

Determination of In-Situ Hydrocarbon Volumes in Liquid-Rich Shale Plays*

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Abstract

The determination of accurate in-situ oil and gas volumes is critical for unconventional “liquid-rich shale” (LRS) plays to determine total resource in-place and accurate recovery factors. Here, we present a methodology using geochemistry applied to pristine core samples to determine in-situ oil volume per volume of rock (bbls/acft), using open system Rock-Eval pyrolysis and solvent-extract-based geochemistry to determine the total hydrocarbon volume. An additional method is shown which attempts to correct for the mass of light oil lost due to evaporation during core recovery. The oil lost during core recovery is mostly low-boiling-point hydrocarbons less than C15 in the diesel and gasoline-range compounds. The loss of this material can be estimated from the density of the hydrocarbon fluid in-place determined from a whole-oil-extract gas chromatogram or correlations to biomarker compounds. Examples of the methodology are shown for oil- and water-based drilled cores to assist in lateral well placement for enhanced liquid yields. The pyrolysis-based method (Rock-Eval pyrolysis) does a reasonable job of prediction of C6+ hydrocarbon volume and can be used to help constrain the recovery factor and determine the heterogeneity in resource density for optimization of development drilling. The next phase of understanding in-place fluids will require the quantification of gas in-place (C1-5) to obtain accurate gas-to-oil ratios.

References Cited

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Outline

- Value Statement – the problem
- Methodology for in-place oil
 - $(S1^* \times \text{Rock Density}) \div \text{Oil density} \times \text{unit conversion factor} = \text{bbls/ac-ft}$
 - Where $S1^*$ is the $S1$ corrected for loss of oil during sample retrieval
- Example Results
- Mobile Oil
- Conclusions

Value Statement: in-place volumes?

“What you produce at the surface is not what you have in the reservoir. This is the general problem for liquid-rich shales producing with large drawdowns.”

SPE 155499 PVT in Liquid-Rich Shale Reservoirs

Rates

- Predict rates using the correct physics

Recovery factor

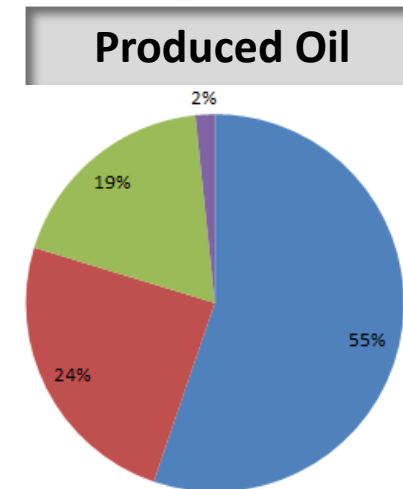
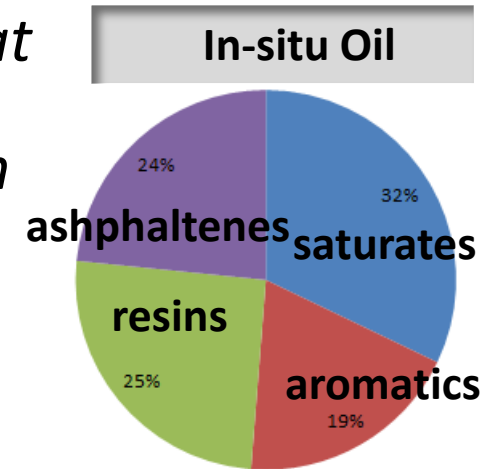
- In-fill drill spacing

Mobility

- Proper bubble pt. or dew pt. determination

Completion design

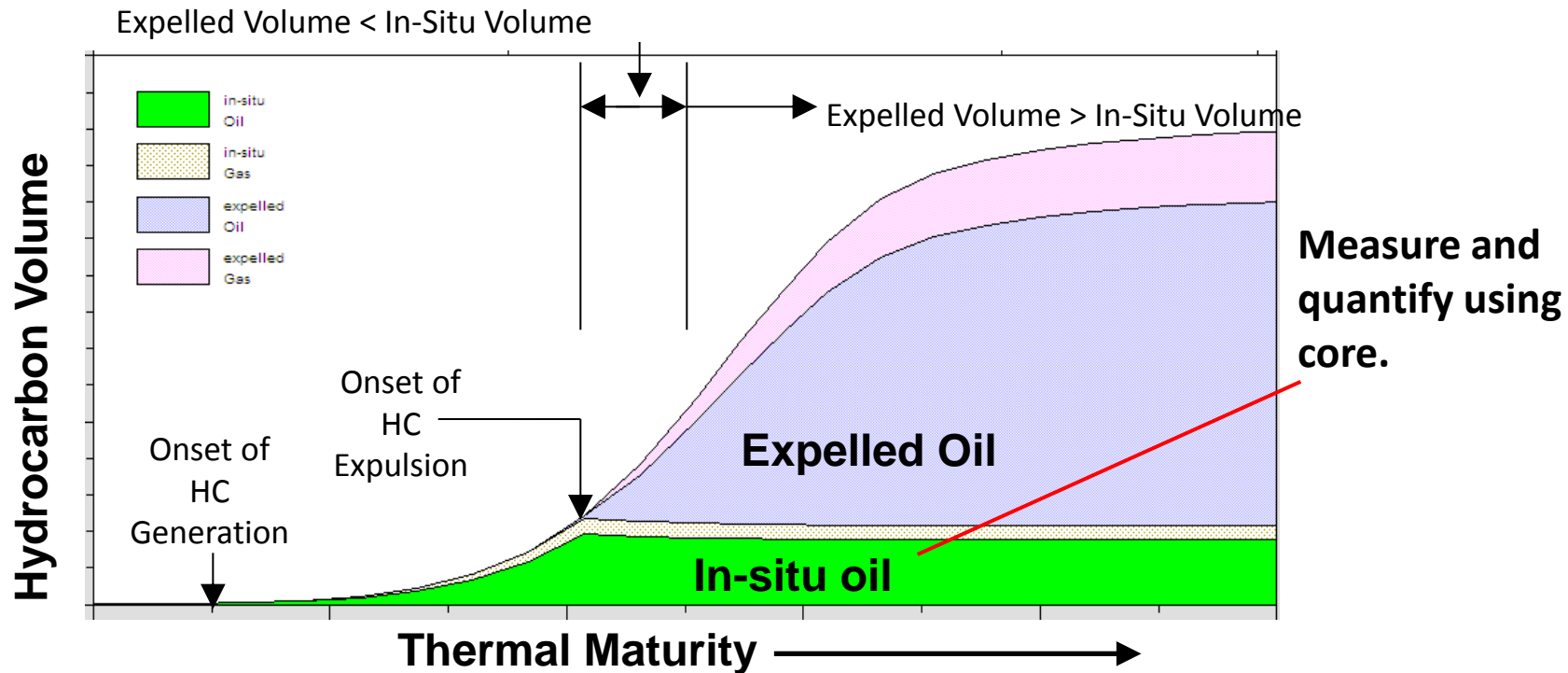
- Vertical heterogeneity in resource density



