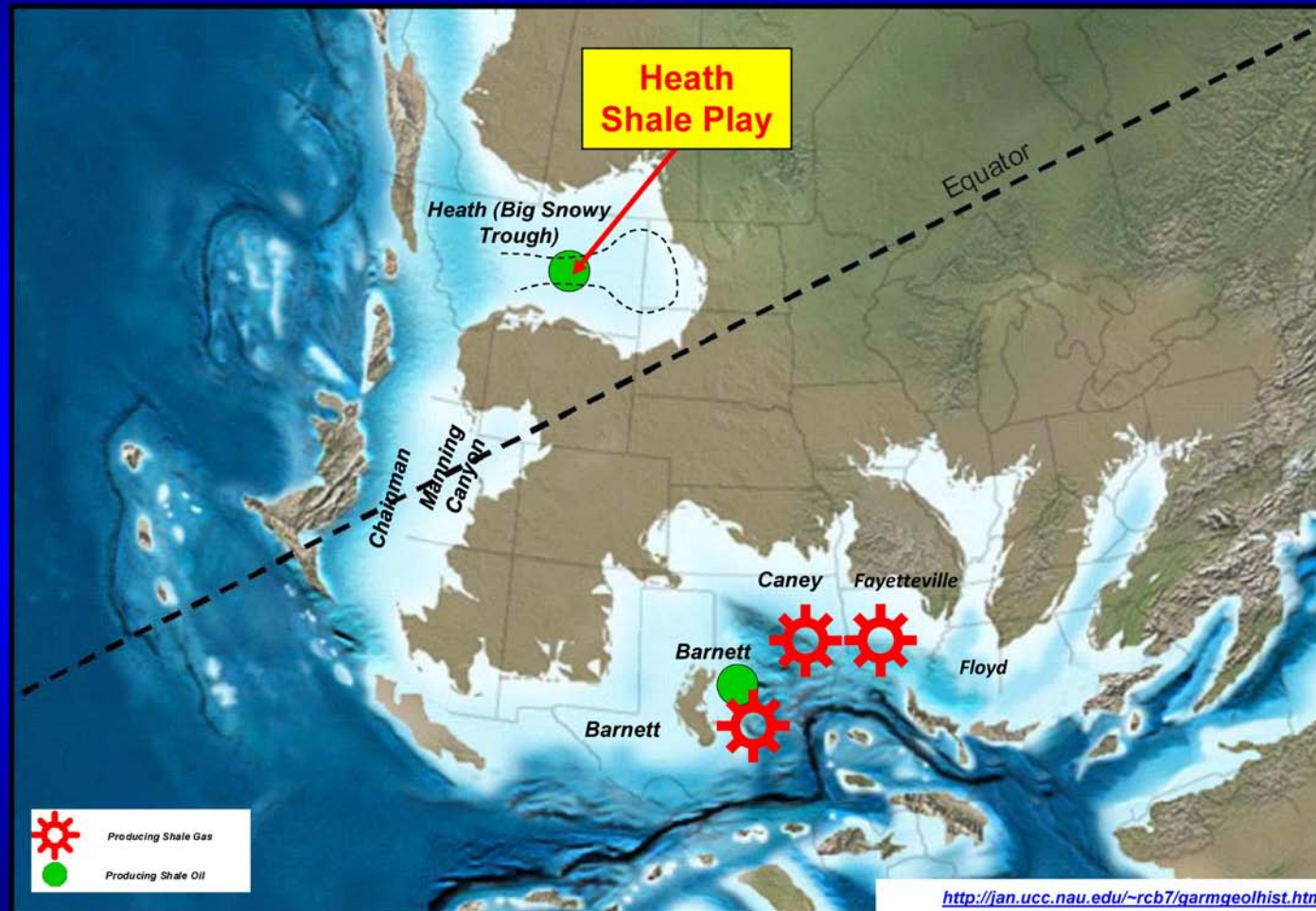
HEATH PLAY – SUMMARY

- **Heath Production**
 - Initial Oil Discovery at Devils Basin in 1919
 - 1st Heath Horizontal Well in 2010 (CMR)
 - 15 Heath Horizontal Wells Drilled 2010-2012
- **Mixed Lithologies – Dominantly Marine**
 - Dark Gray to Black “Shales”, Dolomite, Limestone, Anhydrite,
 - Thin Coals & Claystones in Lower Heath
- **Organic Richness**
 - TOC up to 26%, Thermal Maturity Ranges from Immature to Peak Oil
 - Source for > 95 MMBO of Tyler Oil Production
 - Oil Generated > 30 Billion Barrels
- **Total Heath up to 450 Feet Thick – All Oil Saturated**

Presenter's notes: The Heath is not a new play. Oil was first discovered in the Heath at Devil's Basin in 1919. More recent logging, coring, and horizontal drilling have advanced our understanding of this oil resource. The Heath is not a “pure” shale but consists of a complex mix of lithologies, including limestone, dolomite, shale, and coal. The Heath is so organic-rich that it was evaluated by the MBMG for oil shale mining potential in the 1970s to early 1980s.

Late Mississippian Paleogeography

North America ~ 325 MYA

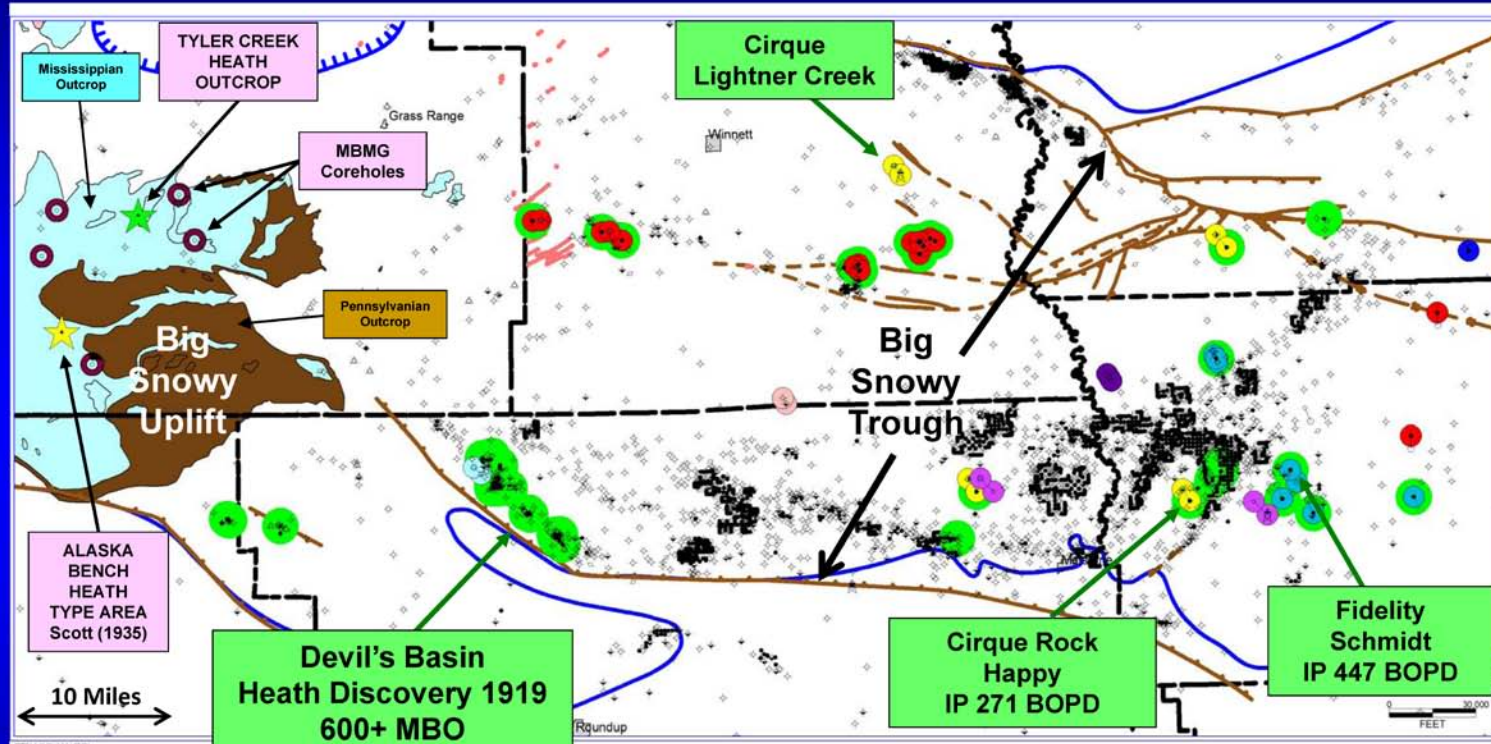


<http://jan.ucc.nau.edu/~rcb7/qarmgeolhist.html>

(Blakey (2005) and Loucks & Ruppel (2007))

Presenter's notes: Ron Blakey's paleogeographic reconstruction for western North America in the latest Mississippian. The Heath was deposited in the east-west oriented Big Snowy Trough in central Montana.

