The ELLA GRA Process - Concepts and Methods for the Prediction of Reservoir Hydrocarbon Type Using Ratios of Gas Chromatography C1-C5 Gases*

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Abstract

The presentation will help provide greater understanding of the application of gas ratio analyses for the purposes of predicting the hydrocarbon type from which the gases were liberated during drilling. Using the various ratios described and contained in this presentation, it becomes possible to predict and interpret the hydrocarbon source types (not to be confused with the source rock). This is possible based on the premise that rock cuttings from any particular formation "produce" the gases, or the hydrocarbon vapors they contain, into the drilling mud. These same gases are detectable at the surface with the use of Gas Chromatography. It is reasonable to assume that the same formation, if completed, would produce gases of a similar composition. The use of ratios becomes a help in "fingerprinting" the source hydrocarbons. The presentation begins with an overview of basic concepts, then presents various analytical tools and techniques, discusses data applications and concludes with examples of how the ratios are integrated into and enhance reservoir description using the techniques presented.

Selected References

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2017 RMS - AAPG

“The ELLA GRA Process - Concepts and Methods for the Prediction of Reservoir Hydrocarbon Type Using Ratios of Gas Chromatography C1-C5 Gases”

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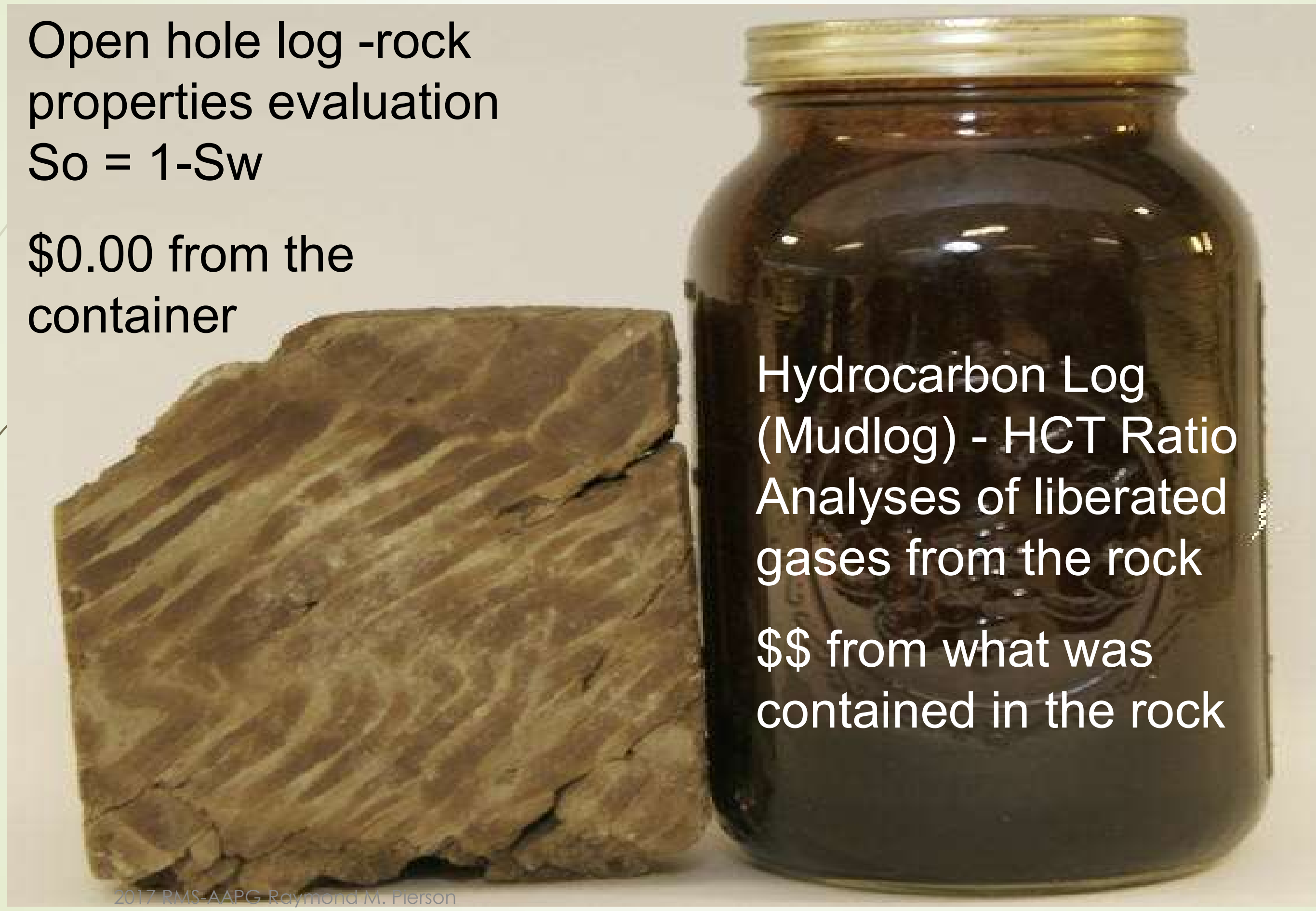
Presentation Outline

- Previous Technical Resources
    - Components of a Mudlog
        - Premise for applying gas ratios
- Defining Hydrocarbon Ratios
    - Hydrocarbon Polar Value
        - Liberated Gas Volumes
- Tight Gas Indicators
    - Gas and Oil Indicators
        - Gas Summations
- Results and Examples

Published Technical Resources

- B. O. Pixler, SPE-AIME 1968
  - Pixler Ratios Plot
- J. H. Hawthorn, AAPG 1985
  - Descriptive use of wetness, balance, and character
- Alun Whittaker, Handbook 1991
  - Mudlog Handbook for Numerical Methods of Mudlog Analysis
- D. P. Hawker, Datalog 1999
  - Modified use of wetness, balance, and character
- H. L. Ten Haven, AAPG 2000
  - Total Gas Ratio
- D. Kandel, et al., SPE 2000
  - Improved integrated reservoir interpretation using gas while drilling
- P. Blanc, et al., SPE 2003
  - Reducing uncertainties in formation evaluation through innovative mud logging techniques

Rock Oil = Petroleum



Conflicting Consensus

"The Mudlog giveth and the e-log taketh away"

-- Owen Hopkins, March 12, 2007, Suemaur Exploration, Inc.

Liberated Hydrocarbons

Once the hydrocarbons are liberated from the rock into the drilling mud; which scientific discipline owns them?

Using Greek, we could call it:

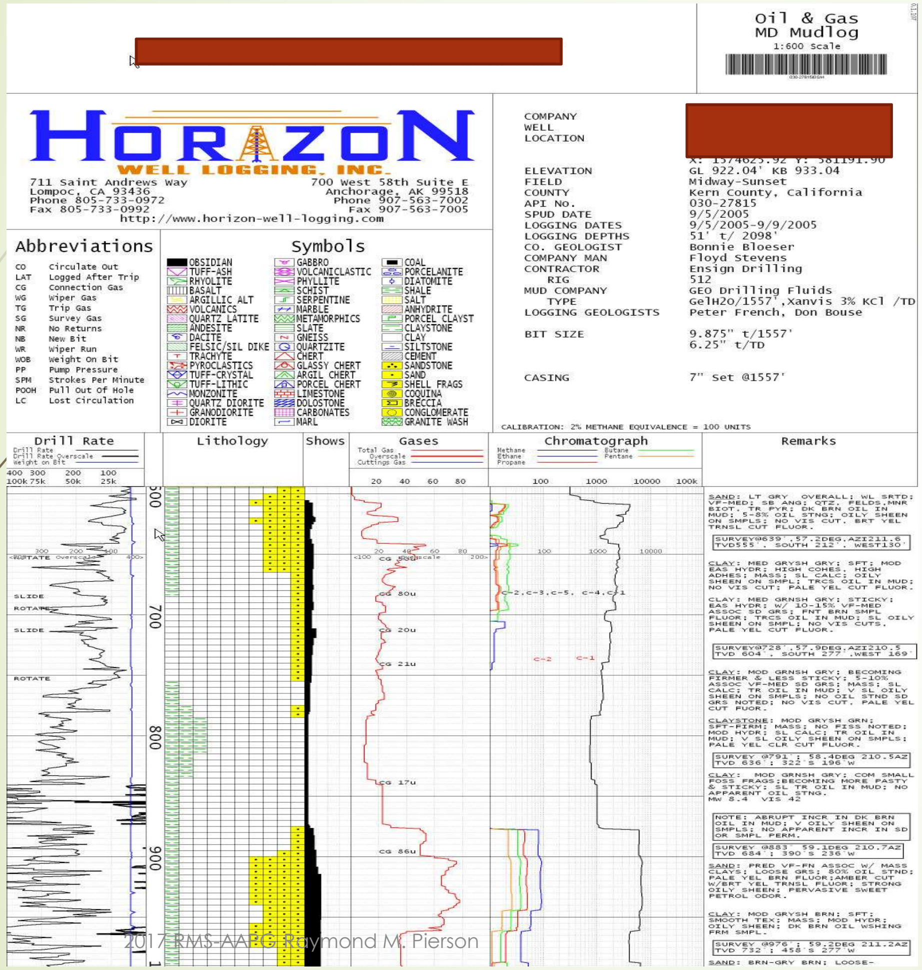
Eleytheria **L**aspi **L**adi **A**erinology, or Liberated Mud Oil & Gas study.

ELLA for short.

We have the Pierson **ELLA GRA** (Gas Ratio Analysis) process.