***Permian Basin
SARA analysis***

Summary of what is calculated

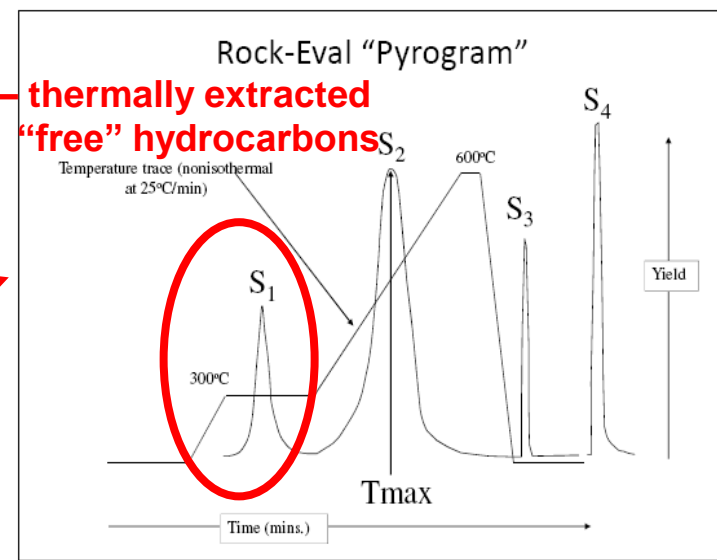
- Estimate OIP for oil shale & some tight rock source rock plays using geochemistry analytical method
- Method can derive a minimal in-place oil estimate and with correction a maximum estimate



Analytical Methods

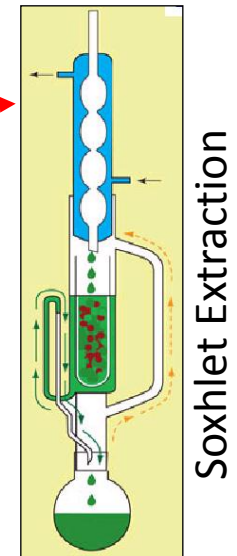
- **Rock-Eval pyrolysis**
 - Most mobile oil portion
 - S1 mgHC/gRock

S1 – thermally extracted
“free” hydrocarbons



Powdered sample, 100 mg

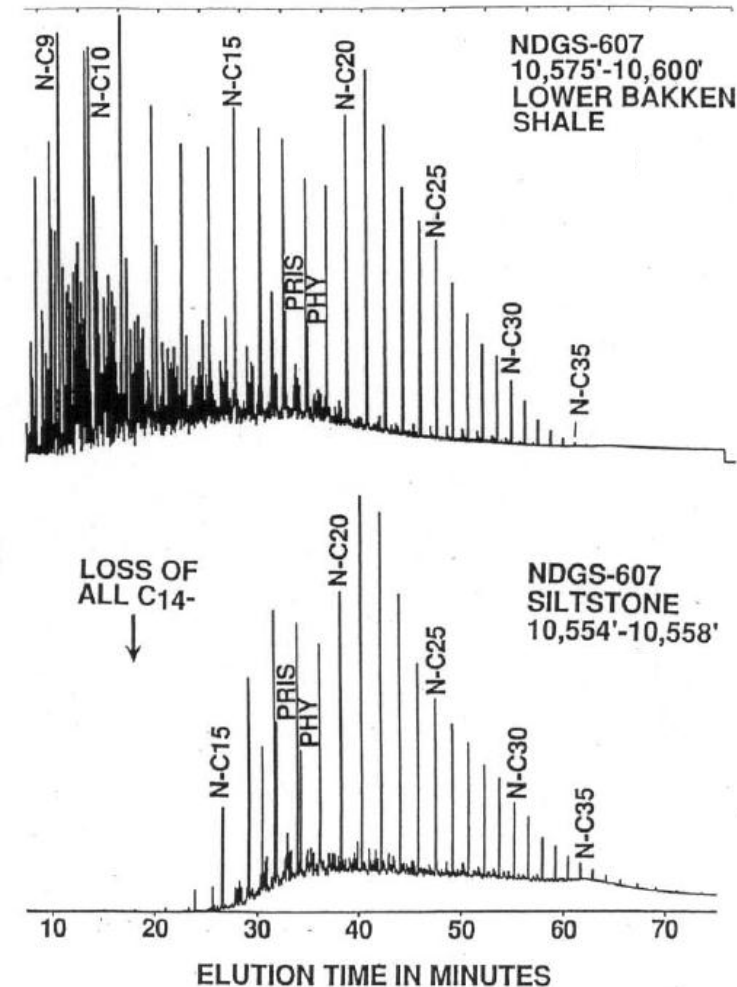
- **Solvent extract**
 - Similar to GRI oil saturation calculation
- **GRI Dean-Stark solvent extract method**
 - ...determining oil saturation in shales. For instance, the widely used Dean-Stark solvent extraction procedure for intact core samples (e.g., Koepf, 1978) is not suitable for low-permeability shales. (Noble et al., 1997 AAPG Memoir 67)



20/35 mesh size, 20 g

Estimating in-place oil from Rock-Eval pyrolysis (S1)