HEATH PRODUCTION AND RECENT ACTIVITY



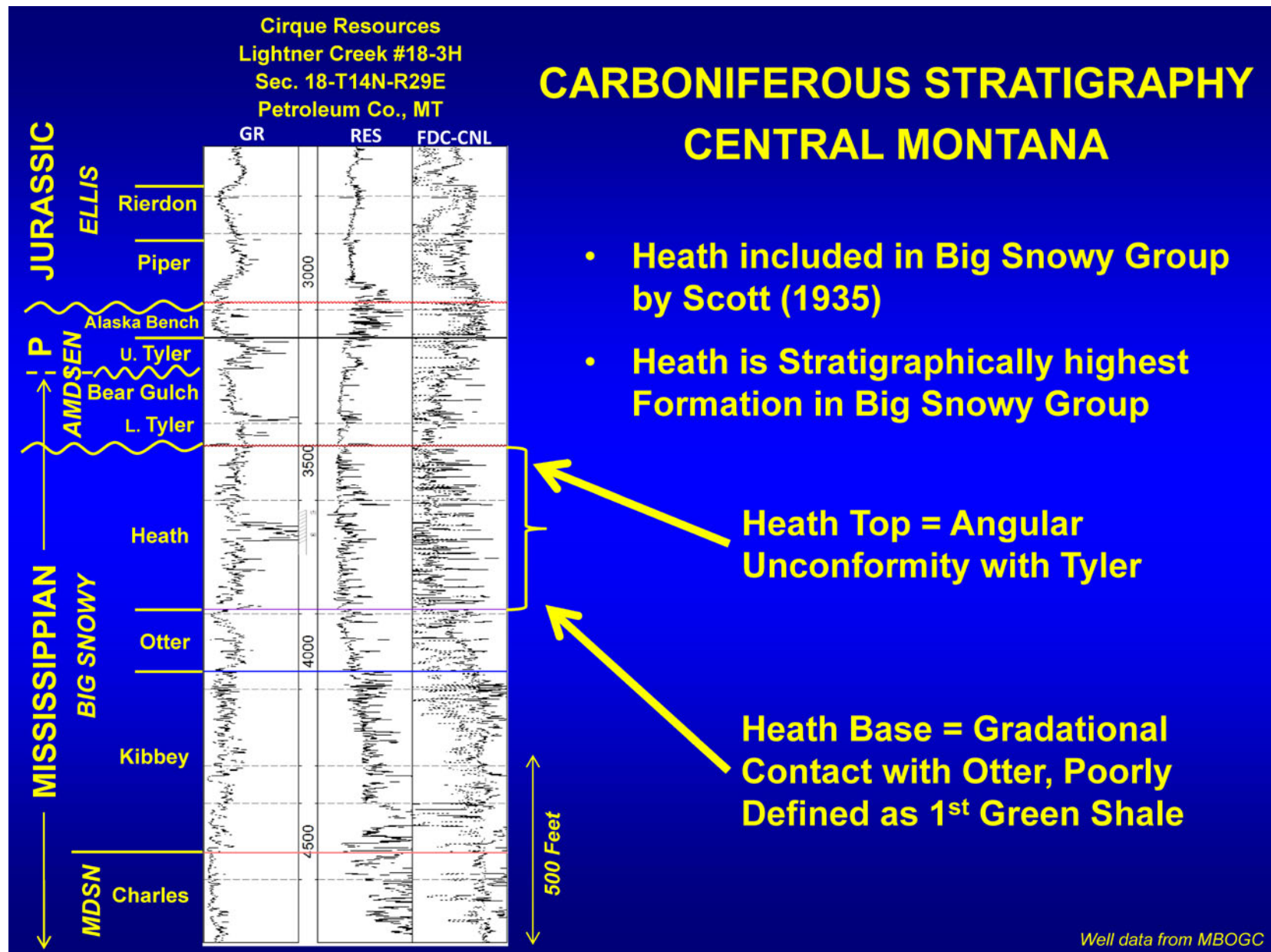
RECENT OPERATORS



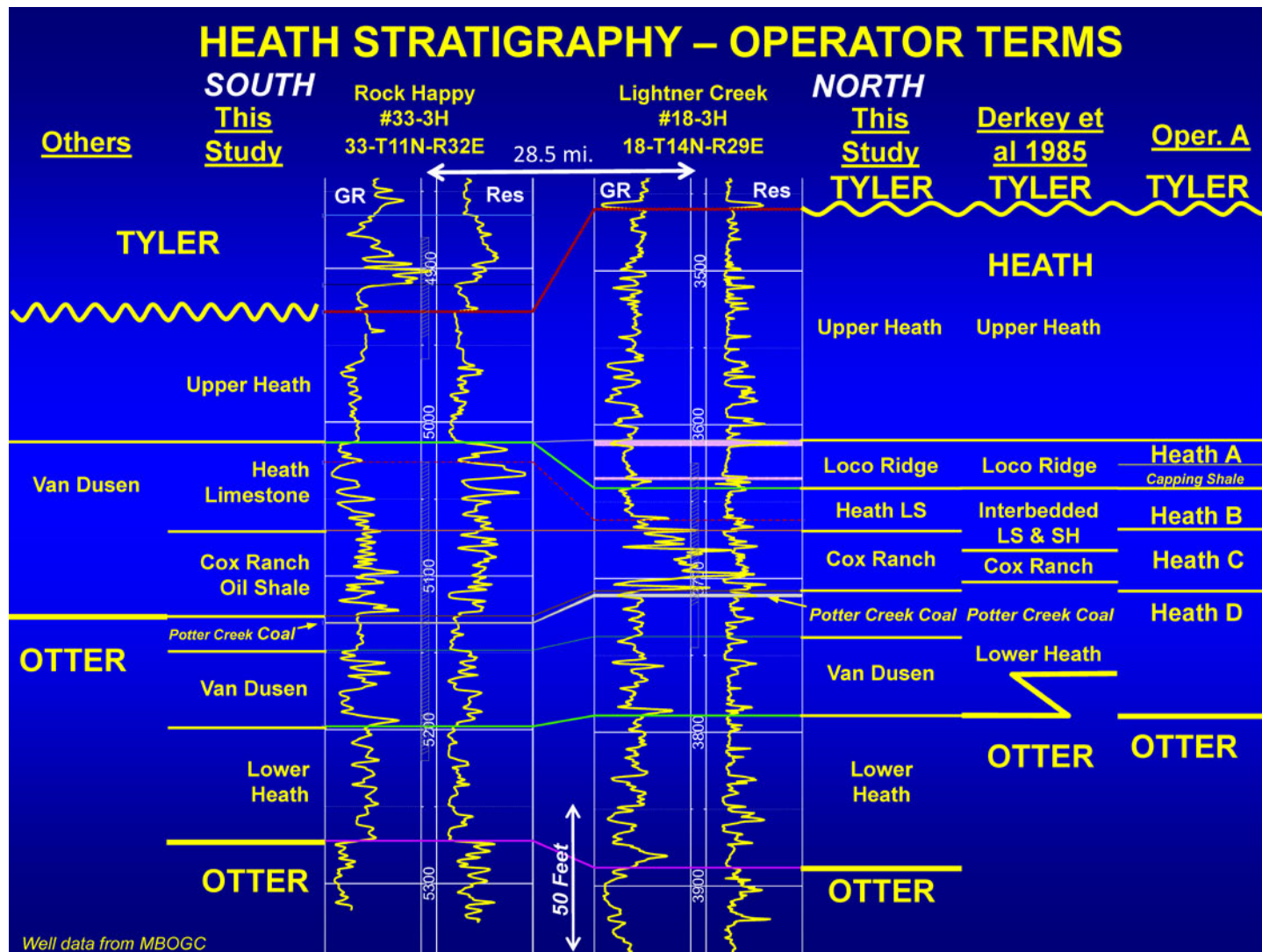
HEATH OIL PRODUCING WELL

Well locations and data from I.H.S. Energy, MBOGC, and Derkey et al (1985)

Presenter's notes: Heath outcrops and type area are in the Big Snowy Mountains on the west side of this map. Heath Producing wells in green, original 1919 discovery at Devils Basin close to the outcrops and more recent horizontal drilling further to the east. We will look at the Devil's Basin type log and will compare it with the Rock Happy and Lightner Creek modern logs and cores.



Presenter's notes: Big Snowy Group defined as the interval of rocks found in central Montana between the Madison Group below and the Amsden Group above. The Heath is the uppermost Formation in the Big Snowy Group.



Presenter's notes: Poor outcrops, facies changes in the upper parts of the Heath, and the definition of the top of the Otter at the first green shale has led to confusion in terminology. In the extreme case, the Van Dusen zone as defined by Knapp could be placed in the Otter, which is misleading at best. With new log and core data, we can better define these formation boundaries. I recommend using the fossiliferous, laterally continuous limestone at the bottom of the logs shown as the top of the Otter – this is a mappable and laterally continuous unit, and lithofacies above it have organic-rich beds that have more affinity with what the Heath was originally defined to be. Operator A gave up on historical terms and picked tops Heath A-D in their wells.