"data-driven imaging technique, allowing companies to visualize what was previously hidden." (quote by Anadarko CEO Al Walker 6/5/17)

Components of a Mudlog (Hydrocarbon Log)



1.) Header (Meta-Data)

2.) Drillers Log

- ROP
- WOB
- Depth

3.) Lithology Log

- Symbols & % of sample

4.) Hydrocarbon Log

- Shows (Ed Sullivan column)
- Gases (Total & Cuttings)
- Chromatography (C1-C5)

5.) Remarks

- Sample Descriptions
- Mud weight
- Direction, etc.

Premise For Gas Ratio Analysis

- Crushed rock from any particular formation "produce" the gases, i.e., the liberated hydrocarbon vapors, into the drilling mud.
- These same gases are detectable at the surface with the use of chromatography.
- It is reasonable to assume that the same formation would produce gases of a similar composition. Gas ratios would therefore be descriptive of the hydrocarbons in the reservoir.

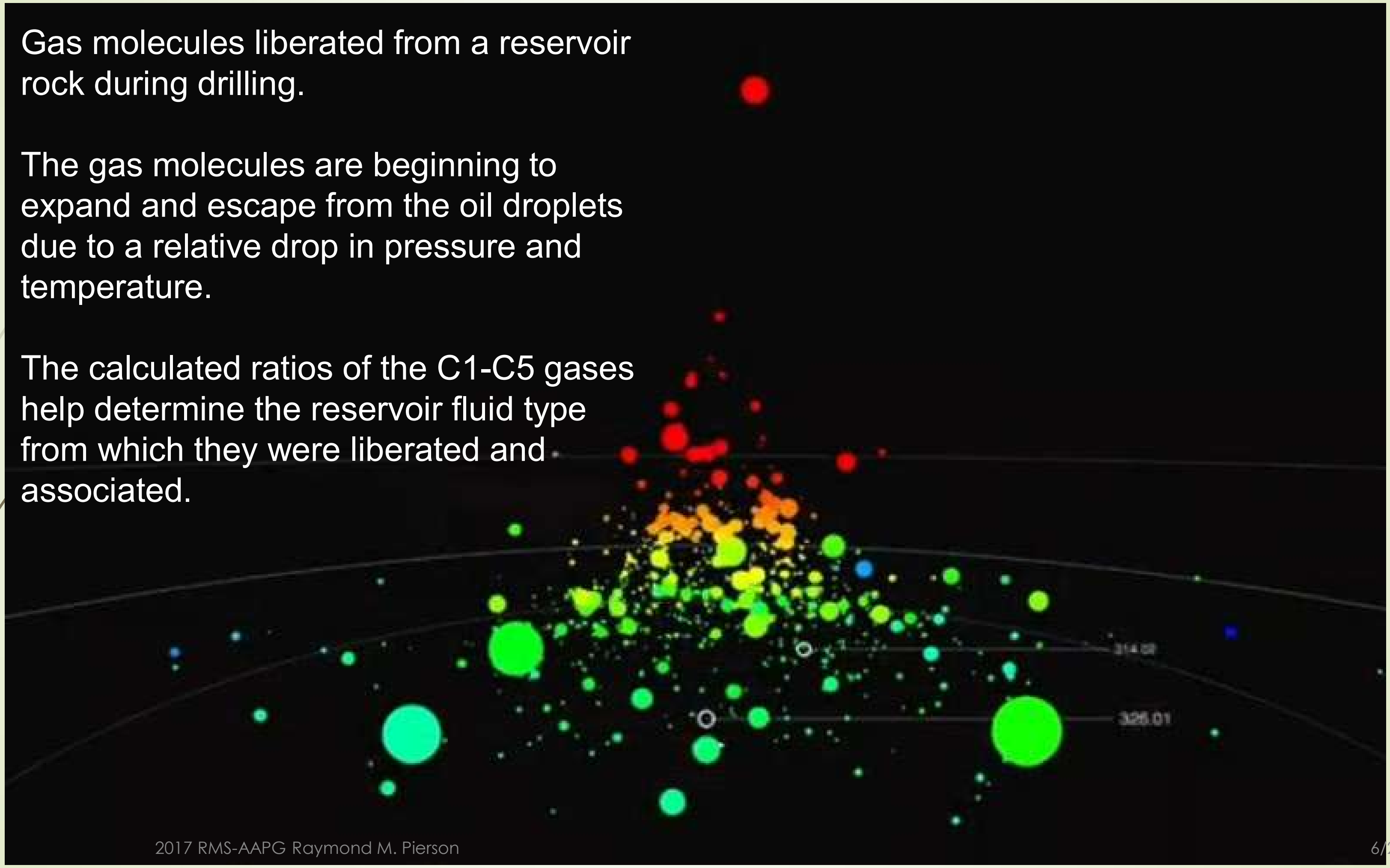
Mudlog Gas Chromatography

- Mudlog gases are extracted at the surface from the drilling mud. “Live Witnesses”.
- Chromatographic Gases are C1-C5 Alkanes which are comprised of:
  - (C1) Methane
  - (C2) Ethane
  - (C3) Propane
  - (C4) Butanes (i+n)
  - (C5) Pentanes (i+n)
- Ratios of C1-C5 gases determine the source hydrocarbon type, i.e., dry gas, condensate, light oil, residual oil, etc.
- C1-C5 ratios determine the Wetness, Balance, and Character of the extracted gases.
- Ratios act as the hydrocarbons’ fingerprints.

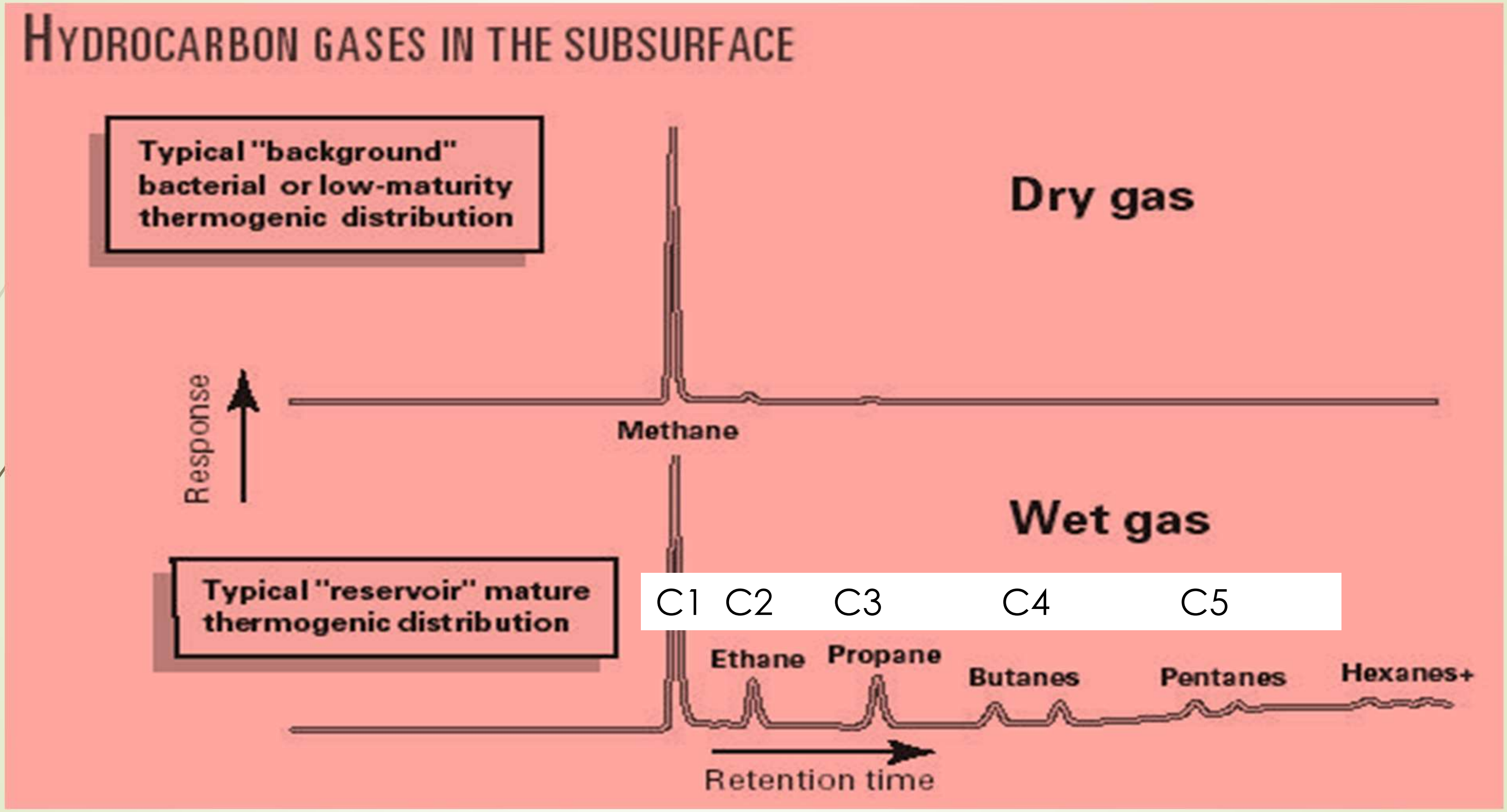
Gas molecules liberated from a reservoir rock during drilling.

The gas molecules are beginning to expand and escape from the oil droplets due to a relative drop in pressure and temperature.