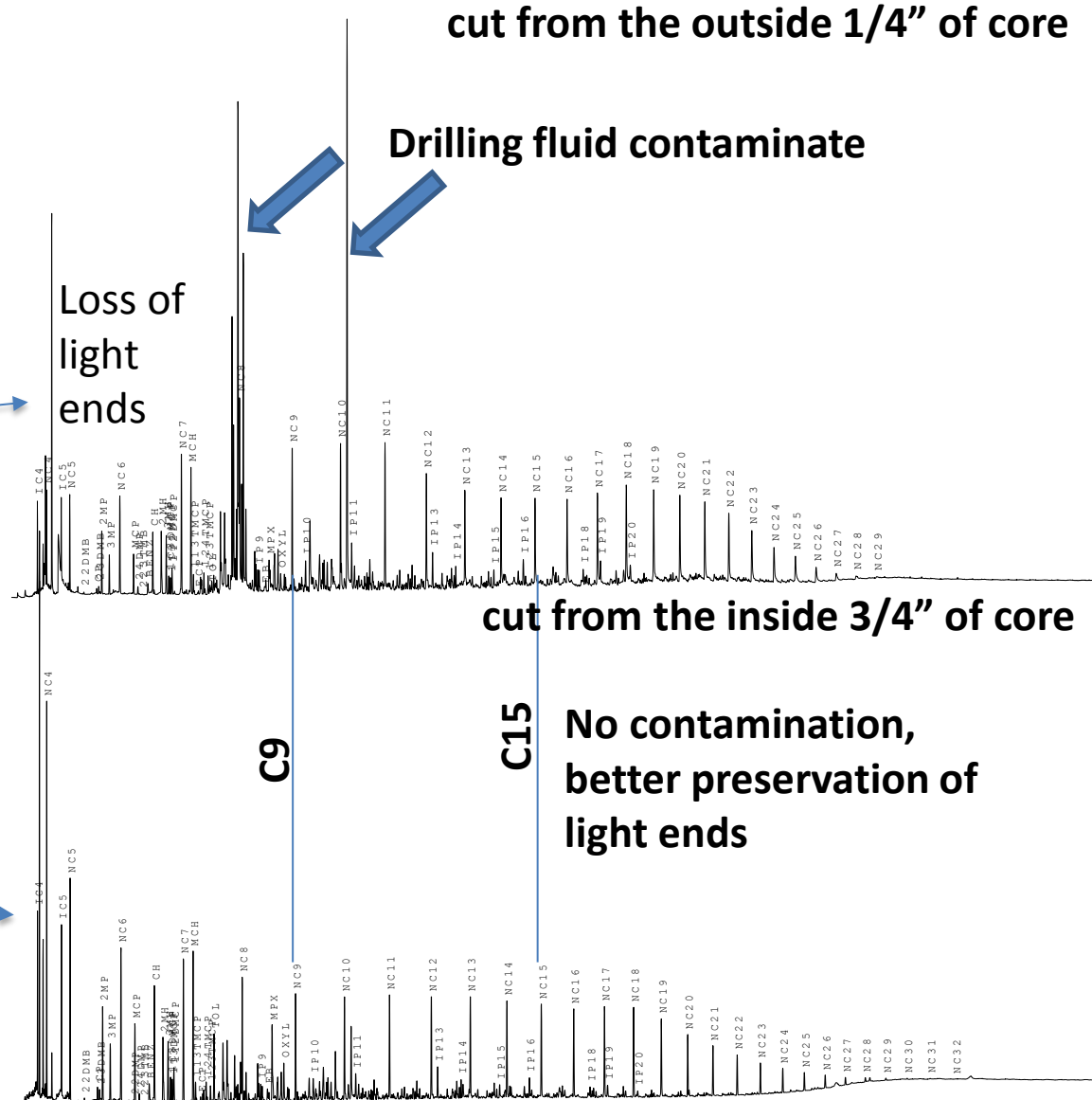
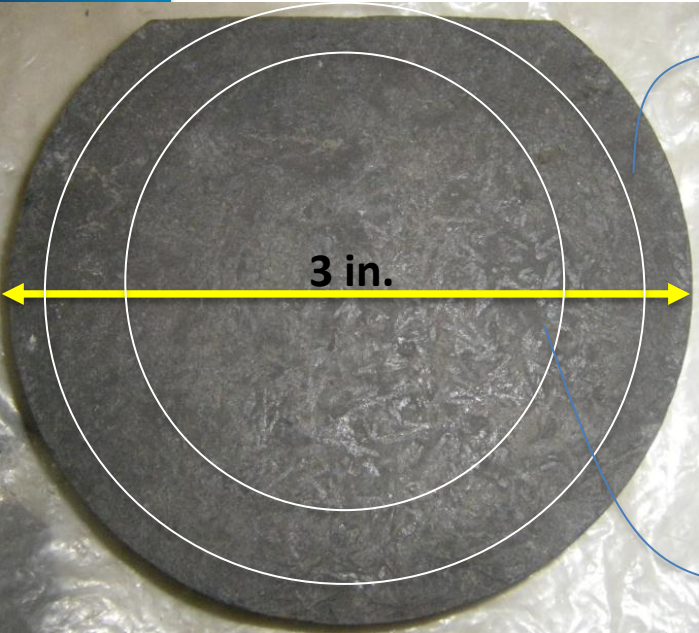
- S1 (mgHC/gRock) response is affected by permeability of the rock matrix & sample handling
 - Lower permeability results in higher volumes retained
- Core better than cuttings samples
- Hydrocarbon lost is lower molecular weight, lower-boiling-point-range compounds, referred to as C15 minus fraction
- Qualitative correction to the S1 can be done if extract-based information is available (extract gas chromatogram) in order to determine oil API gravity



Price, USGS

Interior core material for oil in-place

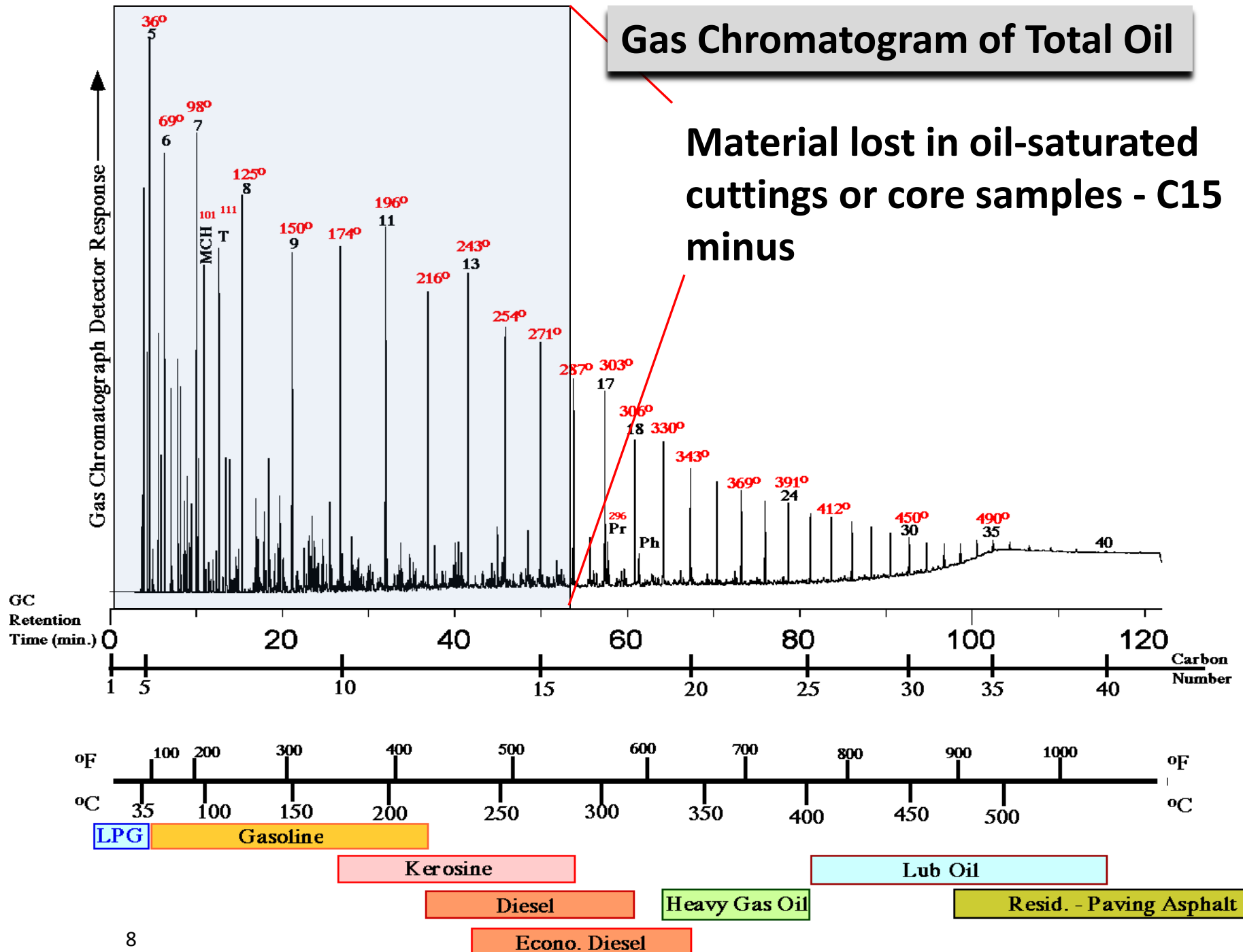
- Core interior is free of OBM contamination.