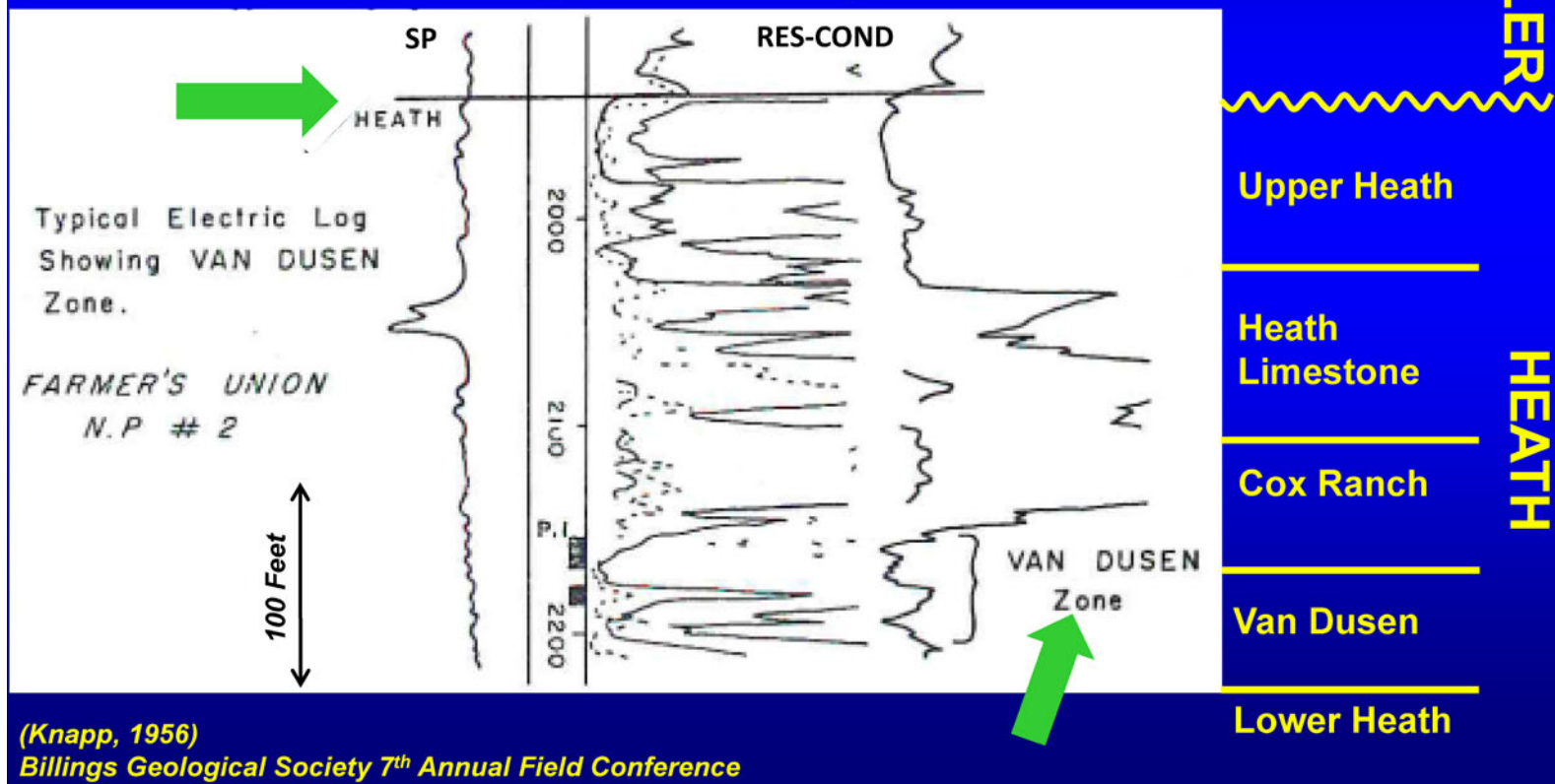
HEATH SUBSURFACE STRATIGRAPHY DEFINITIONS FROM KNAPP 1956

Devil's Basin Oil Field

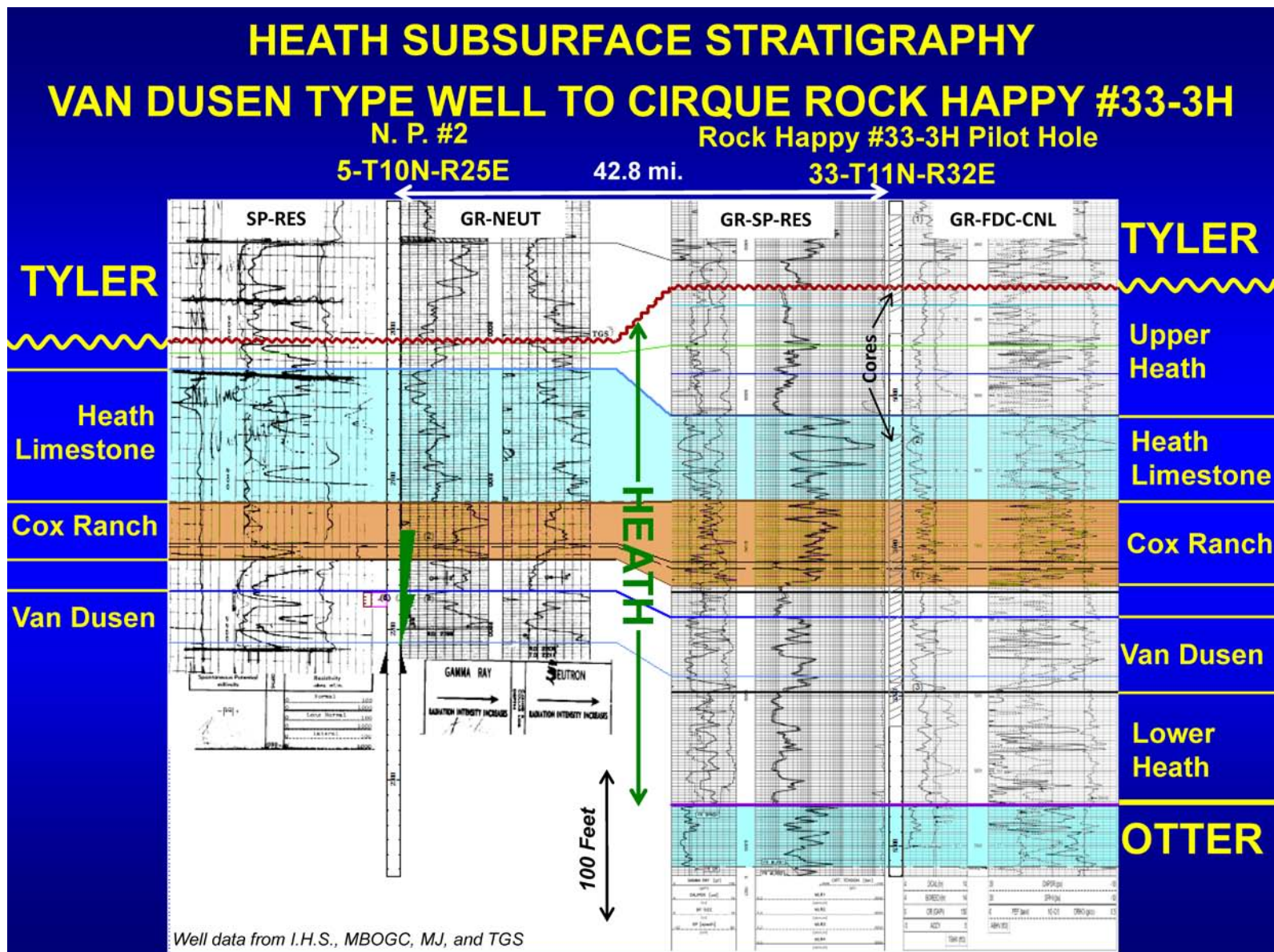
Van Dusen Zone "Type Log"
Farmers Union Central Exchange
N. P. #2

