



Comparison of Oil Shale Kerogen Assay Methods

October 2011; revised December 2011

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Laboratory Measurements of Total Organic Carbon (TOC) 1/2

Indirect Method (SGS, Toronto)

Total carbon (TC) is determined by oxidation at 950°C, with produced carbon dioxide measured by coulometry. Inorganic carbonates are dissolved by warm, dilute perchloric acid, and the produced carbon dioxide is measured by coulometry to determine total inorganic carbon (TIC). $TOC = TC - TIC$.

Rock Eval 6 (TOTAL, Pau)

Volatilization, pyrolysis and oxidation, with analyses of hydrocarbons, carbon monoxide and carbon dioxide; both total organic carbon and total inorganic carbon are determined.

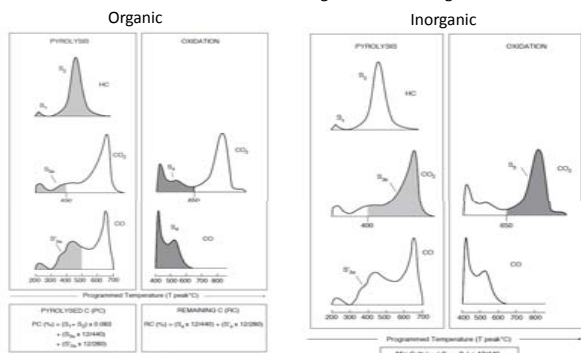
References: Lafarque, Marquis, Pillot, Revue IFP, 53, 421-437 (1998)

Behar, Beaumont, Pentecando, Revue IFP, 56, 111-134 (2001)

Rock Eval 6 Precision for Six Blind Replicates (% of mean)

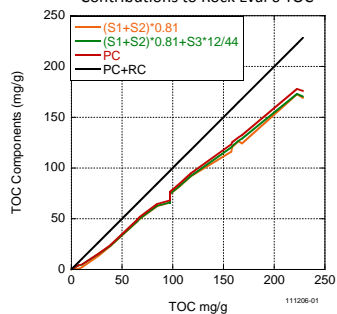
TOC	1.66%
S1	4.64%
S2	1.94%
S3	3.65%
Tmax	±1.2°C

Rock Eval 6 Determination of Total Organic & Total Inorganic Carbon



Lafarque, Marquis, Pillot, Revue IFP, 53, 421-437 (1998)

Pyrolysis (PC) & Oxidation (RC) Contributions to Rock Eval 6 TOC

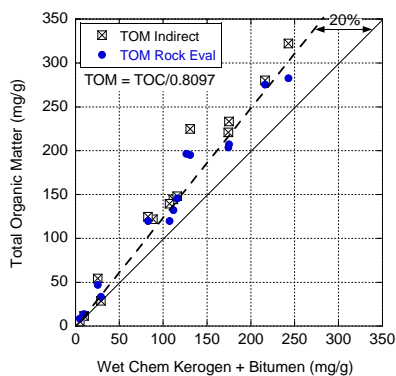
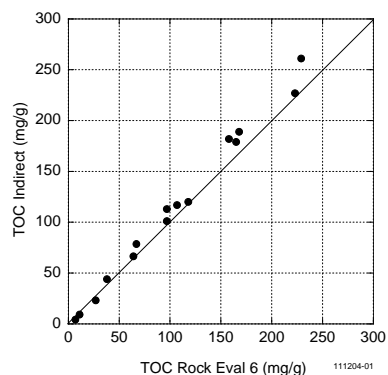


1/1 Introduction

The most important property of an oil shale reservoir is its kerogen content, which determines its potential to produce oil and gas. Kerogen is the preserved organic matter that is the source of petroleum gases and liquids. We compare multiple physical and chemical methods of determining the kerogen content of native state Green River oil shale. Seventeen powdered samples were selected from core obtained from a well in the Piceance Basin, Colorado. Sampled intervals include rich and lean strata of the Garden Gulch member and mineralogically varied strata of the Parachute Creek member. The methods include Fischer Assay, Rock Eval 6, Total Organic Carbon (Indirect Method), wet chemistry demineralization, infrared spectroscopy and nuclear magnetic resonance. These laboratory results are compared to well log estimates of total organic carbon (TOC) and producible hydrocarbon.