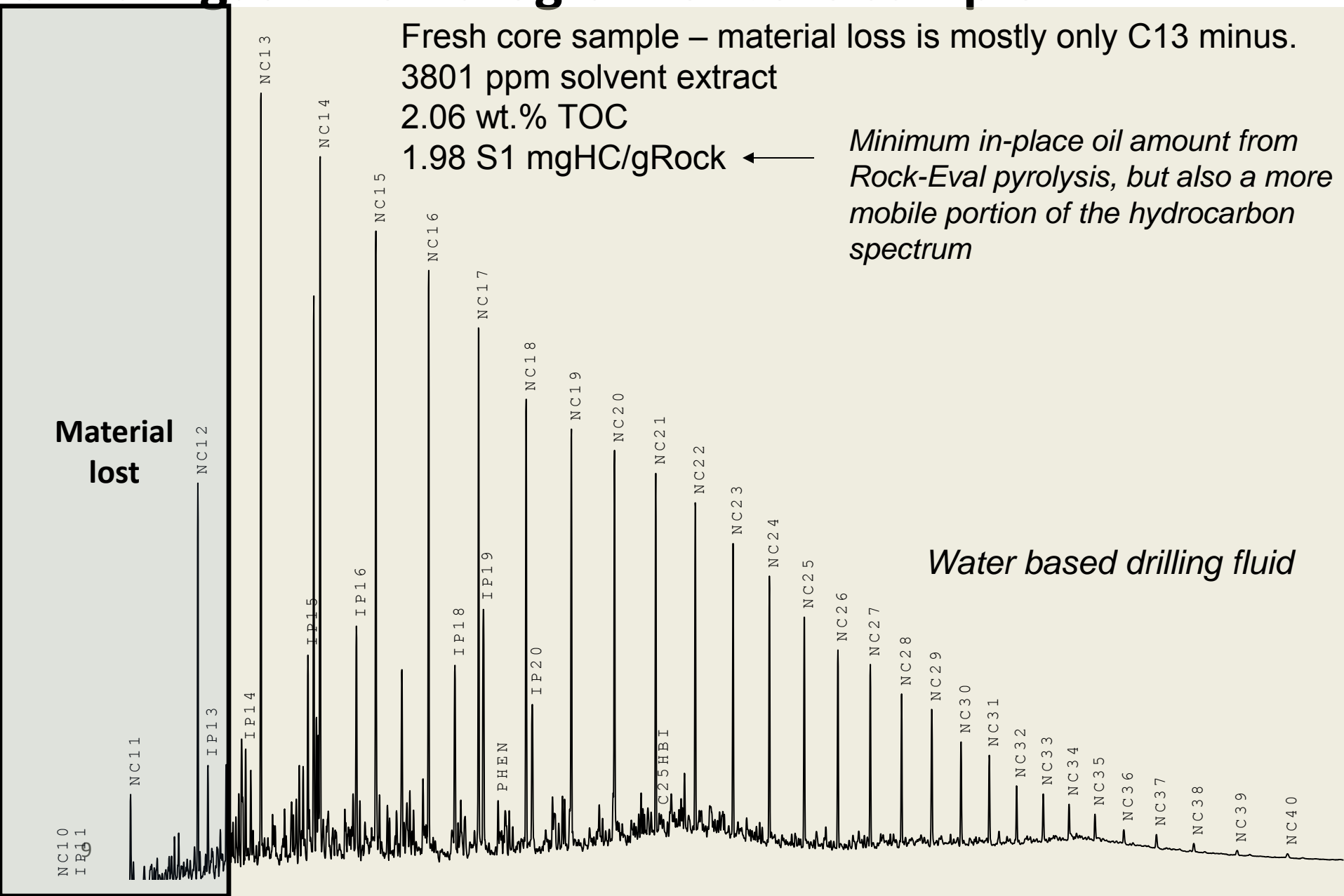
Pyrolysis-gas chromatography

Gas Chromatogram of Total Oil

Material lost in oil-saturated cuttings or core samples - C15 minus



Example of lost oil portion derived from whole-extract gas chromatogram of core sample