Sec. 5-T10N-R25E, Musselshell Co., MT

RECOMMENDED TERMINOLOGY

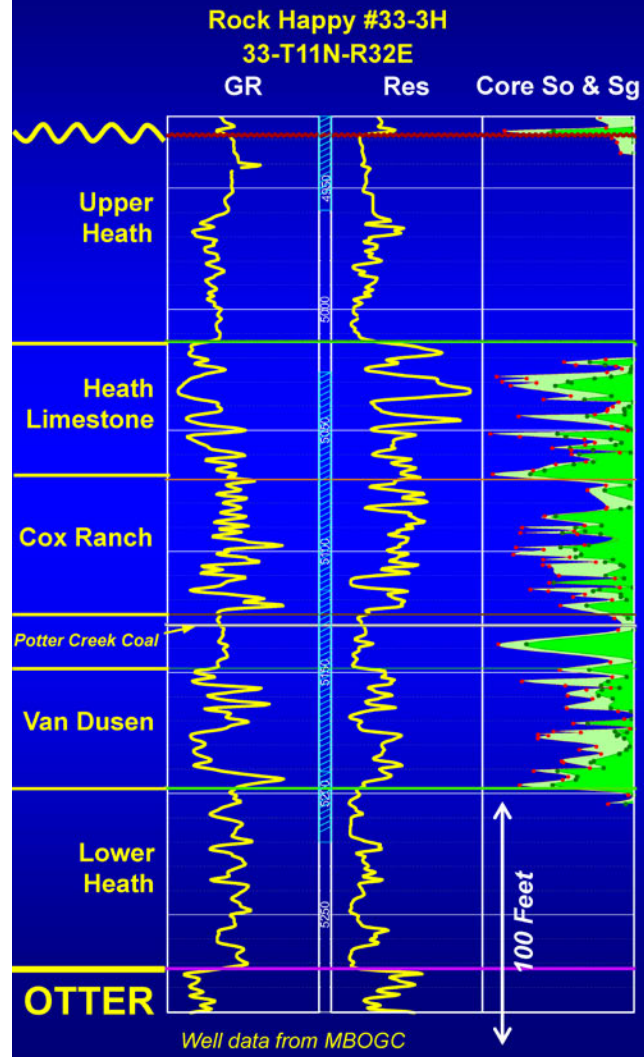


Presenter's notes: Original definition of the Van Dusen zone, approximately 200 feet below the top of the Heath as defined by Knapp in 1956.



Presenter's notes: Knapp's Van Dusen Zone type log on the left, with gamma-neutron for added log character, correlates well with the Rock Happy pilot hole nearly 43 miles to the east. The Van Dusen zone type log did not penetrate the bottom of the Van Dusen Zone as I would recommend using the term, nor did it reach the top of the Otter.

Heath Lower Van Dusen Zone



Gray Marine Limestone
(partially dolomitized)

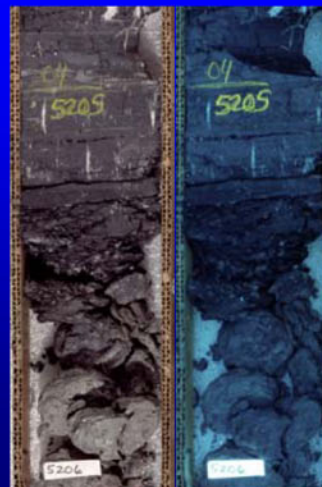


Fossiliferous, Calcareous Black Shale

RockEval @
5199.7

TOC 9.60
S1 7.60
S2 42.72

XRD wt%
Calcite 57%
Quartz 10%
Clay 25%



Coal

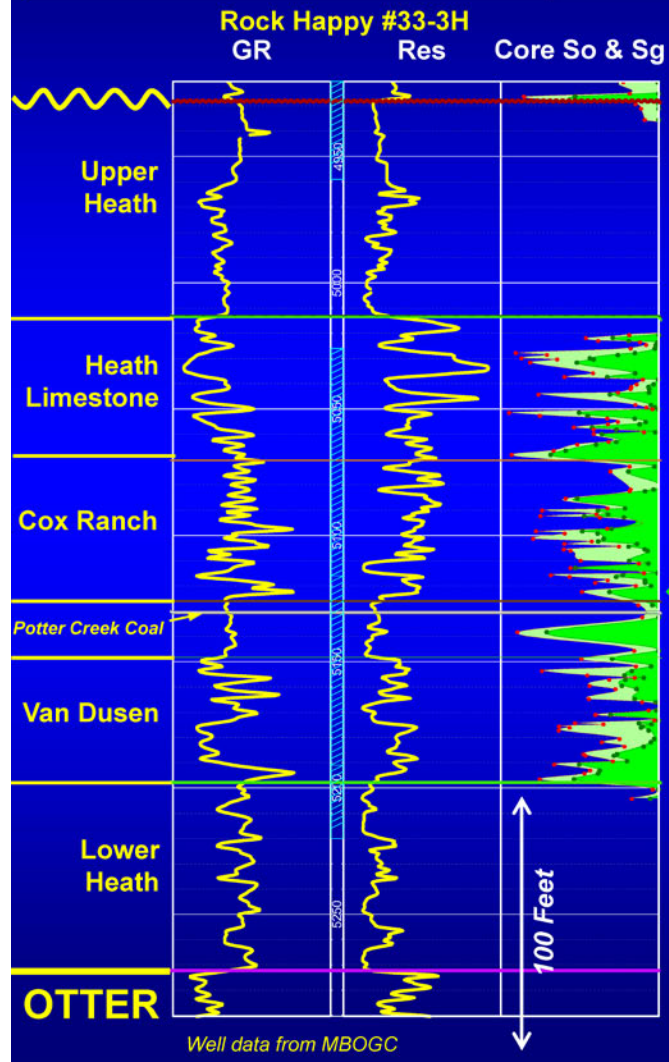
RockEval @ 5204.6
TOC 34.62
S1 18.17
S2 80.31

Paleosol

Depth Shift Log = Core - 8'

Presenter's notes: Logs – gamma, resistivity, and core oil and gas saturations. Note fully oil saturated interval where cores were recovered. Lower Van Dusen lithotypes. These are organic-rich beds that should be included in the Heath. Note “shales” have low clay content and high TOC and could be called limestones. This interval documents a transgressive period, with (in ascending order) a paleosol, a liquids-rich coal seam, a high-TOC fossiliferous shale, and an open marine limestone.

Potter Creek Coal & Lower Cox Ranch Oil Shale



Gray Marine
Dolomite,
burrowed
wackestone

Gray Marine
Limestone
Packstone

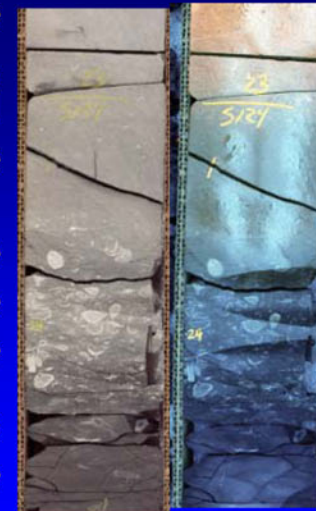
Calcareous
Black Shale

Fossiliferous,
Calcareous
Black Shale

Fossiliferous,
Black Shale

Coal

Paleosol



RCA @ 5123.4
Phi 1.9%
So 27.0%
GD 2.79 gm/cc

RockEval @
5125.2
TOC 10.88
S1 4.95
S2 40.02

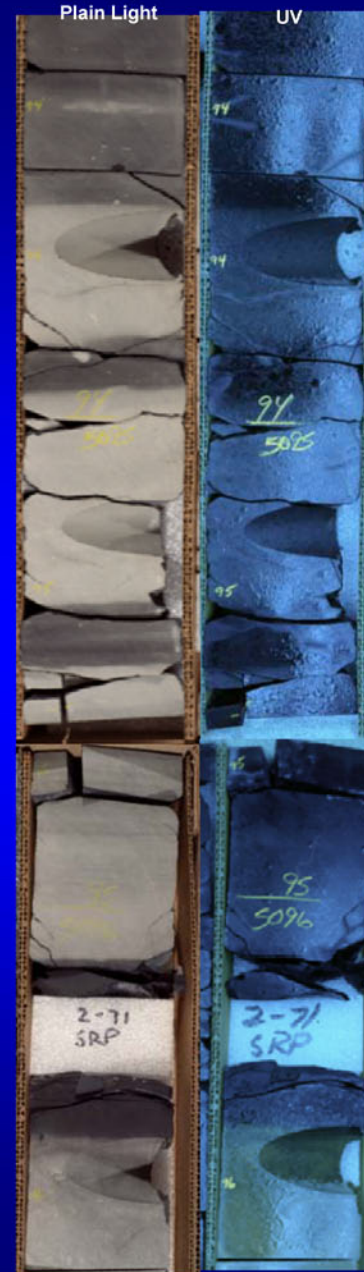
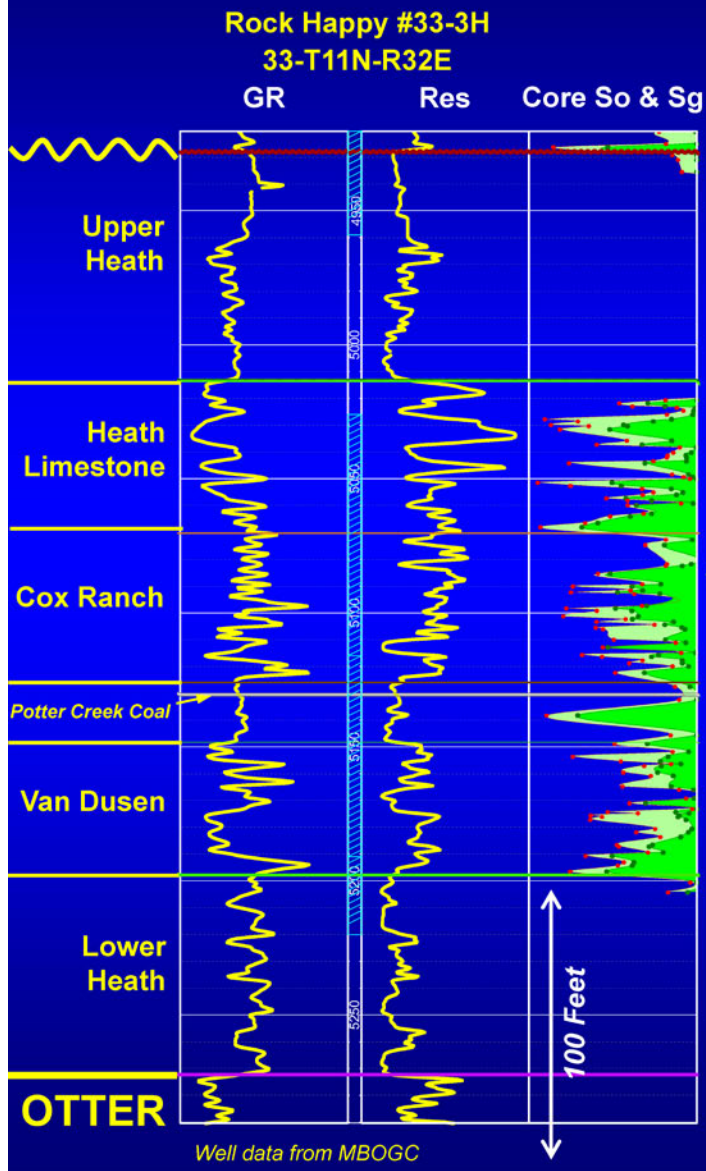
XRD wt%
Calcite 44%
Quartz 14%
Clay 34%