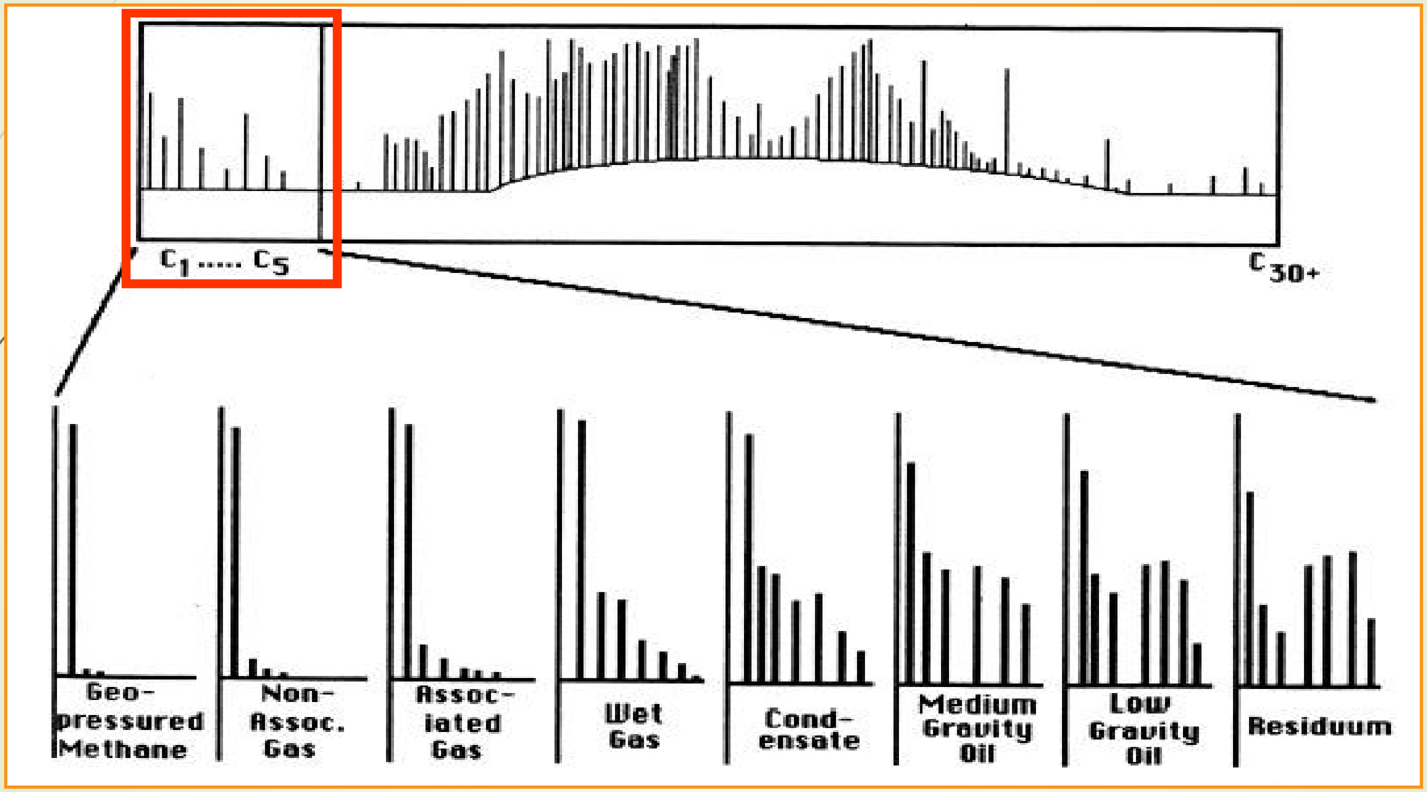
The calculated ratios of the C1-C5 gases help determine the reservoir fluid type from which they were liberated and associated.



Hydrocarbon Gas Wetness



The composition of the gaseous portion of the hydrocarbon spectrum (C1-C5) will give an indication (fingerprint) of the nature (type) of the entire fluid from which it came.



Definitions of Hydrocarbon Ratios

- Wetness (Wh) – liquid portion of C1-C5 alkanes.
- Balance (Bh) – lightest to heaviest C1-C5 alkanes.
- Character (Ch) – compares C3-C5 Alkanes (wet gas-oil phase).

Ratios can be plotted as curves to refine the evaluation of hydrocarbon fluid type and productivity.

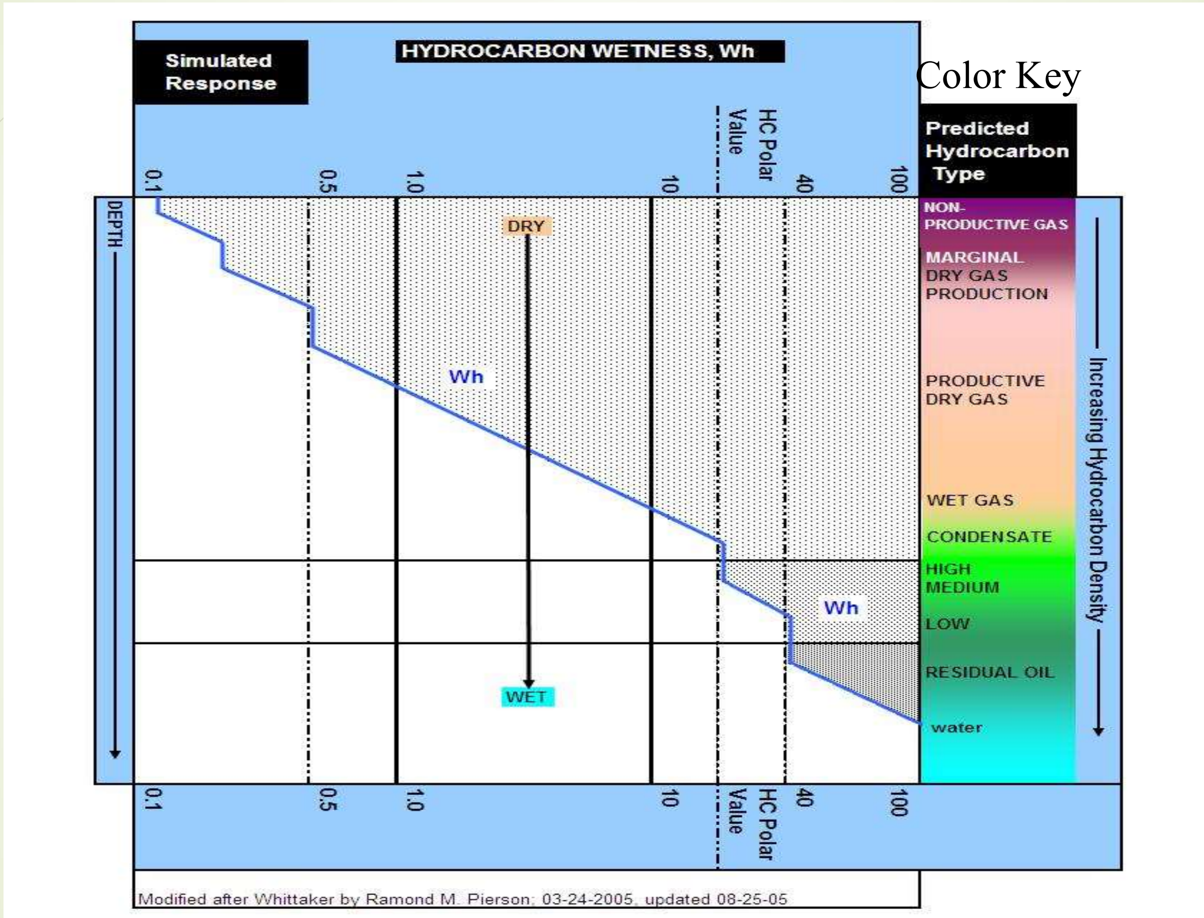
Wetness Ratio

- Wh (Gas Wetness) – liquid portion of C1-C5 alkanes.

$$Wh = \left[\left(\sum C2 \ldots C5\right) / \left(\sum C1 \ldots C5\right)\right] \times 100$$

Result is in percent

Simulated Wh Response



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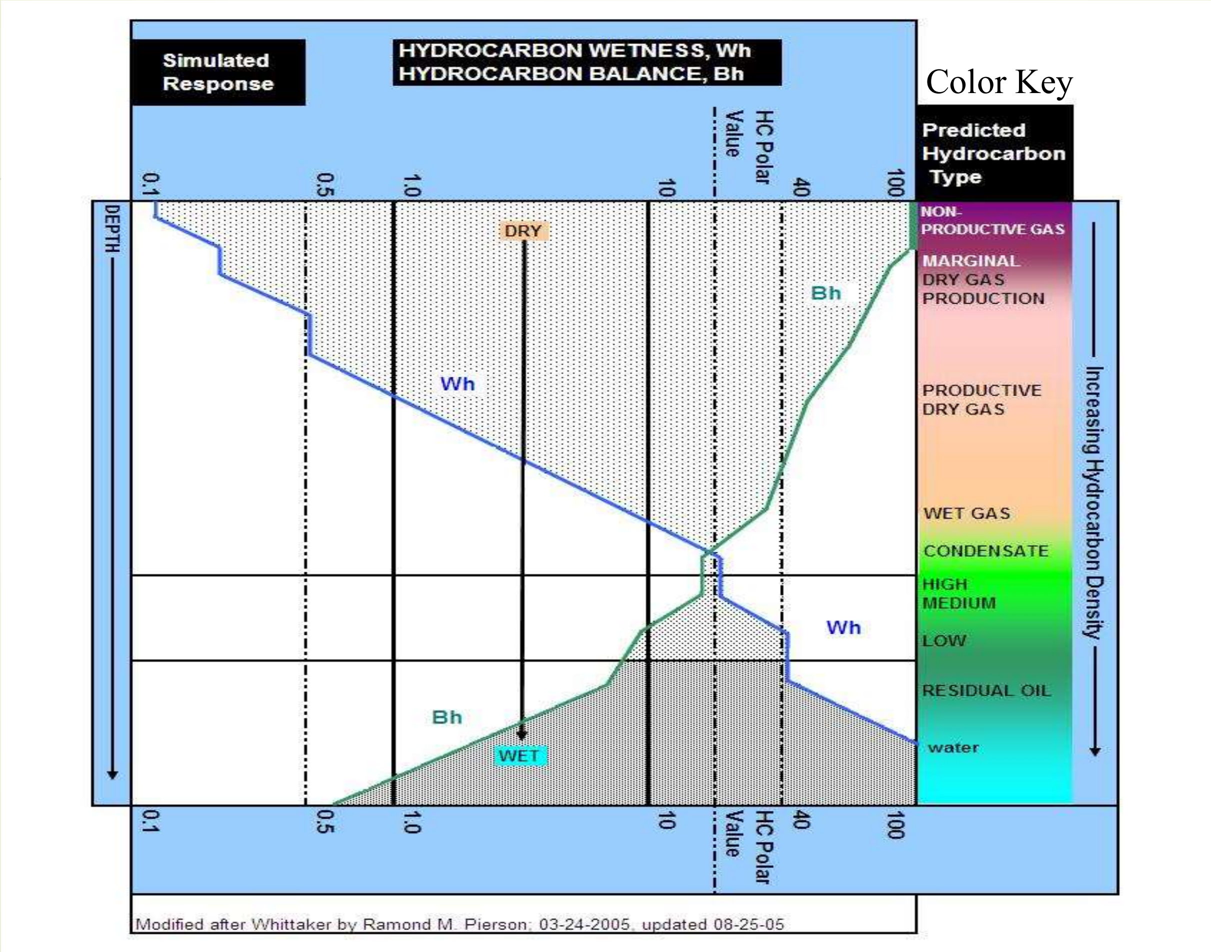
Balance Ratio