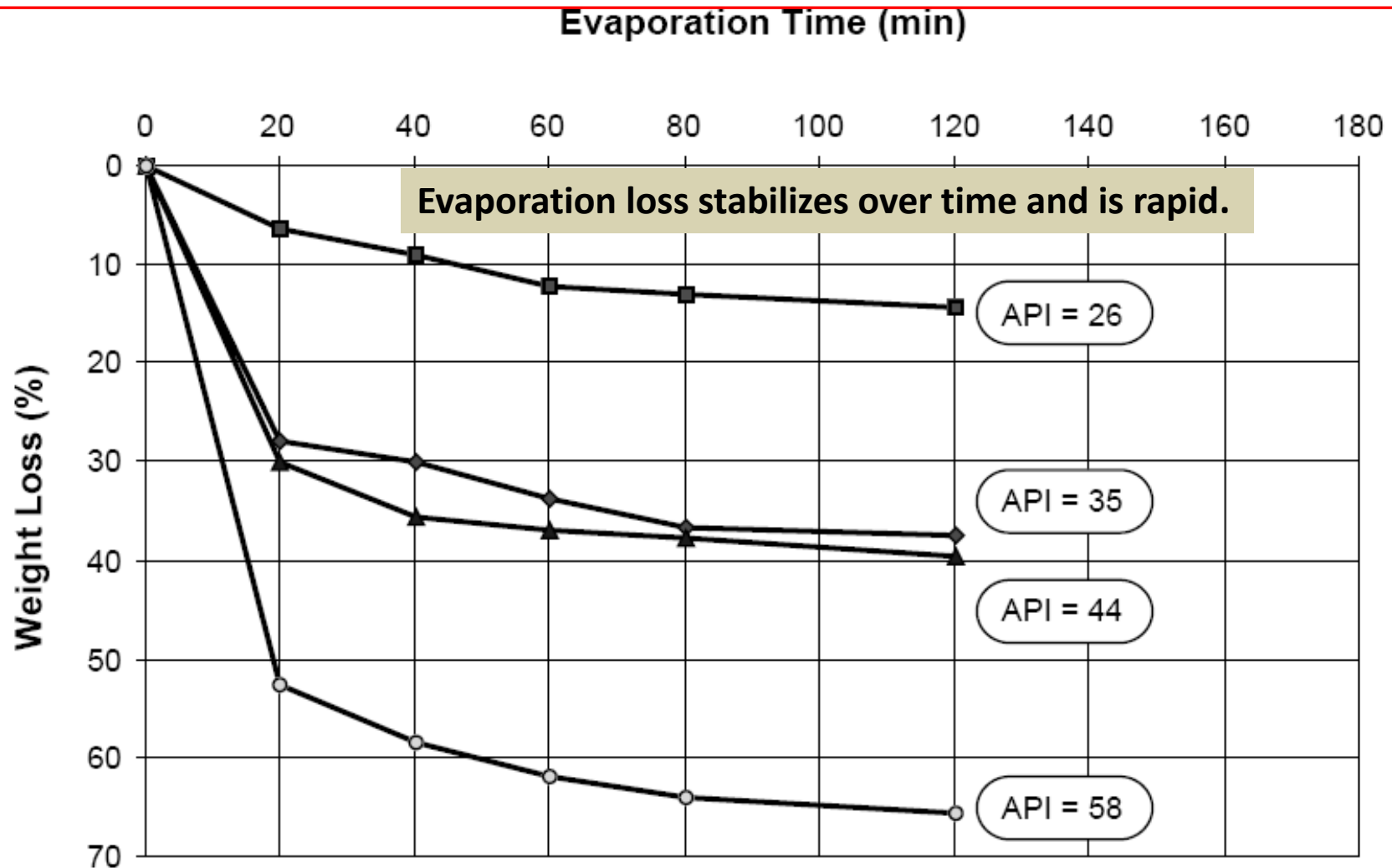


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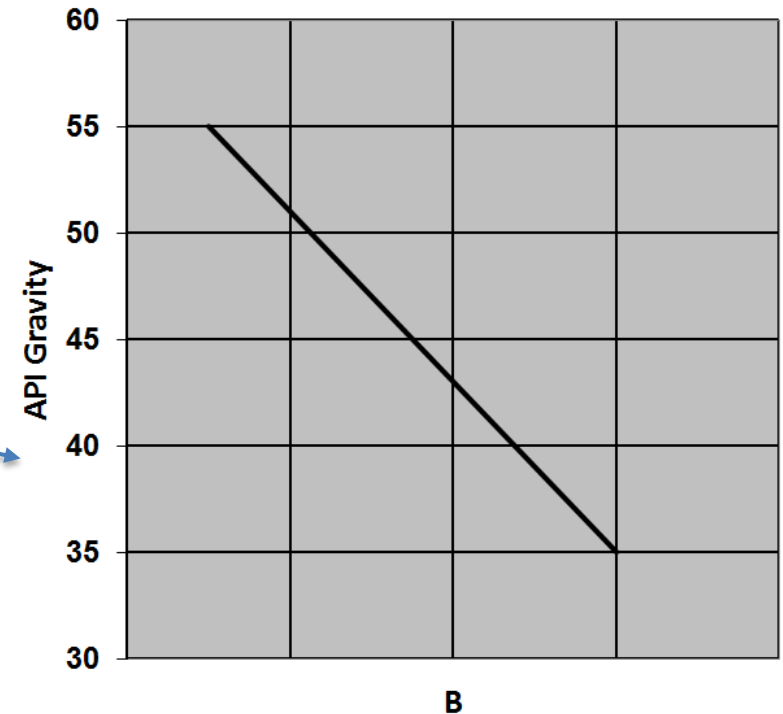
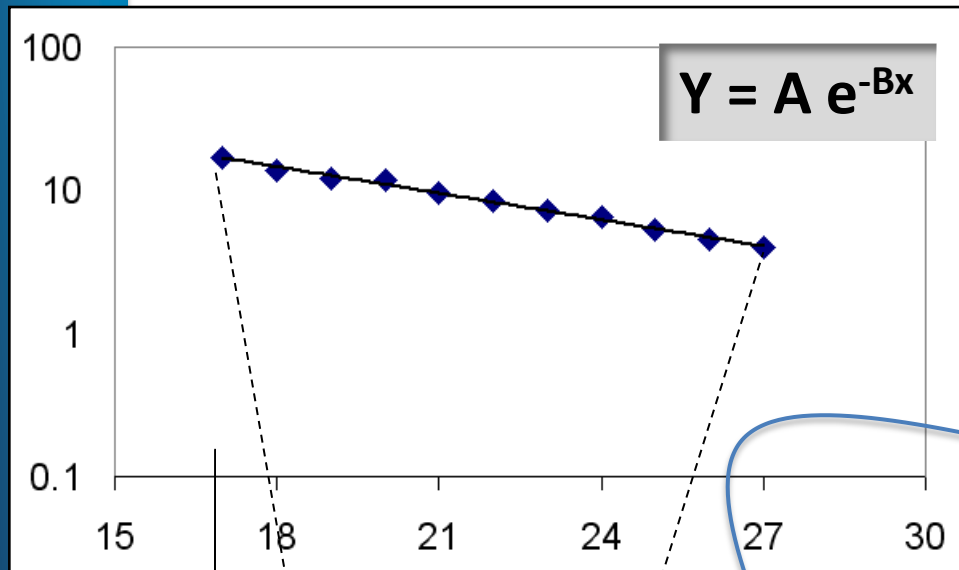
Correction for lost hydrocarbon:

- The Hydrocarbon weight loss is a function of the oil API gravity

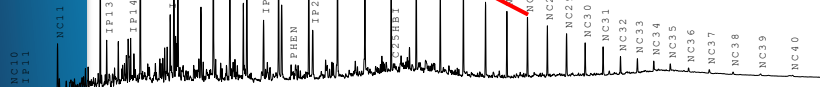


Determination of API gravity from Core Extract

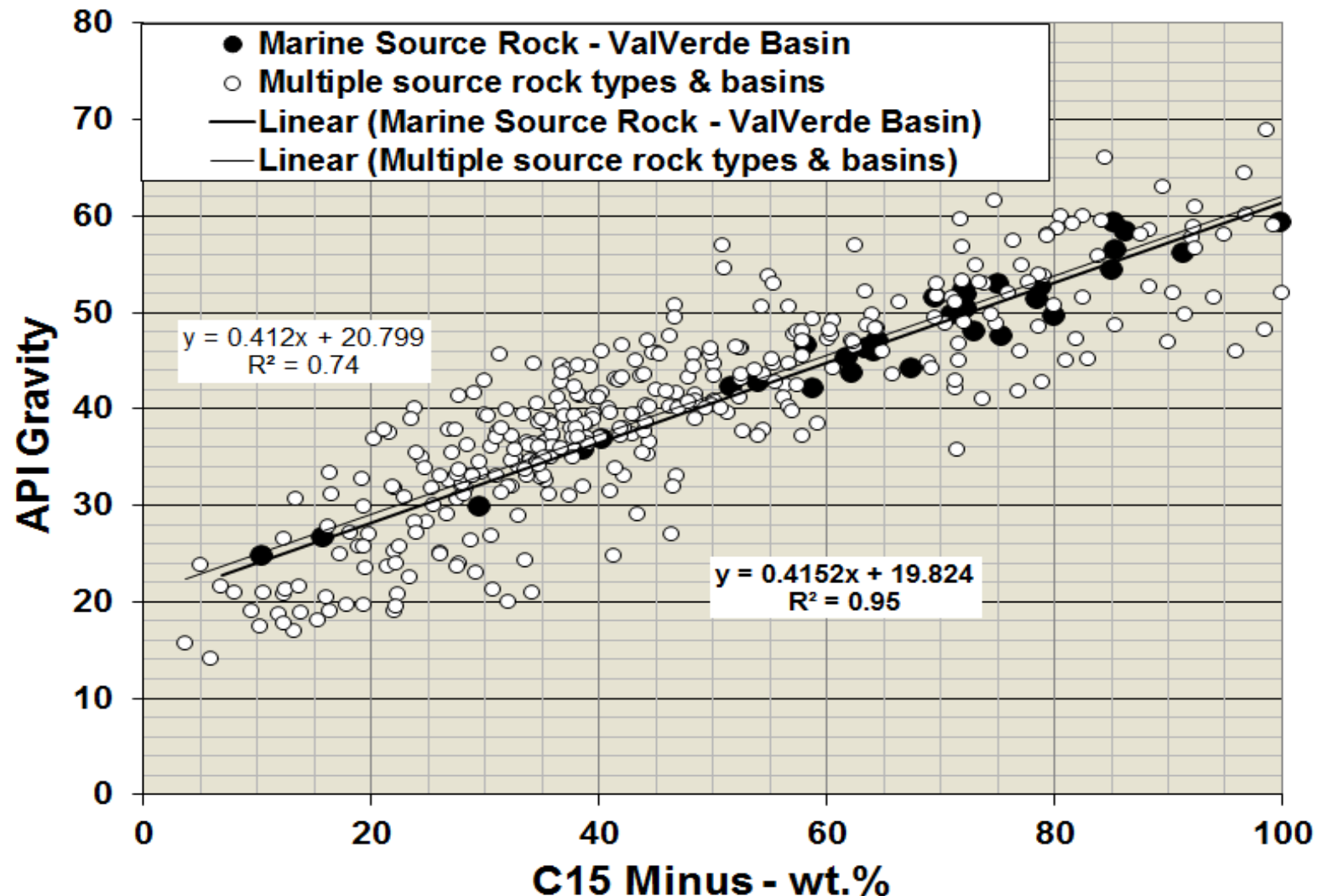
- The slope of the n-alkanes in an oil is related to the oil API gravity for a single-sourced oil (patent pending)