Potter Creek Coal
= Stratigraphically
Highest Coal in
Heath

Depth Shift Log = Core - 6.5'

Presenter's notes: Lowest part of the Cox Ranch Oil Shale. These are similar lithologies to what was documented in the Van Dusen zone; a transgressive interval, with (in ascending order) a paleosol, a liquids-rich coal seam, a high-TOC fossiliferous shale, and an open marine limestone with partial dolomitization in the upper part.

Heath Cox Ranch Oil Shale



**INTERBEDDED
Gray Marine
Limestone
Wackestone
and
Dark Gray to
Brownish Black
Calcareous Shale
(Oil Shale)**

**COX RANCH 35-80
Feet Thick**

RockEval @ 5096.3
TOC 10.65
S1 6.20
S2 38.54

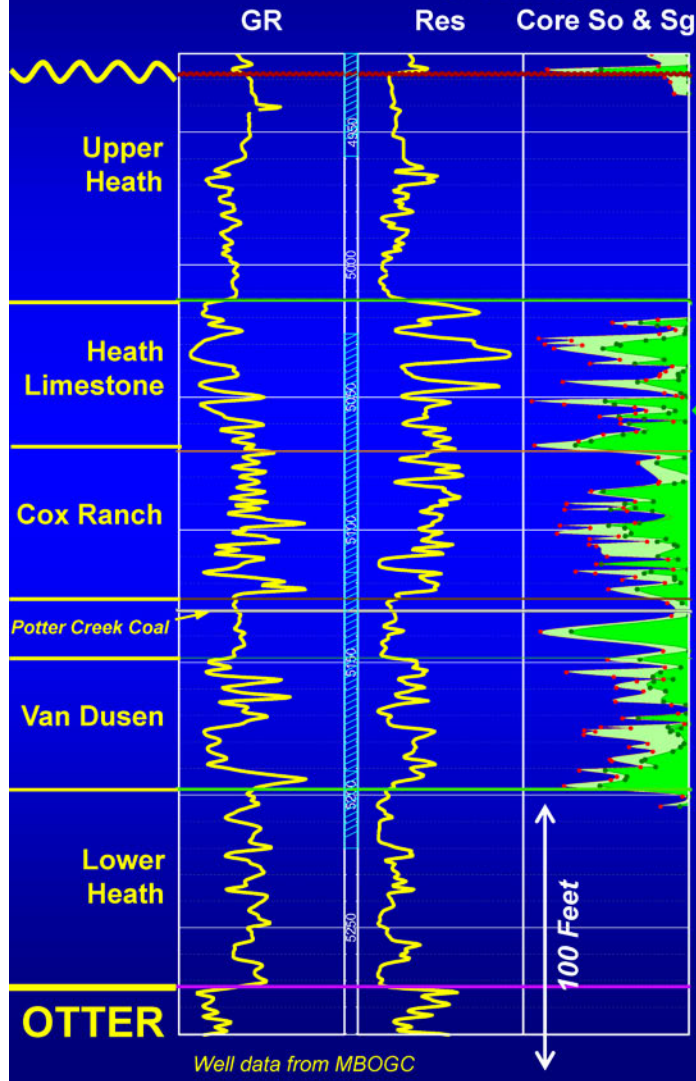
XRD wt%
Calcite 42%
Dolomite 7%
Quartz 12%
Clay 24%
Pyrite 4%

Depth Shift Log = Core - 7.0'

Presenter's notes: Typical lithologies for the Cox Ranch Oil Shale. Hard, competent rocks, very high carbonate content, low clay content.

Lower Heath Limestone – “4th Bench”

Rock Happy #33-3H
33-T11N-R32E



Laminated
Limestone
Wackestone

TSE

Laminated
Dolomite
Grainstone



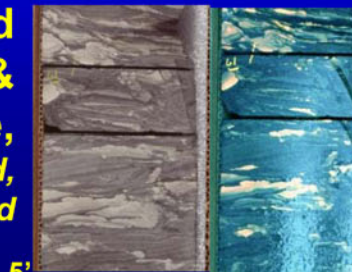
RCA @ 5058.2
Phi 17.3%
So 50.5%
GD 2.88 gm/cc
XRD wt% @
5058.2
Calcite 1%
Dolomite 80%
Quartz 13%
Clay 1%

Laminated
Dolomite
Grainstone



RCA @ 5059.2
Phi 17.3%
So 45.0%
GD 2.79 gm/cc

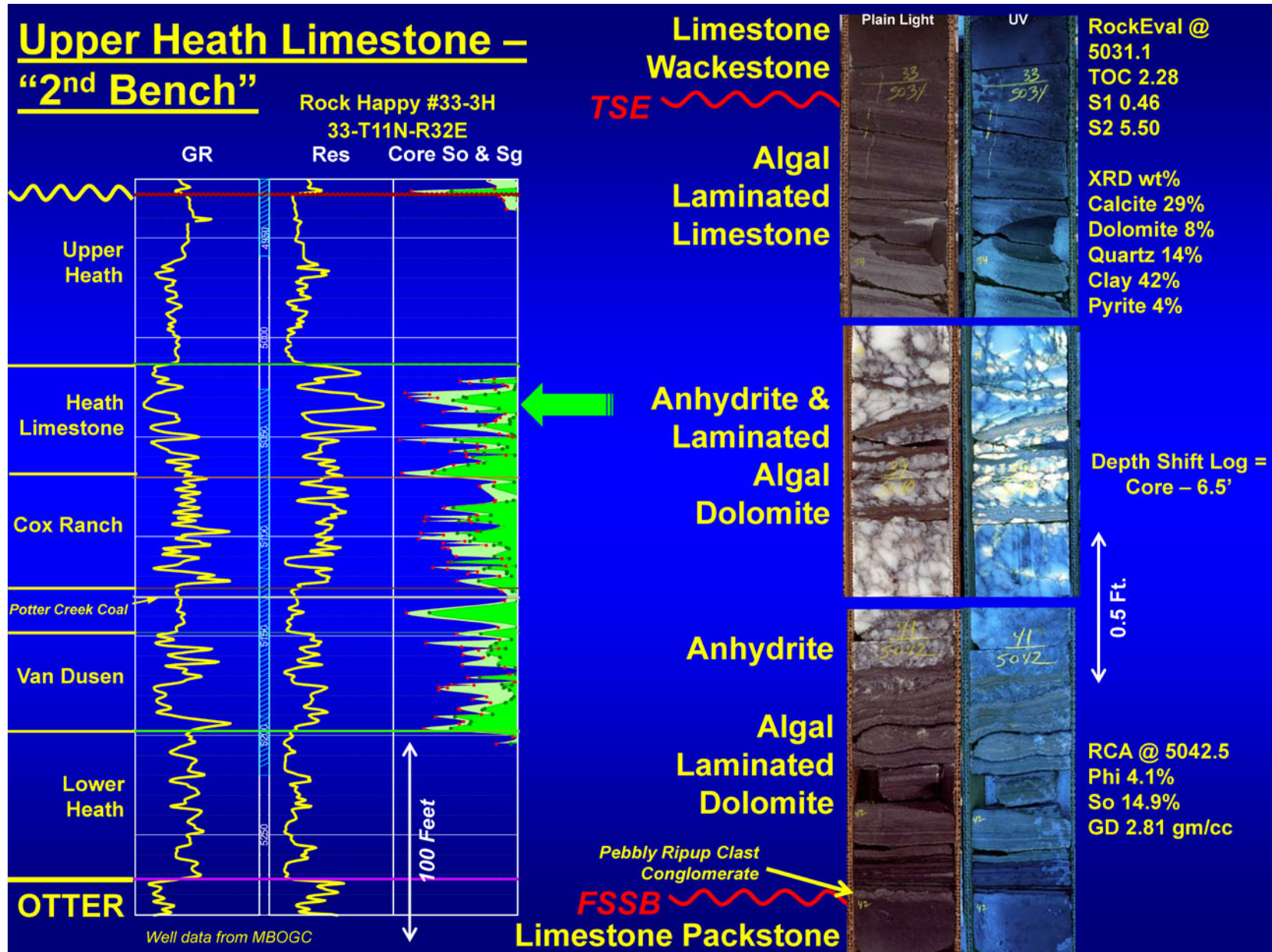
Interbedded
Dolomite &
Limestone,
*Laminated,
Slumped*