- Bh (Balance) – lightest to heaviest C1-C5 alkanes

$$Bh = [(C1+C2) / (\sum C3 \ldots C5)]$$

Result is fractional.

Simulated Response for Wh & Bh



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Character Ratio

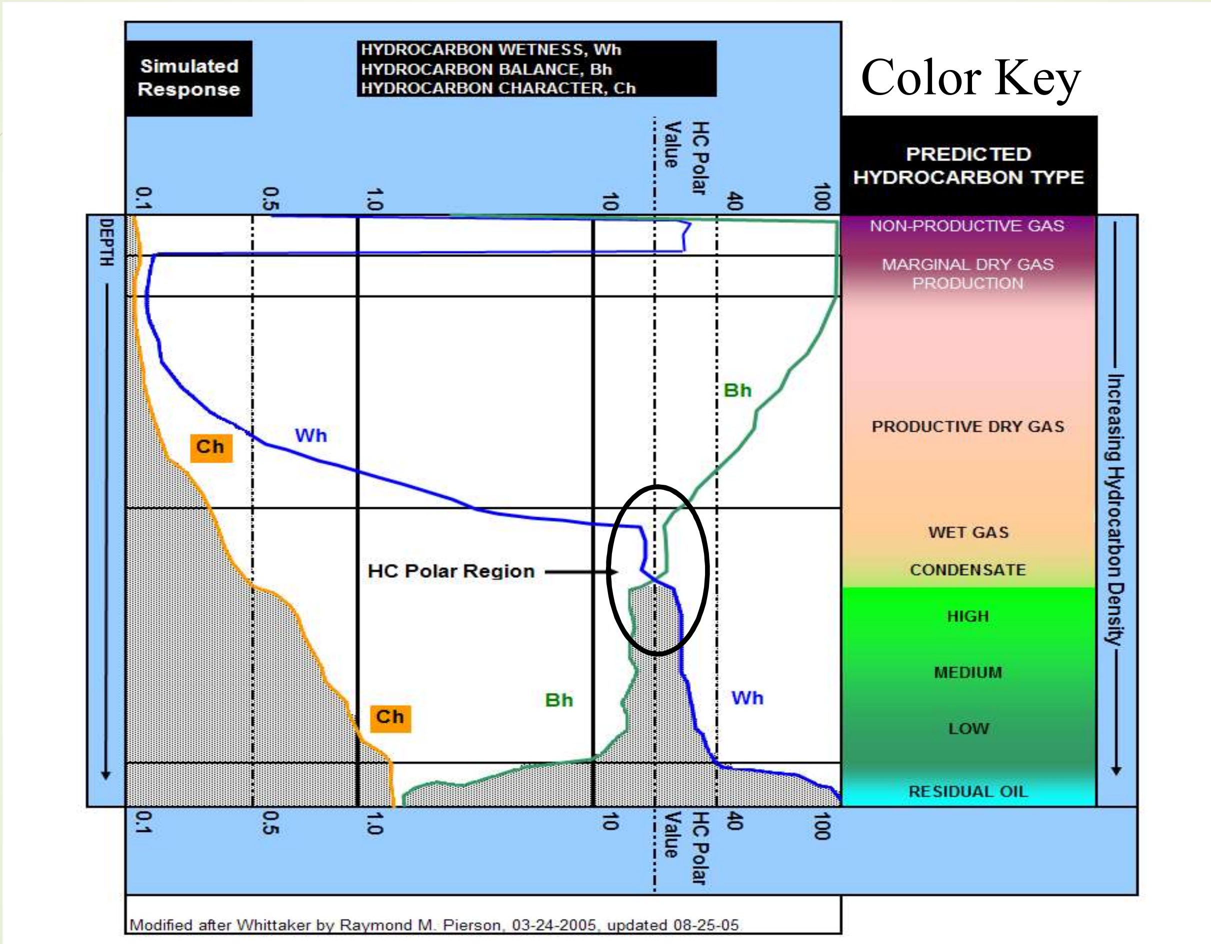
- Ch (Character) – compares C3-C5 Alkanes (wet gas-oil phase).

Oil Character Qualifier

$$Ch = [(C4+C5) / C3]$$

Result is fractional.

Simulated Curve Response using Wh, Bh & Ch Ratios



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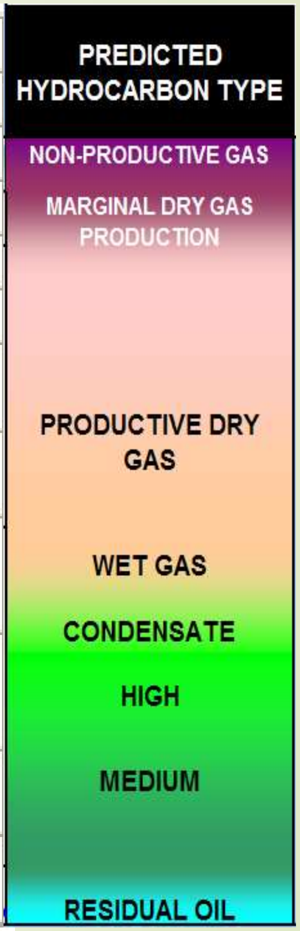
Combined Published Descriptive Algorithms

Generalized Interpretation of Gas Ratios	
Gas Ratio	**Interpretation**
Wh < 0.5	Very dry gas
Wh 0.5 - 17.5	Gas. Density increases as **Wh** increases
Wh 17.5 - 40	Oil. Density increases with **Wh**
Wh > 40	Residual Oil.
Wh < 0.5 AND **Bh** > 100	Light Dry Gas
Wh 0.5 - 17.5 AND **Wh** < **Bh** < 100	Productive gas. Density and wetness increase as the two curves converge
Wh 0.5 - 17.5 AND **Bh** < **Wh** AND **Ch** < .05	Gas condensate or wet gas
Wh 0.5 - 17.5 AND Bh < **Wh** AND **Ch** > 0.5	High gravity/high GOR oil
Wh 17.5 - 40 AND **Bh** < **Wh**	Oil. Gravity decreases as the curves diverge
Wh 17.5 - 40 AND **Bh** << **Wh**	Residual Oil.



Published Descriptive Algorithms

Problem

- Do not work in every field.
- 17.5 cut off is arbitrary.
- Do not actually compare the relationships between Wh, Bh, & Ch for each hydrocarbon type.

Solution

- Create more descriptive algorithms & eliminate the cut off.
- Created 14 algorithms ranging from geopressured methane to non-productive residual oil.