Gas Chromatogram of Extracted Oil from core

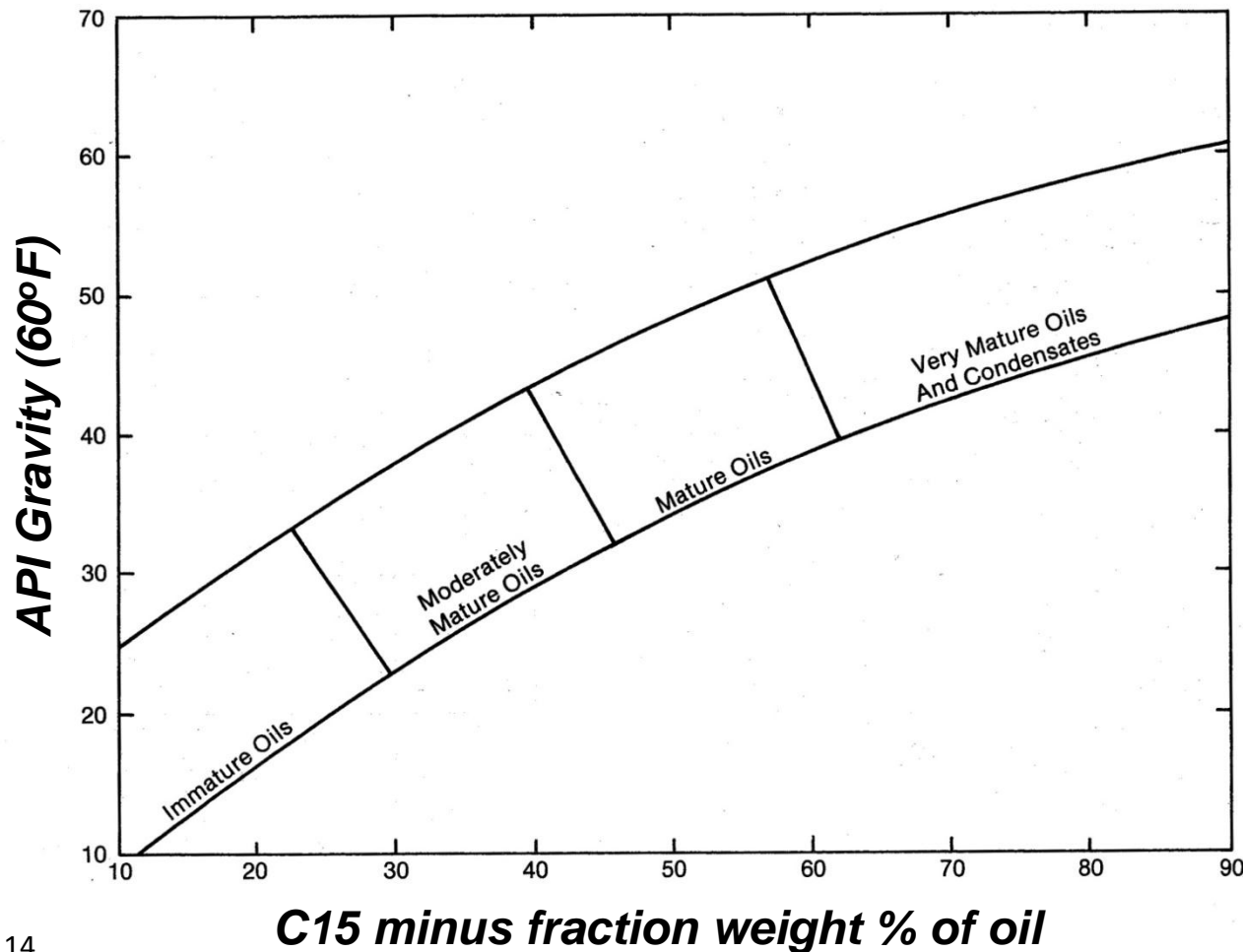


Relationship of API Gravity to C15 minus (wt.%) fraction of oil



Correction for lost hydrocarbon: Relationship of lost hydrocarbon (C15 minus) to API gravity

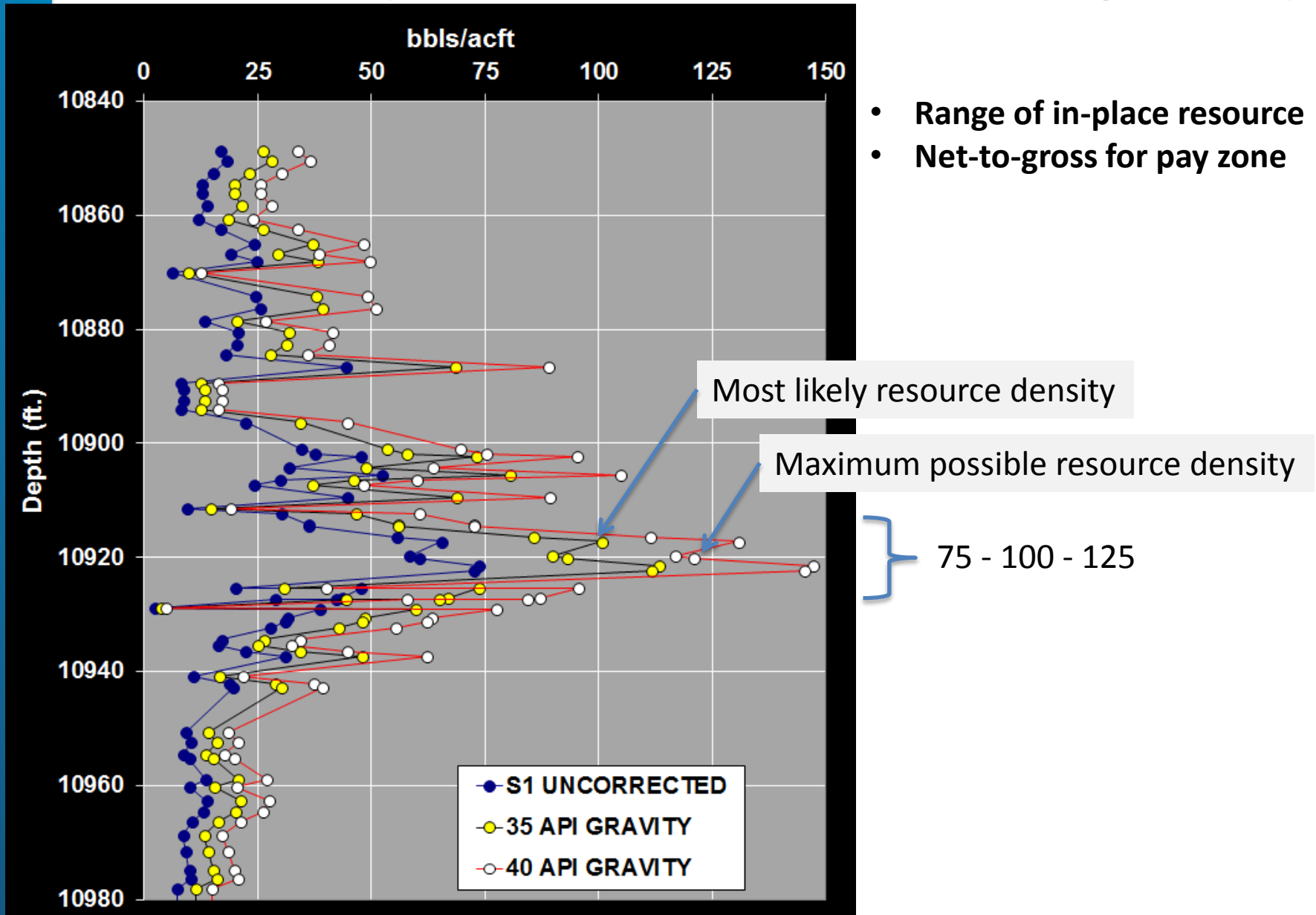
- The lighter the oil in the rock, the greater the component of C15 minus fraction that is lost.
- The lighter the oil, the higher the correction for loss.
- The correlation with density (API gravity) is only approximate as density is controlled at the molecular level (e.g., aromatic v. paraffin, or sulfur content of an oil)