RCA @ 5061.4
Phi 11.7%
So 8.3%
GD 2.78 gm/cc

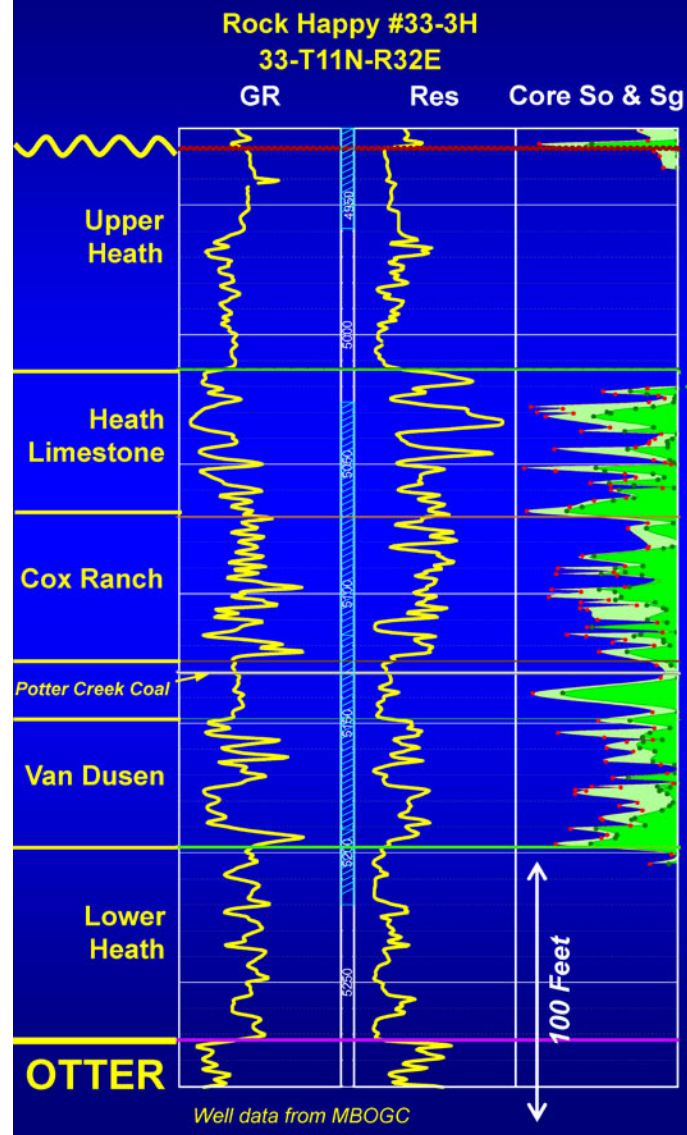
Depth Shift Log = Core – 6.5'

Presenter's notes: Heath Limestone dolomitic shoreline deposits. Best reservoir properties in the Heath that we have encountered so far.



Presenter's notes: Heath Limestone, "2nd Bench". Anhydrites and supratidal dolomites indicate arid shoreline conditions. Dolomites are oil-saturated as indicated by core analyses and UV fluorescence.

Upper Heath Limestone "1st Bench"



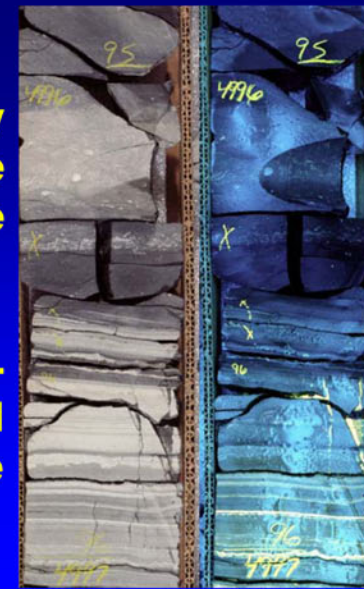
Med Gray
Limestone
Packstone

Lt Gray Algal-
Laminated
Limestone

Depth Shift Log =
Core + 2.0'