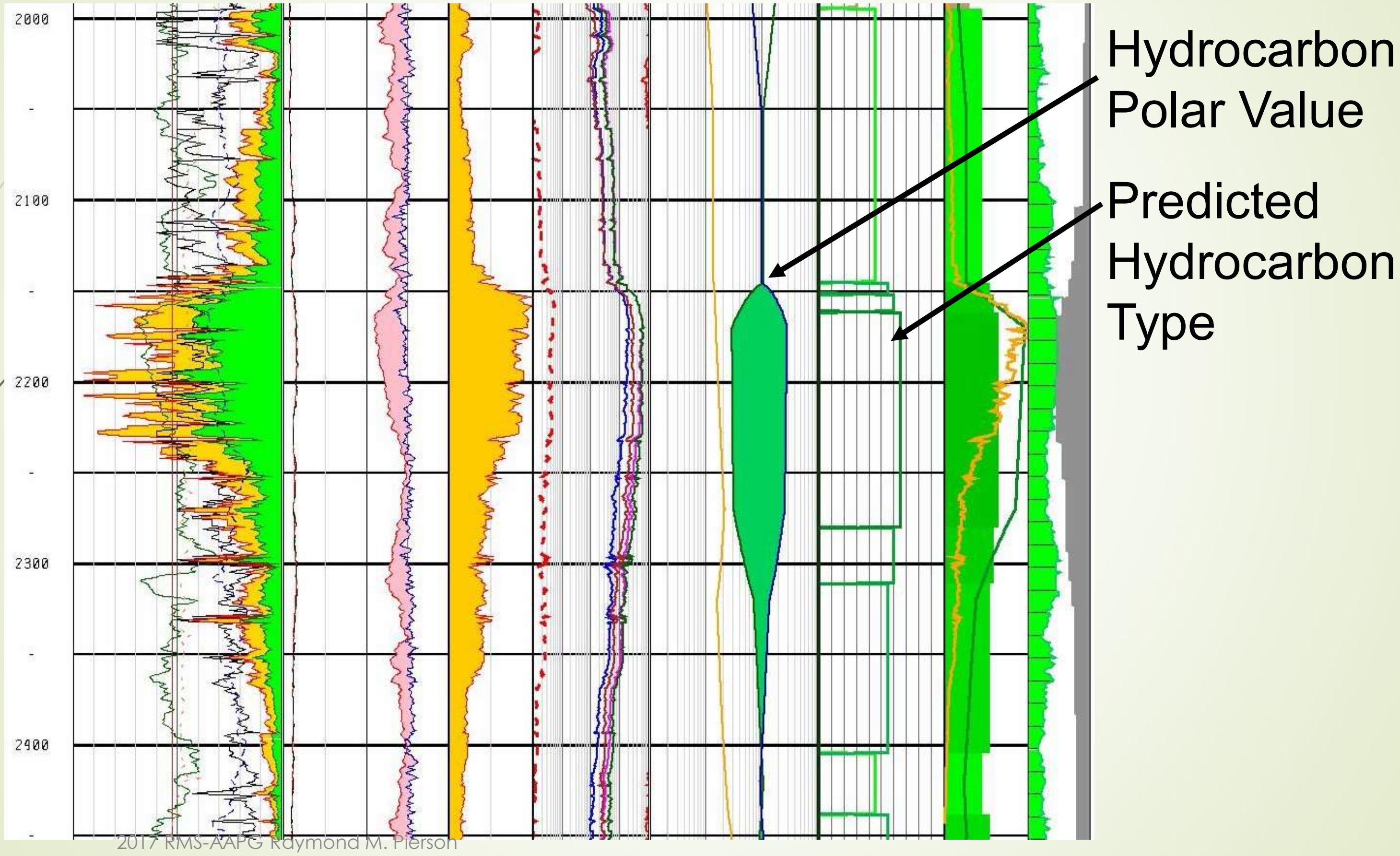
Example of ELLA GRA Descriptive
"If – Then – Else" Algorithm

--(7) **Productive Wet Gas**

IF (("MUDL_INT_Bh" - "MUDL_INT_Wh" <= 10.0) AND ("MUDL_INT_Ch" <= 0.5) AND ("MUDL_INT_Wh" < "MUDL_INT_Bh")) THEN "MUDL_INT_HCT7" = 7.0; ELSE "MUDL_INT_HCT7" = 0.0; END IF;

- Total of 14 Descriptive Algorithms

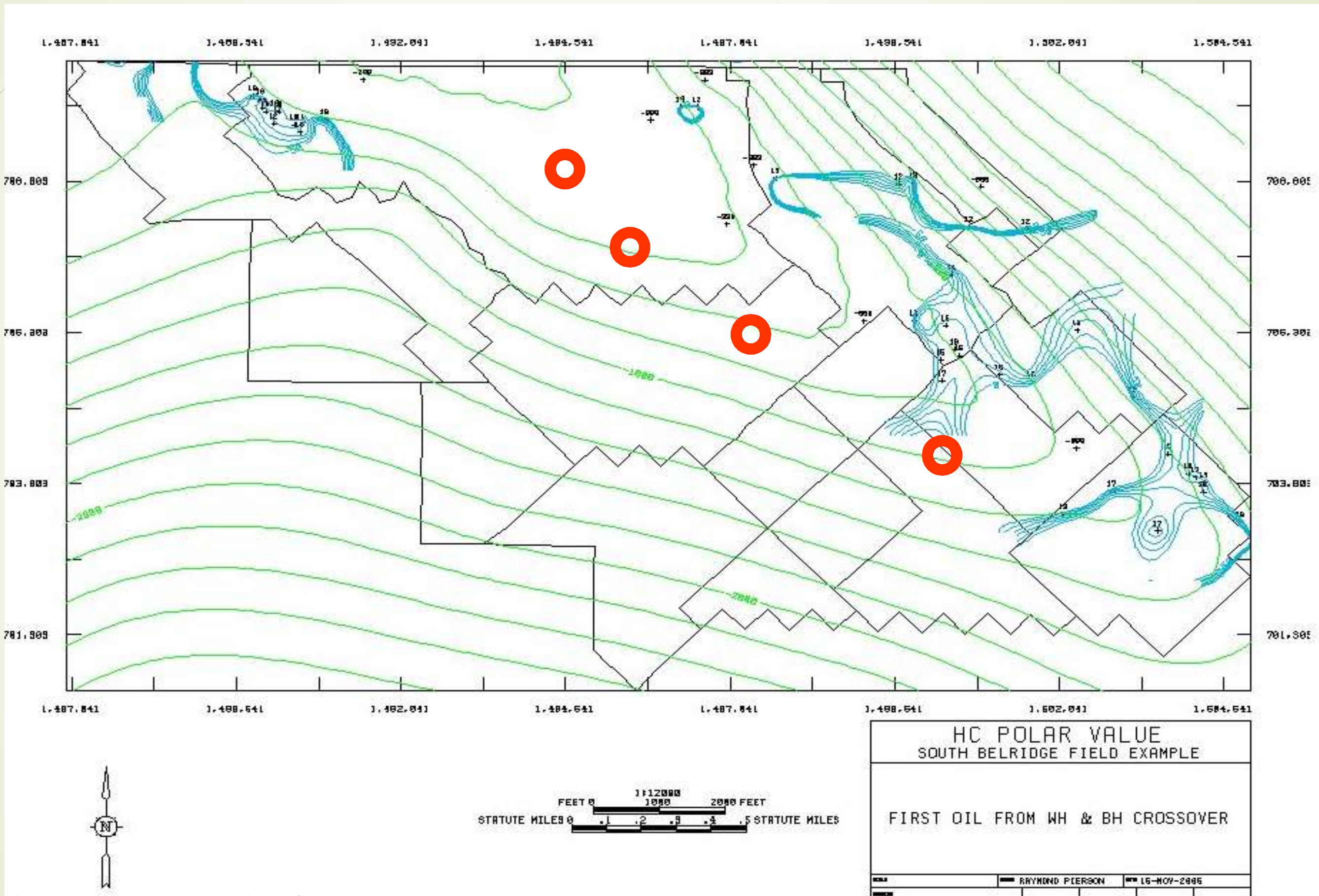
EXAMPLE OF ACTUAL RESULTS



HC Polar Value

- New Term – being introduced!?
- HC (Hydrocarbon) Polar Value occurs where Wetness (Wh) is => than the Balance (Bh)
- This value is a numerical ID for the source fluid type
- Changes with *in situ* reservoir hydrocarbon

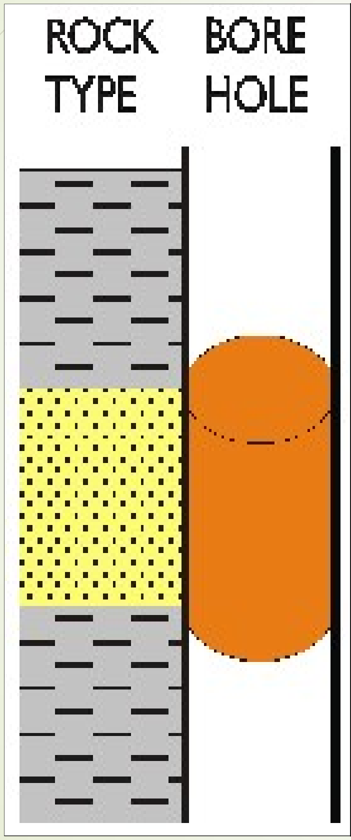
Mapping the HC Polar Value



Liberated Gas Volumes Disclaimer

- Liberated gas calculations do not include ideal gas laws.
  - Gas expands coming to surface.
  - Ratios remain relatively constant.
- Liberated gas calculations do not incorporate changes of state during transportation of gases from reservoir to surface conditions.

Liberated Gas Volume While Drilling



Liberated Gas

LGAS= VF (t) * TGAS

VF (t) = π * (B/24) ^{2} * ROP

Where **VF (t)** = volume of formation crushed by the drilling bit as a function of time in cubic feet per hour.

B = bit diameter in inches.

ROP = rate of penetration in feet per hour.