Outline

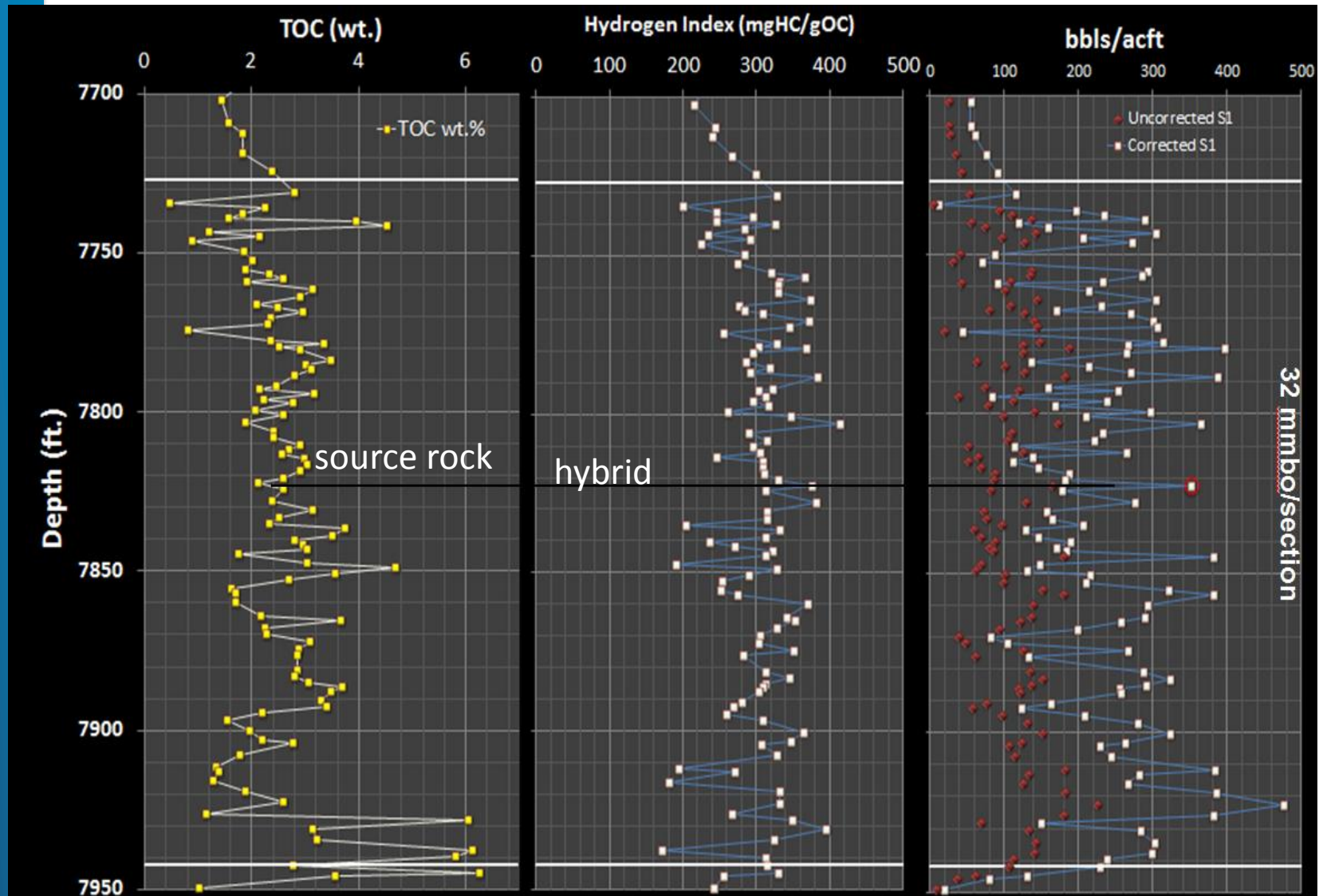
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Sensitivity of correction to API gravity