Gray Marine
Limestone
Wackestone
*With Oncolites &
burrows*

Calcareous
Black Shale



Plain Light

UV

Lucky Strike
#10-4H
10-T13N-R32E

0.5 Ft.

TRANSGRESSION

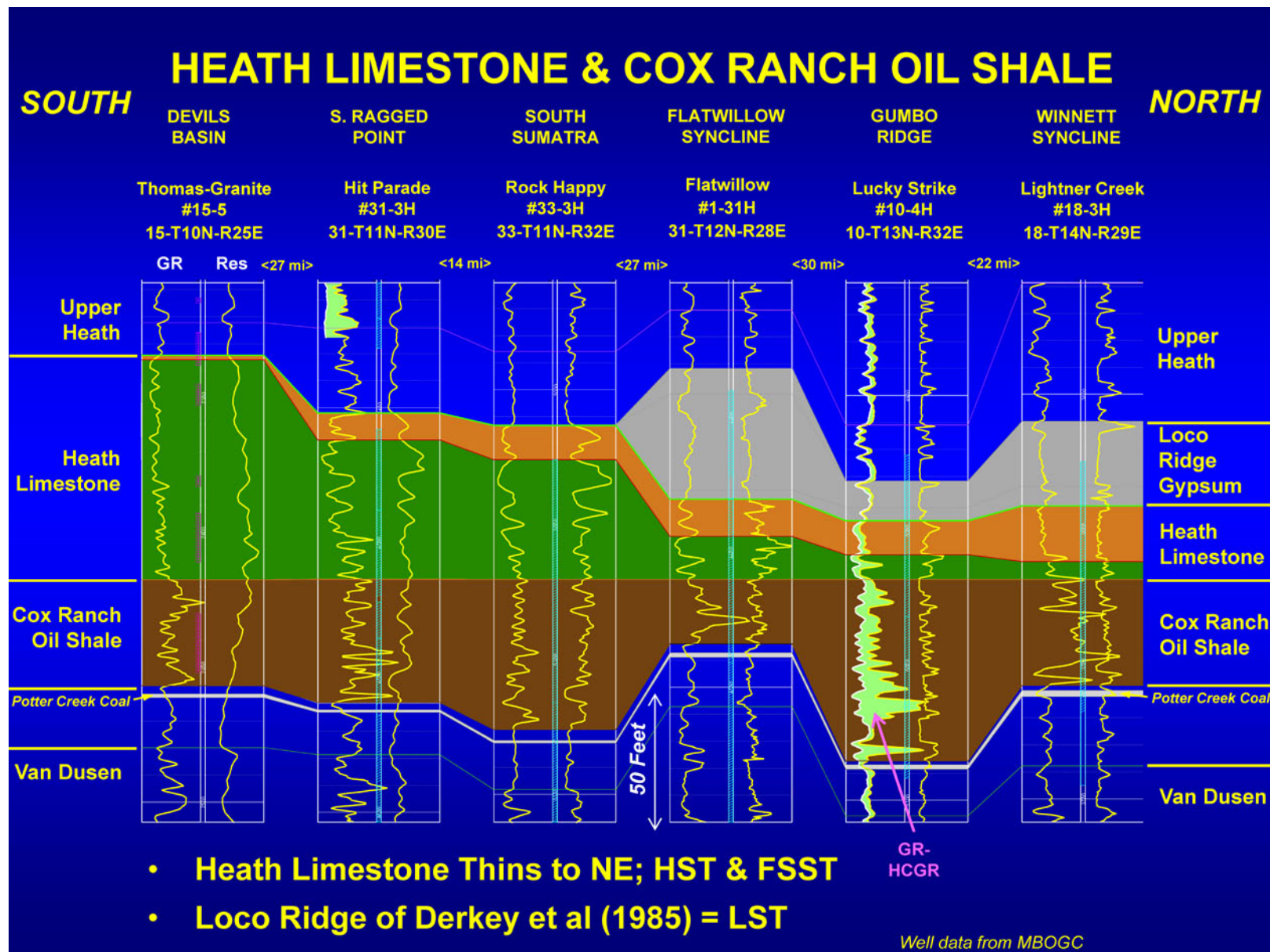


0.5 Ft.

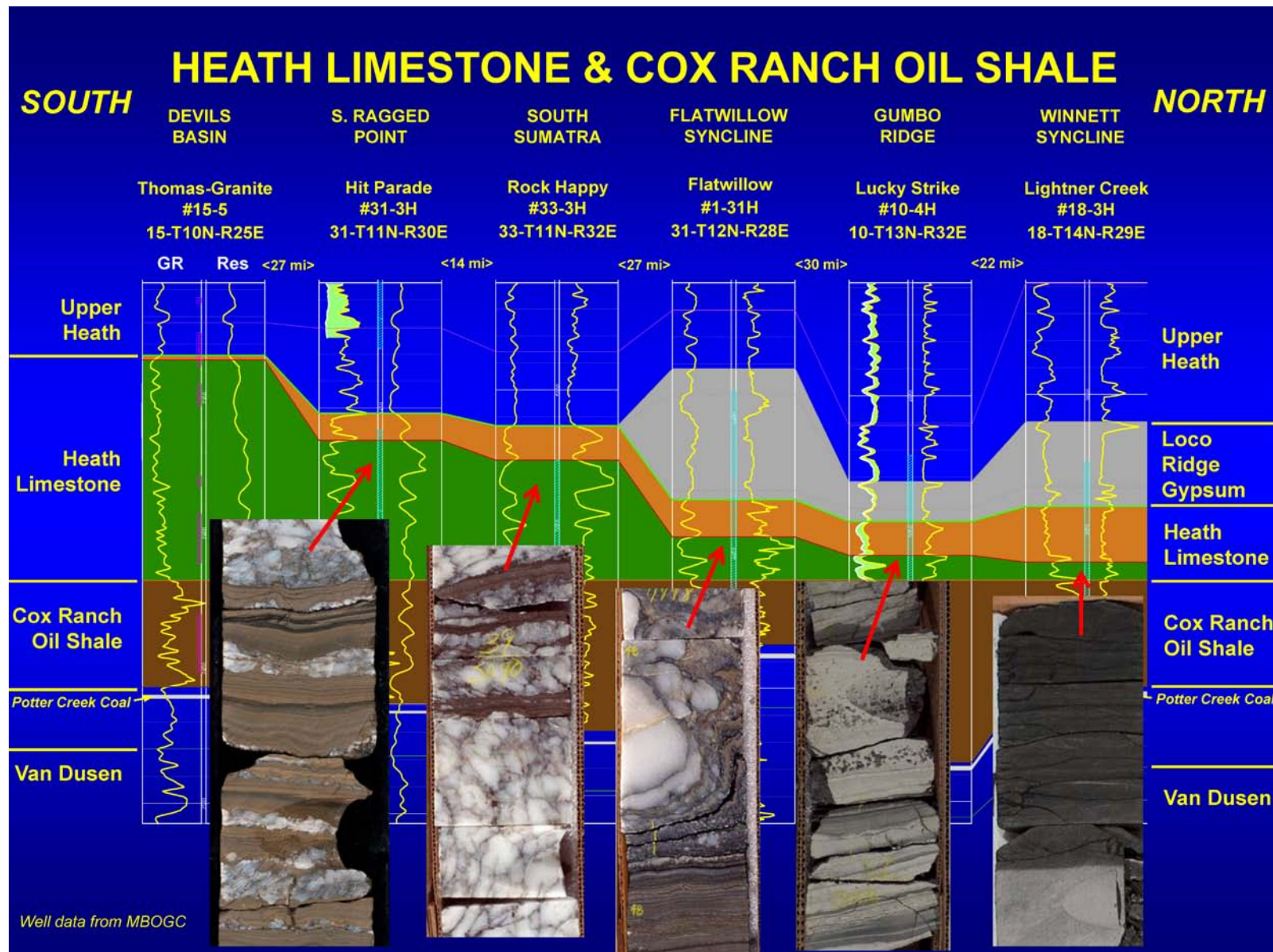
Depth Shift Log = Core - 7.5'

Rock Happy
#33-3H
33-T11N-R32E

Presenter's notes: Heath Limestone, "1st Bench". Oncolites in a skeletal wackestone to packstone overlain by algal laminated limestone. Open marine limestone packstone at the top of the 1st Bench. This is the uppermost unit in the Heath Limestone in this terminology.



Presenter's notes: South to north cross section across Big Snowy Trough. Datum top Cox Ranch Oil Shale. Note lateral continuity of lower units, Cox Ranch, Van Dusen. Heath Limestone thins to the north; the uppermost unit of Heath Limestone (orange) and Loco Ridge (gray) are LST and TST deposits. Their distribution indicates the location of the lowstand basin.



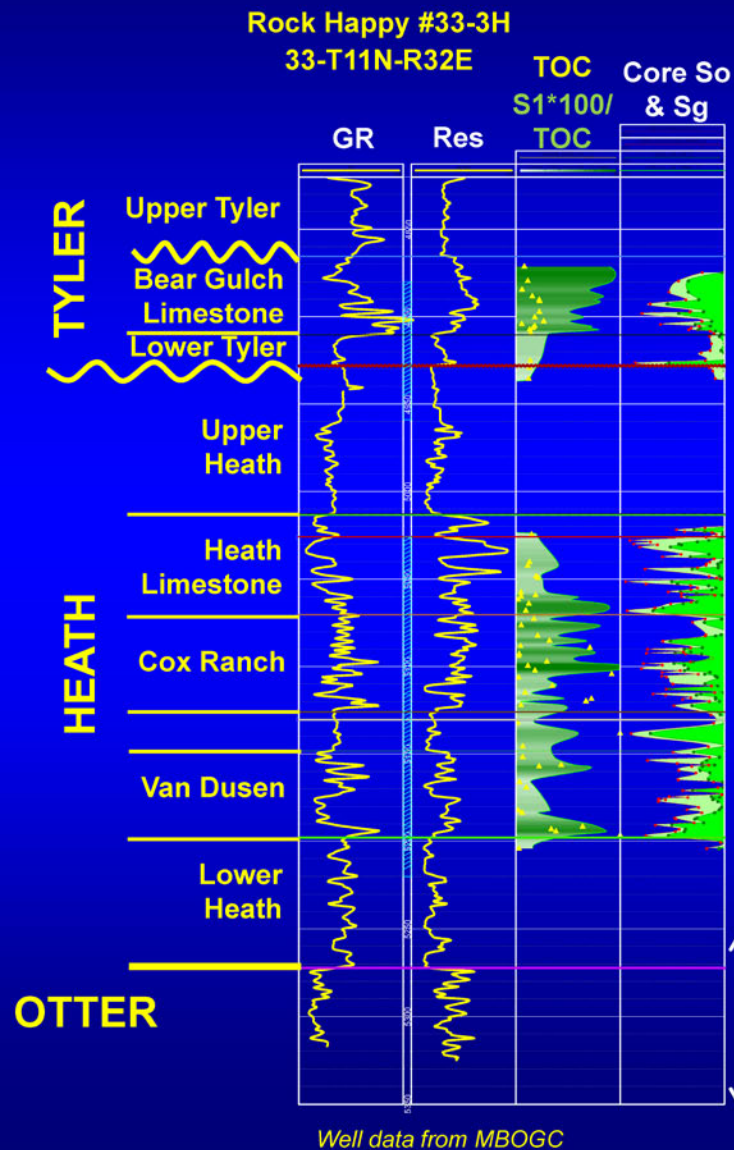
Presenter's notes: Location of anhydrites on this cross section. Anhydrites in Lucky Strike occur as vug-filling cements. This interval in the Lightner Creek is a black calcareous shale that is interpreted as the condensed section and ultimate lowstand basin. This unit may not have been subaerially exposed during this lowstand at the Lightner Creek location.