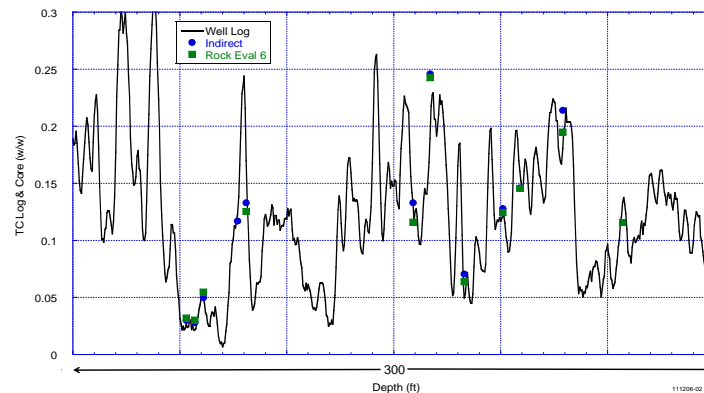
Total Organic Carbon

1/3 Indirect vs Rock Eval 6 vs Wet Chemistry



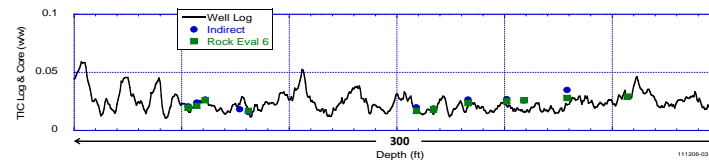
1/4 Well Log Estimates for TC, TIC & TOC Compared to Indirect & Rock Eval 6 Methods

Reference: M. Herron et al., SPE 147184 (2011)

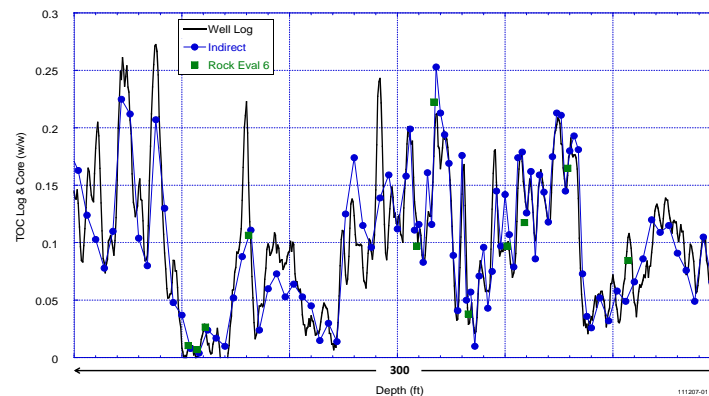


Well log of total carbon (TC). Inelastic nuclear spectroscopy (RST*) and elemental capture spectroscopy (ECS*) are combined to estimate the dry weight percentage of carbon in the formation.