TGAS = Total combustible Gas

(assuming 100% of available porosity)

Liberated Gas from Cuttings

- Cuttings gases are liberated & measured from washed rock fragments crushed in a "Microgas Blender."
  - rock cuttings sample size = one cup = .008 ft^3
- Gas sample is injected into a combustible gas detector, such as an (FID) Flame Ionized Detector and or a chromatograph.
- Cuttings gas is reported in units the same as the total or ditch gas & components in PPM
- Low permeability rock holds the hydrocarbons ~
  - Becomes a tight gas indicator

Volume of Liberated Gas from Cuttings

Total Cuttings gas (microgas)

Cuttings sample = 1 cup

$$TCGAS = 1ft^3/0.008ft^3 * CGAS$$

Where TCGAS is the Total Cuttings Gas in units (100 units = 2% methane in air) California

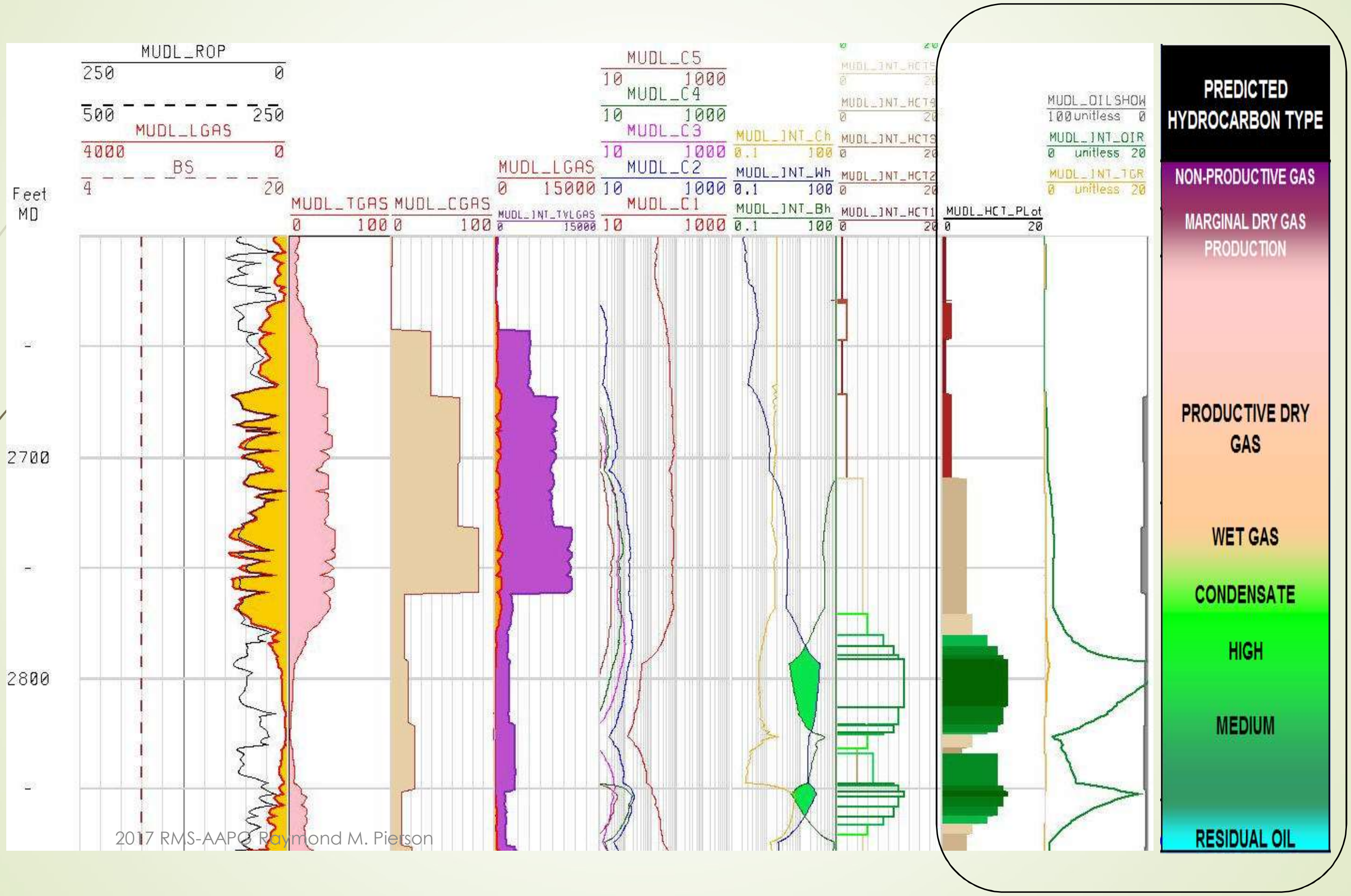
Total Volume of Liberated Gas

- TVLGAS = LGAS + TCGAS

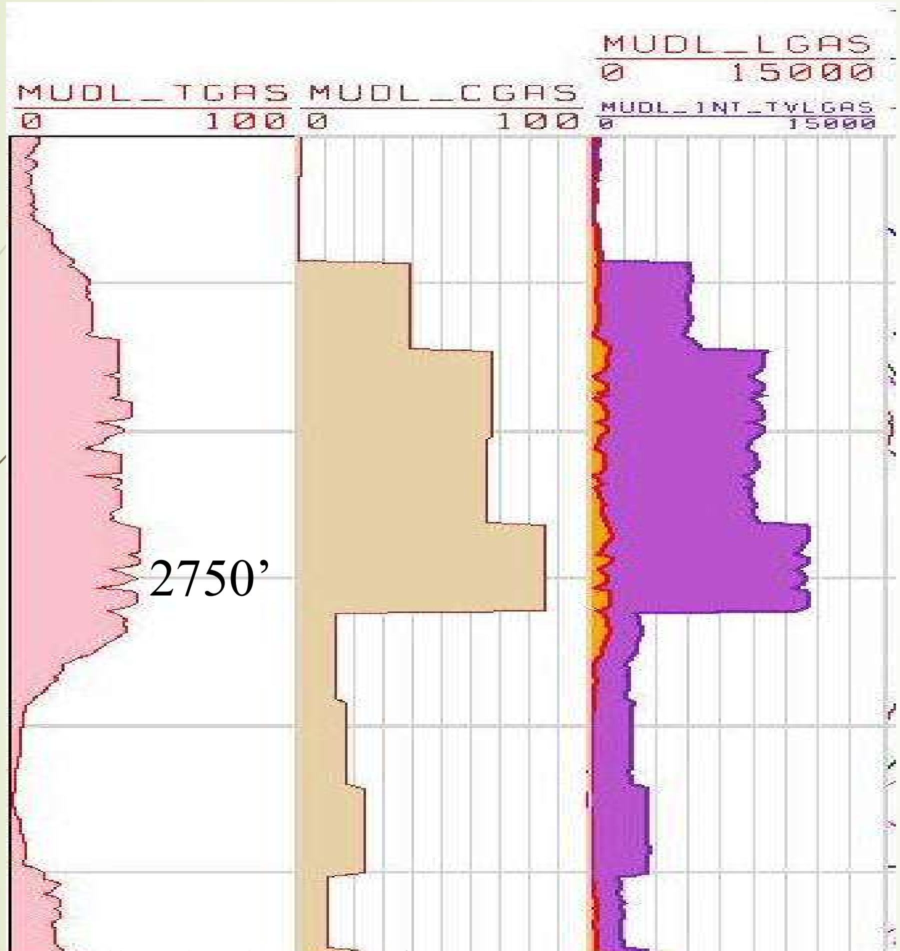
Total volume of liberated free gas from crushed formation + total corrected cuttings gas volume

- Extremely significant in identifying tight gas intervals
- Better evaluation of total gas liberated from rock
- Identifies best zones for completion & stimulation
- Integrated with log analysis
- Indicates zones of highest hydrocarbon concentration

CORRECTED CUTTINGS GAS + LIBERATED GAS = TOTAL GAS (TIGHT GAS INDICATOR)



TIGHT GAS INDICATOR



DITCH & CUTTINGS GAS ARE BOTH < 100 UNITS @ 2750'

Liberated gas = 918 units

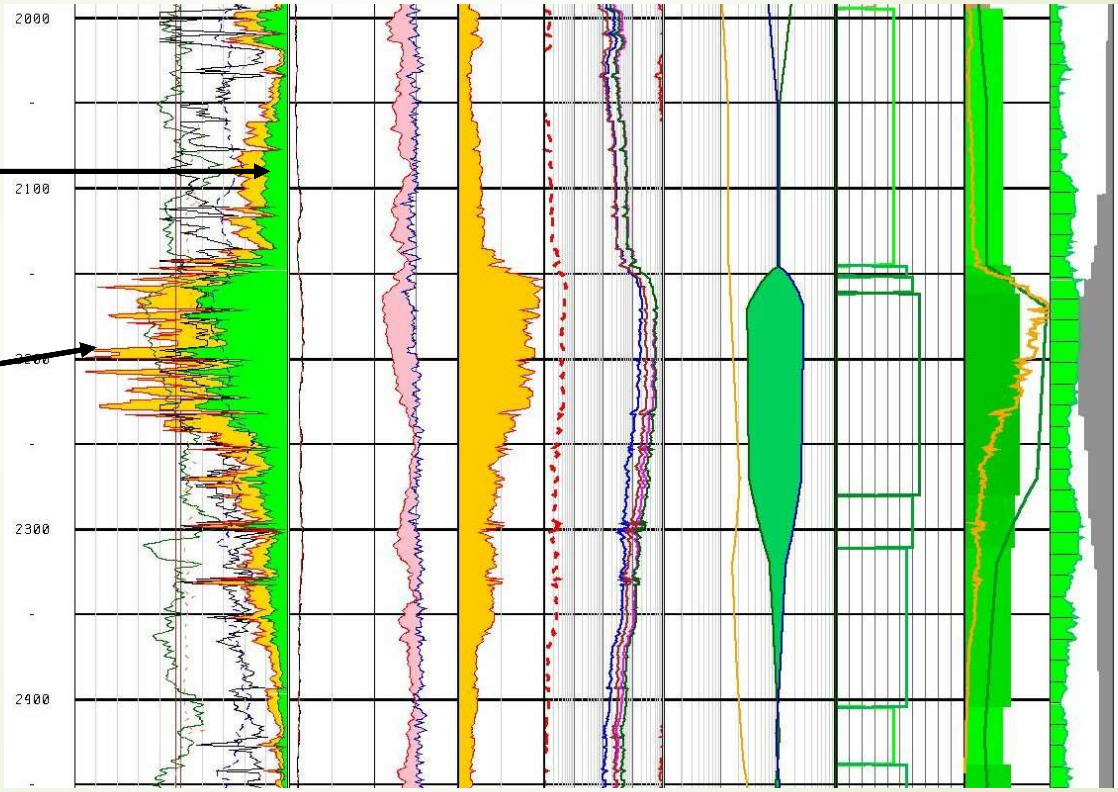
Total Volume of Gas = 11092 units

Difference of 10174 units came from tight gas. (corrected cuttings gas)