HEATH INTERVAL OBSERVATIONS

- **Heath Limestone Carbonate Facies Thickens to South**
 - **Top of “2nd Bench” of Heath Limestone Represents a Period of Drying of the Basin Marked by Intertidal to Supratidal Dolomites and Nodular Anhydrites**
 - **Heath Deposited in Shallow Marine Environments**
-

- **Lower Heath Shorelines had Coal Swamps – Humid Environment**
- **Heath Limestone Shorelines had Sabkha Environments with Intertidal to Supratidal Dolomites and Nodular Anhydrites – Arid Environment**
- **Late Mississippian Climate Change – Drying and Possibly Warming**

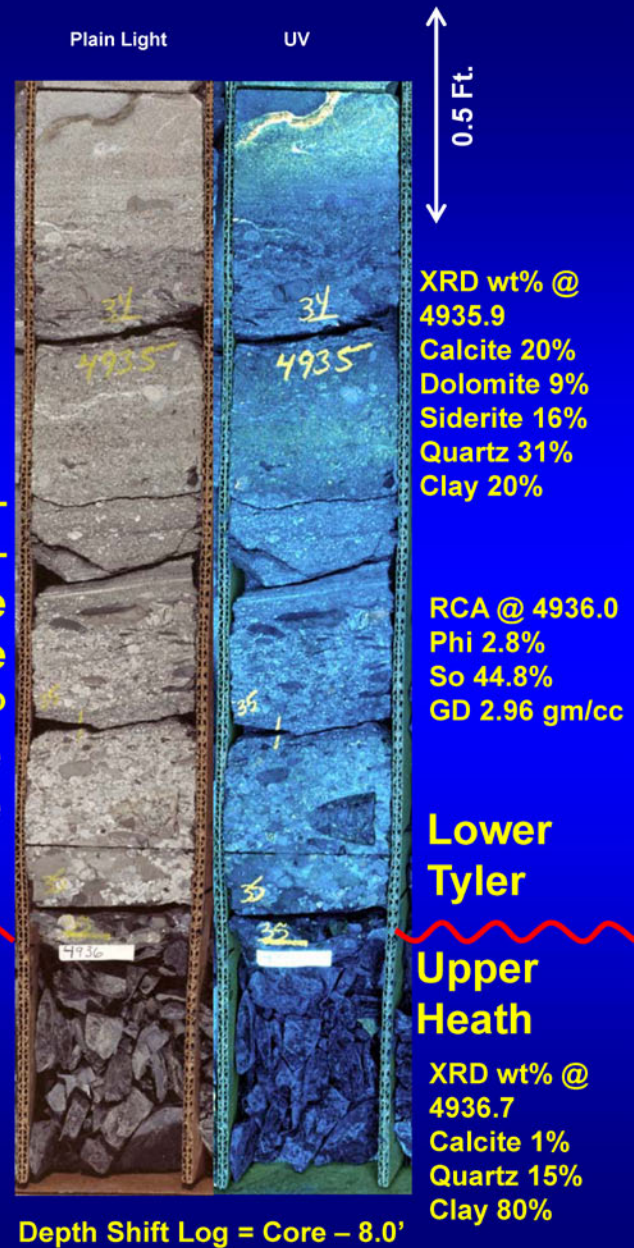
Tyler – Heath Unconformity



Fine –
Medium –
Coarse
Sandstone
grades down to
Pebble
Conglomerate

LSE

Med – Dk
Gray Fissile
Shale



Presenter's notes: Tyler-Heath erosional contact is clear when recovered in core or when interpreted from detailed well log correlations.

HEATH STRATIGRAPHY

CONCLUSIONS & RECOMMENDATIONS

- Nomenclature Problems with Heath Internal Strata Caused by Facies Changes, Poor Definitions, and Poor Outcrops. New Cores and Logs can be used to Improve Definitions
- Top of Heath = Angular Unconformity, Overlain by Tyler
- Heath Base = Top Otter - Poorly Defined as 1st Green Shale
 - ❖ 1st Green Shale is not a consistently mappable unit or marker
 - ❖ Different Operators Pick Otter in Different Places
 - ❖ 1st Green Shale (Otter?) Not Consistent in MBMG Coreholes (Derkey et al, 1985)
 - ❖ Better Definition = Top Otter at Regionally Correlative Cream to Tan Oolitic Limestone (noted as good marker by Scott in 1935)
- Van Dusen Zone is Below Cox Ranch Oil Shale – Use Definition Published by Knapp in 1956

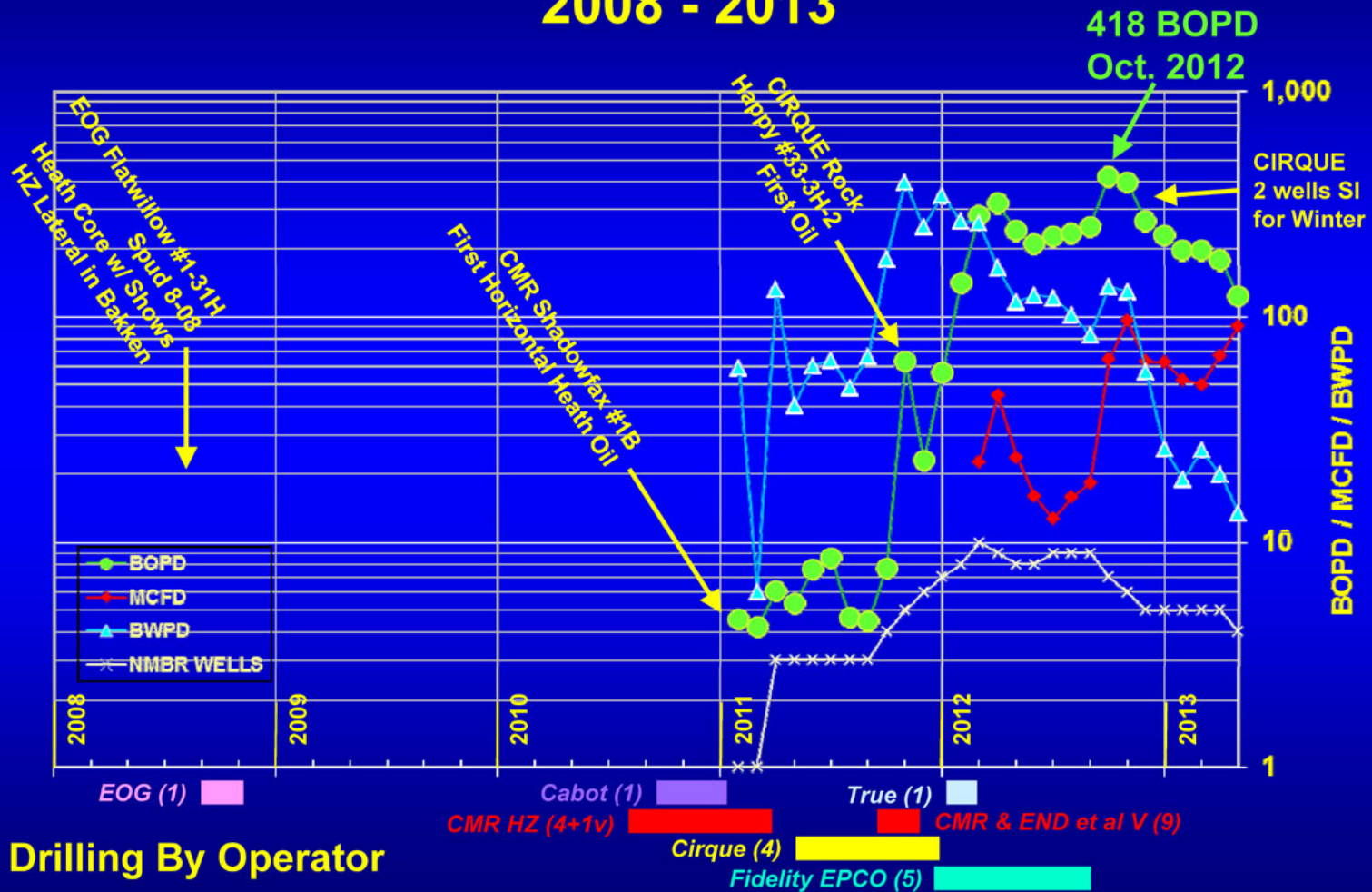
HEATH STRATIGRAPHY

CONCLUSIONS & RECOMMENDATIONS

- **High-TOC / Radioactive “Shale” in Middle Heath = Cox Ranch Oil Shale**
(after Derkey et al 1985)
- **Carbonate-Rich Strata Above Cox Ranch = Heath Limestone**
- **Industry Should Adopt a Common Terminology Based on Modern Logs and Cores**
 - **Upper Heath**
 - **Loco Ridge**
 - **Heath Limestone**
 - **Cox Ranch Oil Shale**
 - **Potter Creek Coal**
 - **Van Dusen Zone**
 - **Lower Heath**

HEATH DRILLING & PRODUCTION, CENTRAL MT

2008 - 2013



Well data from I.H.S. Energy

Presenter's notes: First recent well of interest was EOG's Flatwillow which recovered ~ 130 feet of Heath core with oil shows. CMR and Cabot started drilling in 2010. Production from horizontals started in 2011 and really increased in 2012 as more wells were drilled in the areas of thicker Heath Limestone. Production peaked at > 400 BOPD monthly average in late 2012 before drilling programs ended and operators shut in wells for the winter.

HEATH RESOURCE POTENTIAL

- **Multiple Cores in Heath – Completely Oil Saturated**
 - **250 – 450 Foot-Thick Pay Interval**
- **Petrophysical Solution Accounts for High Dolomite Content, low-TOC Carbonates and high-TOC Shales**
- **Heath OOIP Range 11-22 MMBOE/section**
- **Bear Gulch OOIP Range 4-6 MMBOE/section**
- **More than 780,000 Acres in Peak Oil Maturity Area $T_{max} > 436^{\circ}\text{C}$**
- **Heath Formation has Large Oil Potential in Central Montana**
- **Play is in Early Phase of Development**

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Barron Gimza

Mike Dumestre

Steve Lipari

Chip Oakes

Henry Biggert

Tim McFadin

Thank You



Cirque Rock Happy #33-3H-2
33-T11N-R32E