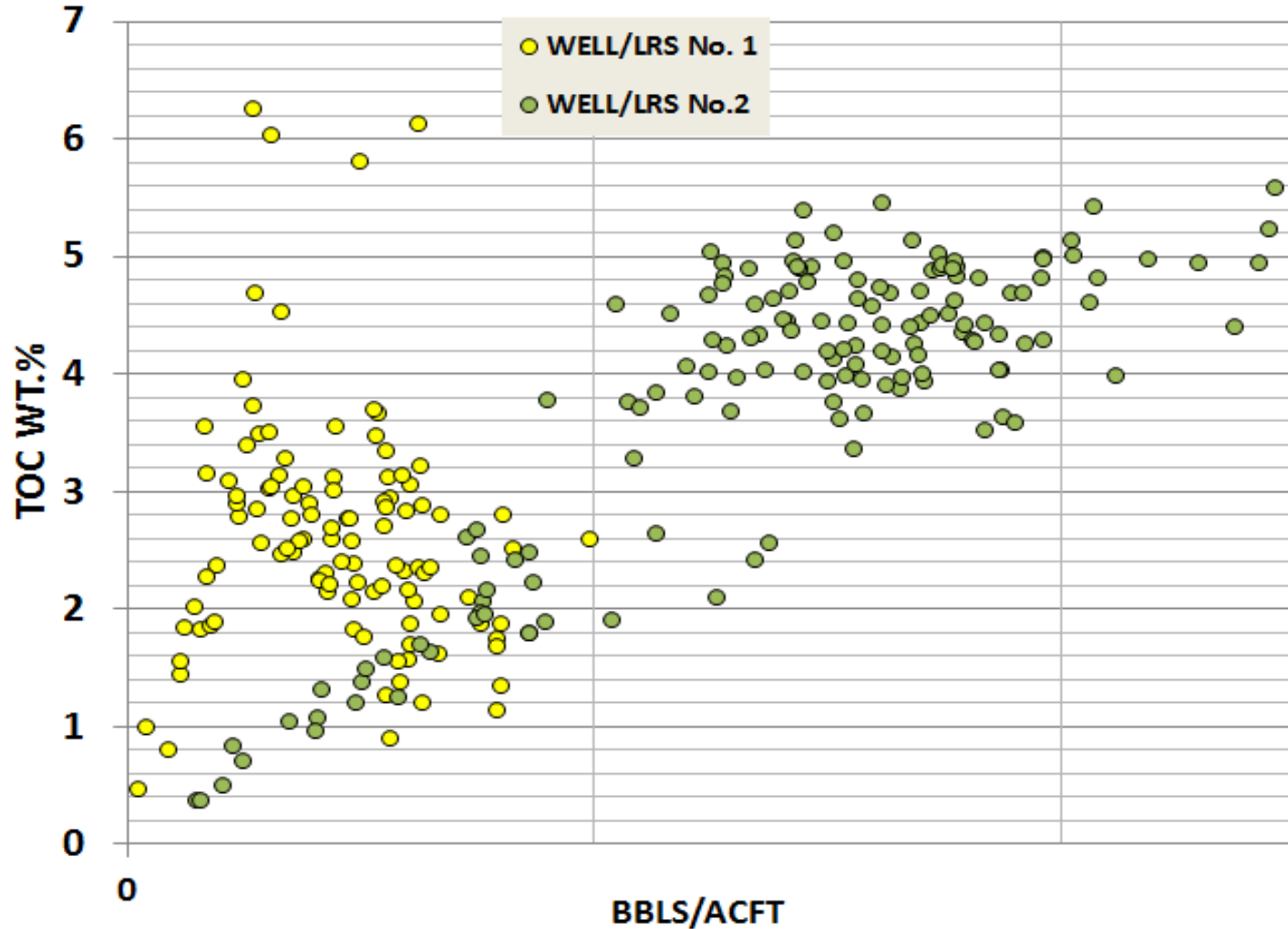
Example of in-place Hydrocarbon Volumes

- Vertical heterogeneity/lateral placement
- In-situ shale and hybrid play assessment



TOC v. in-place oil (bbls/acft)

TOC is a first-order variable on in-place, but stratigraphy matters....

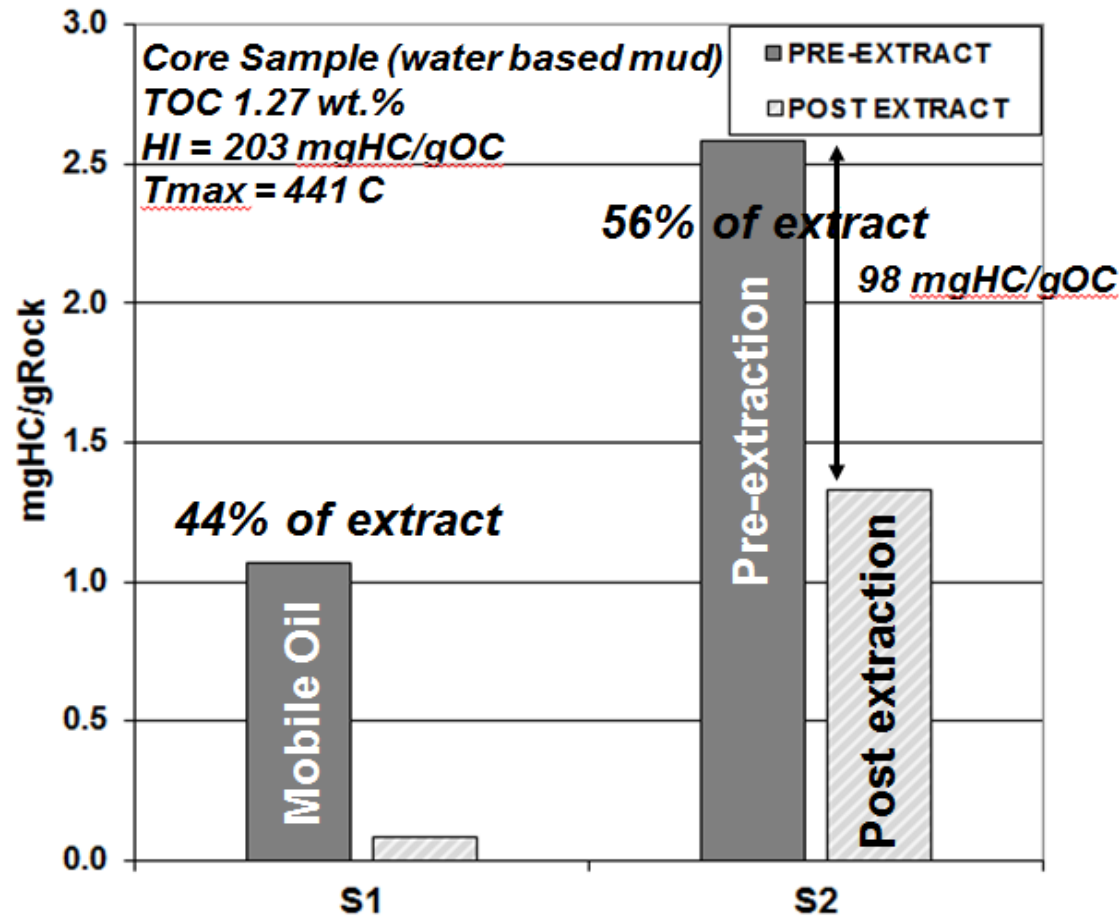
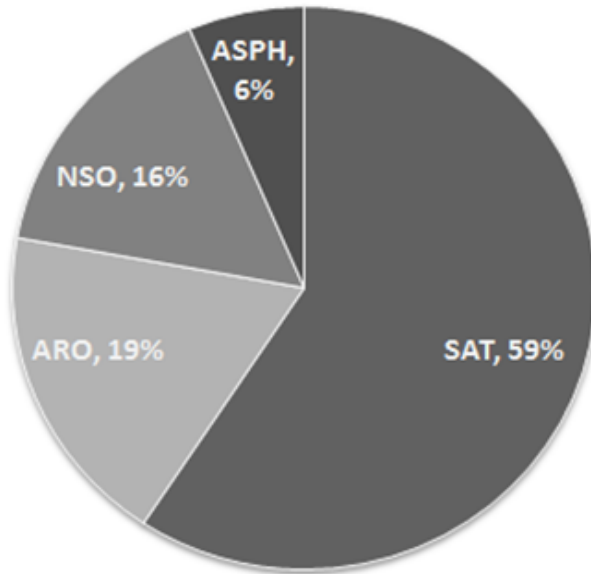


Mobile Oil versus Sorbed Oil

- Amount of oil sorbed to kerogen is ~50-100 mgHC/gOC
- Sorbed oil is mostly higher molecular weight asphaltene and resins
- Sorbed component can be readily addressed by Rock-Eval pyrolysis ***before & after*** solvent extraction and measuring the difference in the S2 peak; which is almost always ~50-100 mgHC/gOC
- This means that mobile oil may be present for S1/TOC values less than 100 mgHC/gOC.

Comparative Rock-Eval pyrolysis

Extract C15+ SARA Composition



Delvaux D., Martin H. Leplat P. and Paulet J. 1990. Comparative Rock-Eval pyrolysis as an improved tool for sedimentary organic matter analysis. Org. Geochem., 16, 1221-1229.

Conclusions & Summary

- **A pyrolysis-based method, independent of measured porosity, can be used to estimate mobile oil in-place**
- **Applicable to liquid-rich shale plays using core material**
- **Oil-based drilling-fluids contamination is minimized using interior core samples**

Thank You

- We would like to thank the management of ConocoPhillips for permission to publish. This work was also conducted and supported by collaboration with several ConocoPhillips L48 business units.
- Questions?