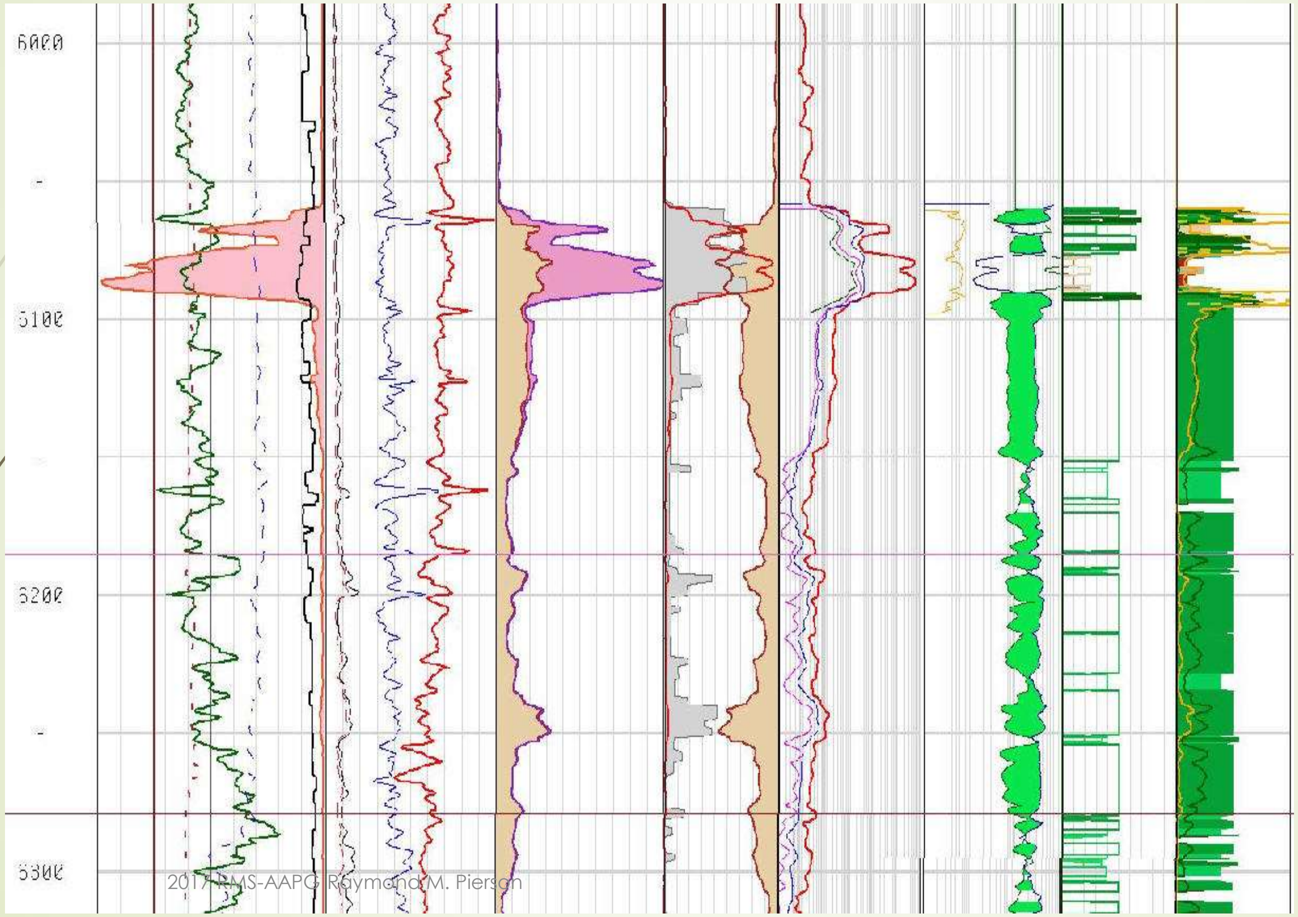
Volume of Liberated Gas Compared to Liberated Pore Volume

Liberated Pore Volume of gas = 506M units

Liberated Gas Volume = 947M units



LOST HILLS GETTY A-533



@6086'

LVGAS = 44M UNITS

TCGAS = 15M UNITS

TLCGAS = 59M UNITS

Gas associated with oil

Distribution of Liberated Gas vs. HCT Values

Gas Indicator Ratio

[(C3-C5) * Total Gas] / (C1-C5)

- The difference between oil and gas is amplified in hydrocarbon zones as compounds heavier than C5, which are more abundant in oil than in gas, are measured by total gas.
- Water-bearing zones have low total gas values, resulting in a low ratio.
- Problems with recycled gas are partly eliminated.

(Ten Haven, H.L., B.S. Simon, and J. P. Le Cann, ABSTRACT: Applications and limitations of mudlogging gas data in formation evaluation and hydrocarbon detection. AAPG Bulletin, V. 84, No. 9, (September 2000), p. 1395-1518) ©AAPG, 2000.

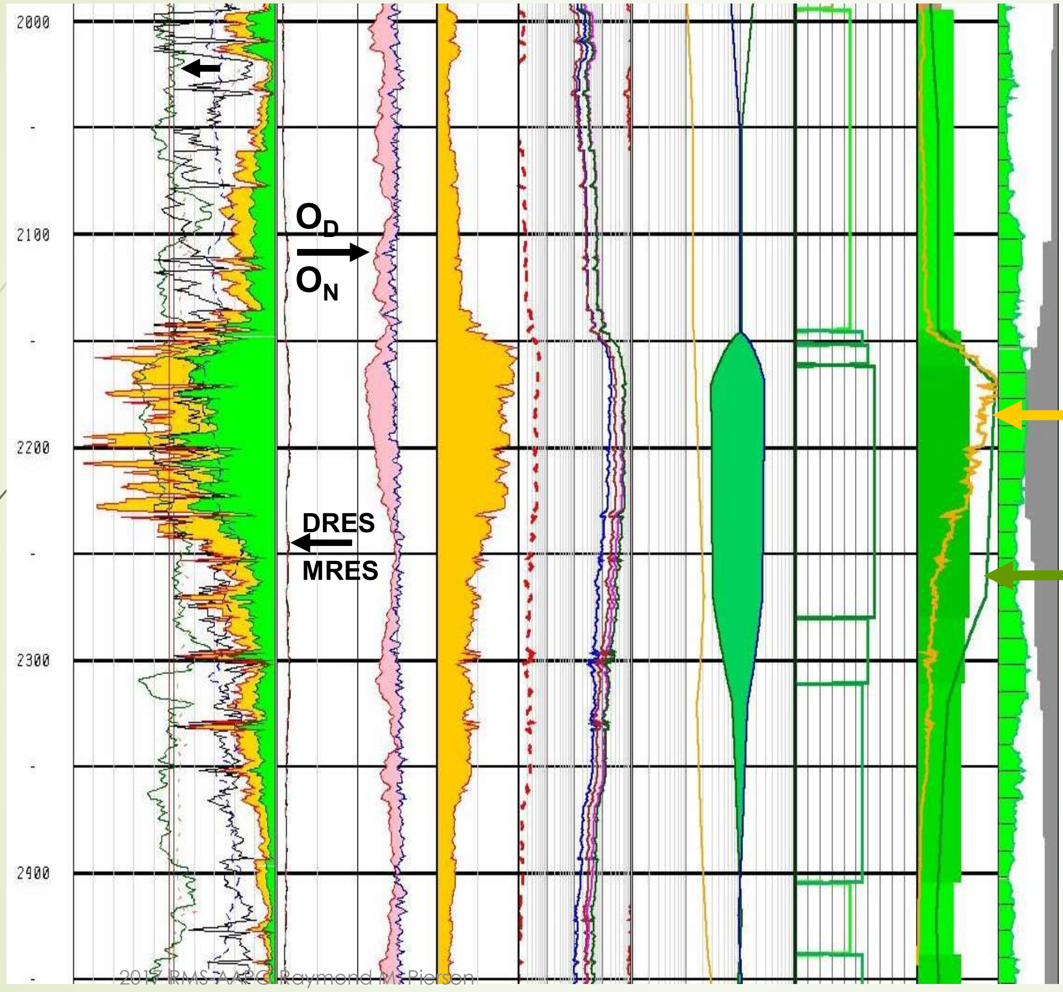
Oil Indicator Ratio

(C3+C4)/C1) * 100

- Compares the relative abundance of C3 and C4 compared to C1. This curve can be plotted along with the Tgas, C1 and ROP.
- It is a very fast (real time) method of observing an oil indicator.