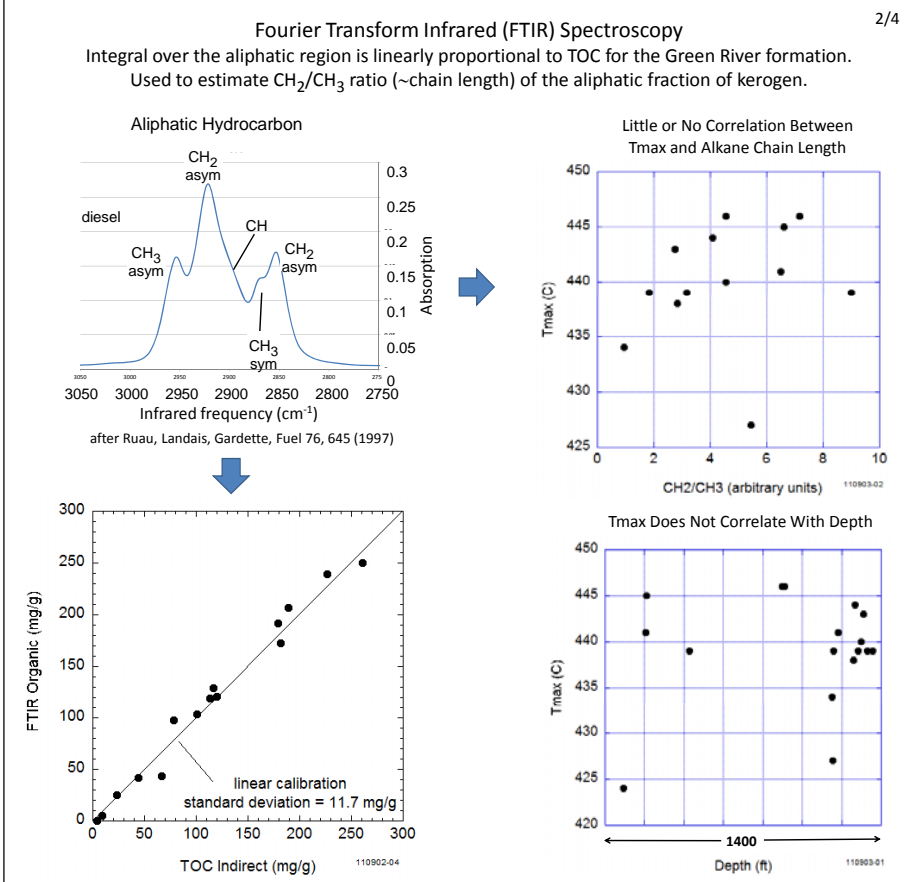
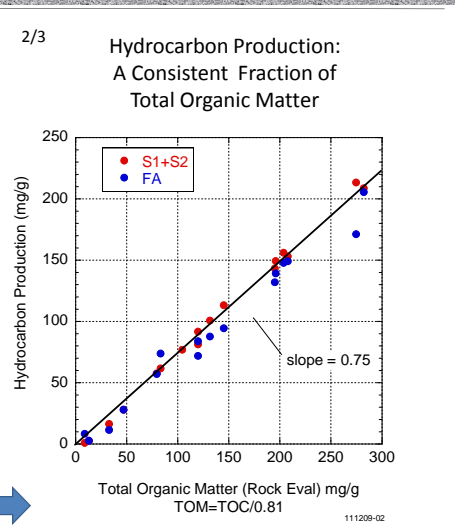
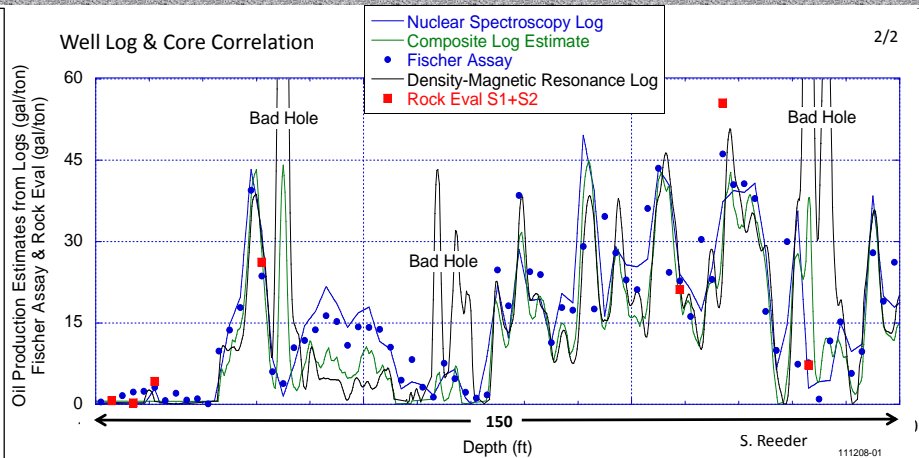
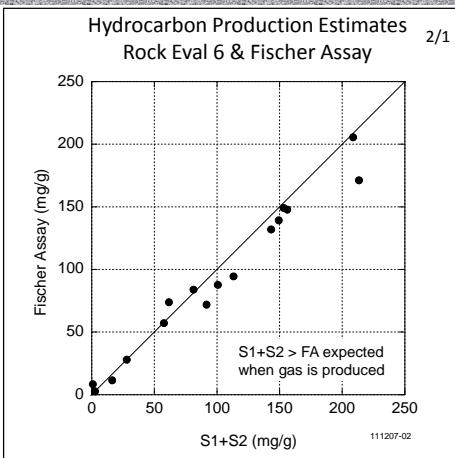
*Mark of Schlumberger



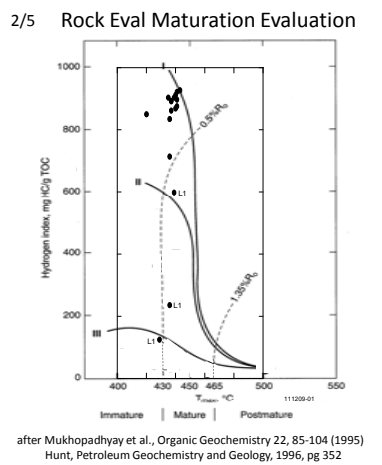
Well log of total inorganic carbon (TIC). Dry weight percentages of calcium, magnesium, and sodium are determined from elemental capture spectroscopy. From these results, the amounts of calcite, dolomite, and dawsonite or nahcolite are estimated, together with the carbon associated with these minerals.



T. Li **Well log of total organic carbon (TOC).** $TOC = TC - TIC$.



Carbon is 81% of Green River kerogen by weight, from an average of at least 84 determinations, primarily of Mahogany zone samples.
 Ref: Brandt, Boak, Burnham, ACS Symposium Series 1032 (2010)



- ### 2/7 Conclusions
- TOC determinations by the Indirect Method and by Rock Eval 6 are in substantial agreement over the entire range found in the Green River Fm.
 - Rock Eval 6 and Fischer Assay both show that pyrolysis converts about 3/4 of Green River organic matter to hydrocarbons.
 - Rock Eval 6 analysis shows that Green River kerogen is immature.
 - For Green River kerogen, infrared absorbance in the aliphatic band is linearly proportional to TOC.
 - Kerogen is invisible, and bitumen is partially visible, to 2 MHz NMR.
 - Log measurements effectively estimate TOC and hydrocarbon production, but have problems where the borehole is of poor quality.