(Dave Hawker, AAPG short Course, Denver Colorado, June 2001)

OIL & GAS INDICATOR RATIOS

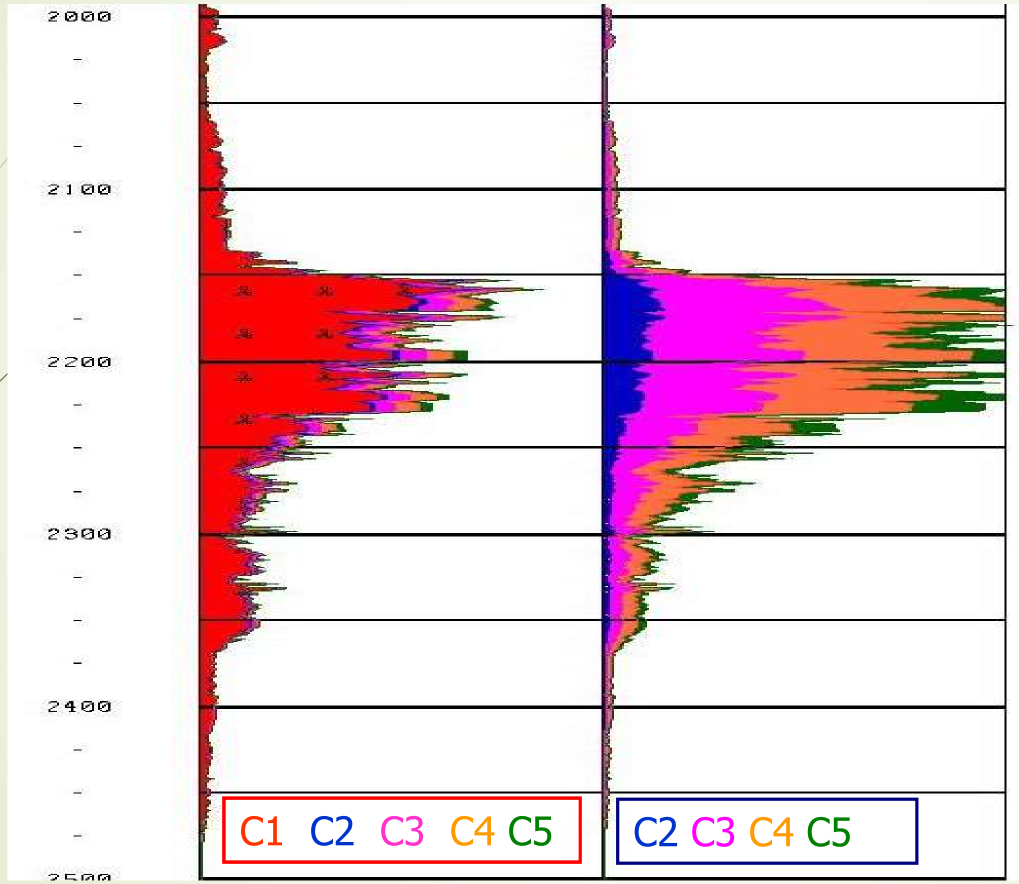


Total Gas Indicator Curve 0-250 Very wet gas

Oil indicator 0-30 Medium – low gravity Oil (554)

C1-C5 GAS SUMMATION

A Production Predictor

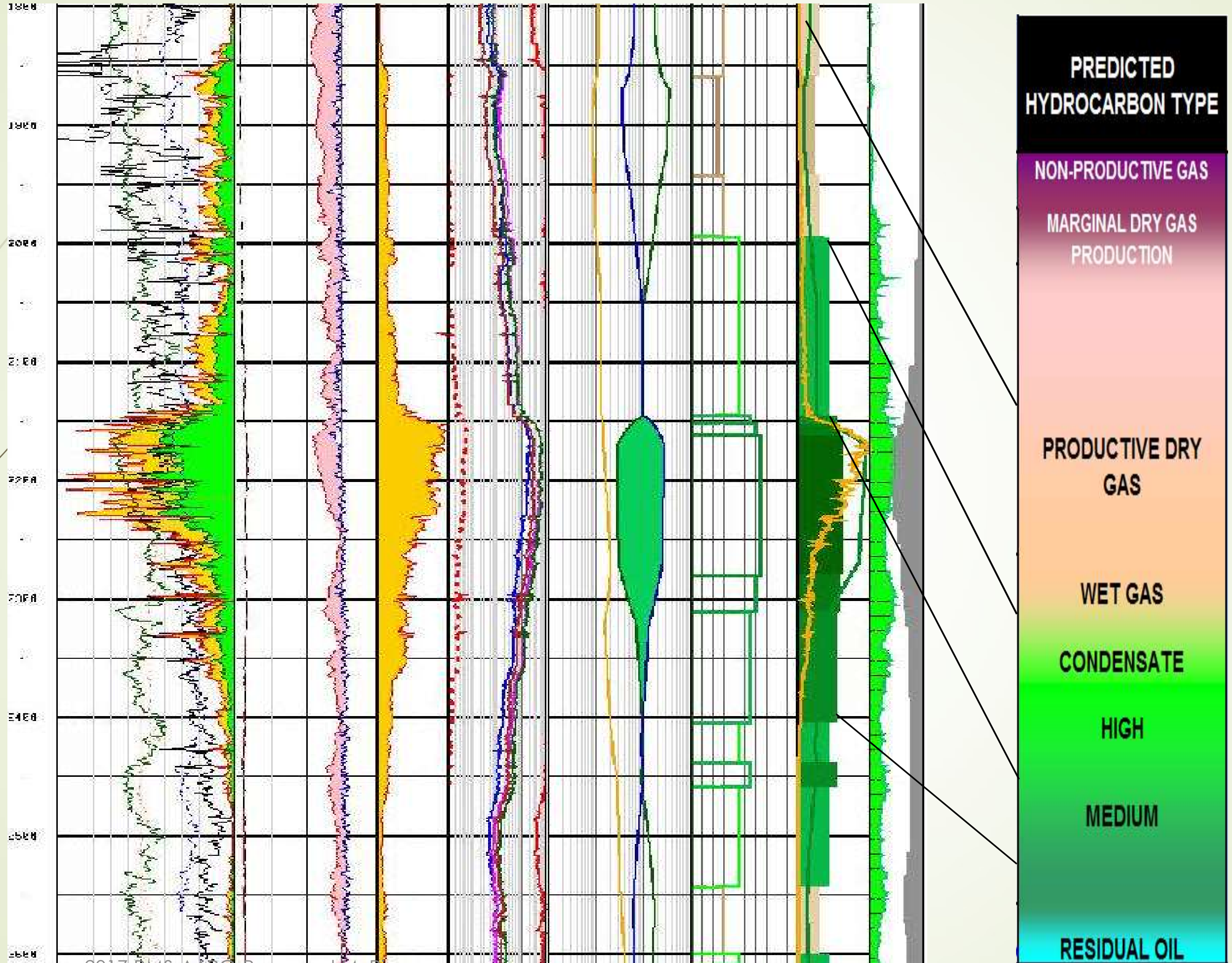


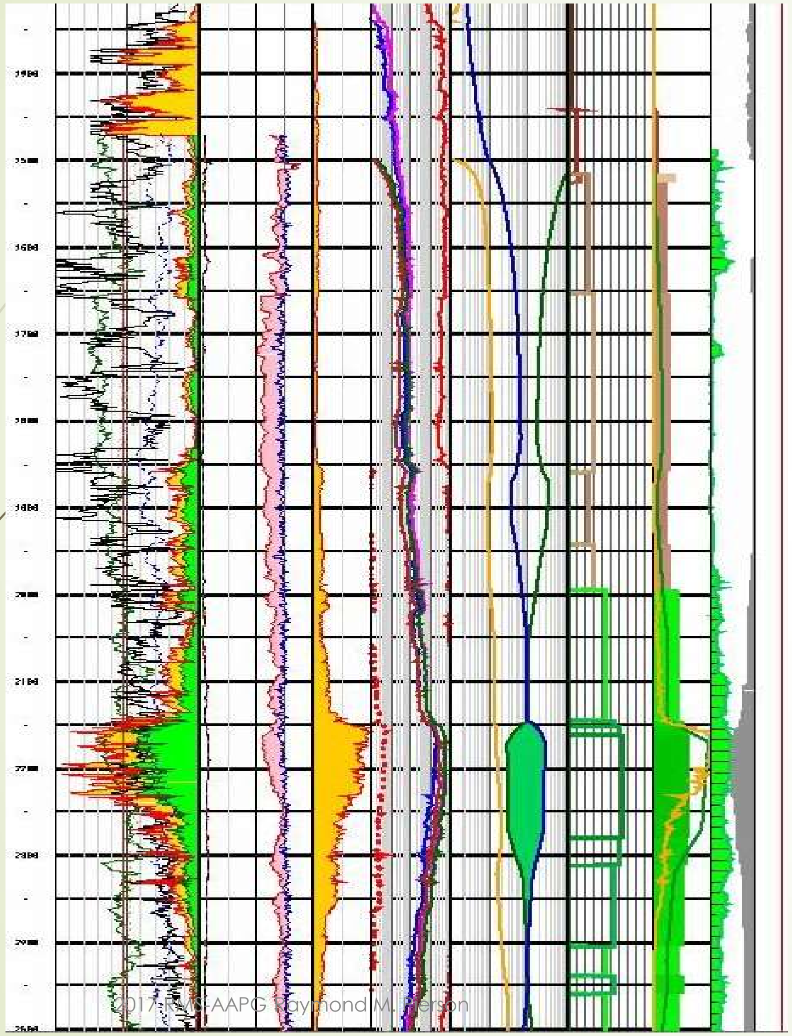
Gas Summation Example 1

Removal of methane (red) from summation reveals high concentrations of Propane and Butane. Very gassy oil but low in Ethane.

Prediction: Oil productive

Visual Model of Predicted





ELLA GRA Model & Interpretation Provides

(Example - Oil)

- All predicted hydrocarbon types occur
- Intervals with highest volumes of liberated gases
- Highest hydrocarbon concentrations are evident even at this very small scale

Major pay zone is very evident.

Applications and Uses of Ratios

- Fully integrated into reservoir property descriptions
- Fingerprint and prediction of hydrocarbon types
- Determine “best show” of hydrocarbons & Flow Units
- Map hydrocarbon movement in producing fields over time
- Comparisons of hydrocarbon gases and types before and after completion
- Identify thermal degradation of hydrocarbons over time in a steam drive
- Identify “tight oil and gas”

~ continued

- Real-time geosteering of horizontal and high angle well bores
- Interval completion determinations
- Well failure analysis
- Identifying faulted lithology
- Map distribution of hydrocarbon types within the same well bore
- Prediction of the hydrocarbon types that may be productive
- Much, much more

Conclusion

The e-log might have taken it away, but get it back with ELLA GRA!

Thank You

& Questions

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