

Tight Oil Reservoir Characterization and the Difficulties Associated with Quantification of Producibile Oil-in-place

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Abstract

The evaluation of tight oil reservoirs differ from tight gas reservoir evaluation in that they require far more sophisticated and comprehensive geochemical evaluation (biomarkers, classification of oil constituents, etc. in addition to routine maturation indicators and organic richness tests). Additionally understanding lithology, rock fabric, pore geometry, and detailed petrology of the associated lithofacies become very important. This is due to the fact most successful tight oil plays are really stratified and laminated sequences of shale and more porous, larger grained, facies like carbonates.

When evaluating unconventional tight oil reservoirs one of the ultimate objectives is the development of a core calibrated petrophysical log model and associated oil-in-place (OIP) estimates. Unfortunately obtaining accurate OIP estimates is difficult and the results can vary dramatically depending upon the analytical techniques that are applied. It really comes down to a matter of defining what we mean when we say oil, or more importantly, producible OIP. The predominant complication stems from the simple fact that these reservoirs are technically source rocks and/or associated carrier beds, and as such frequently contain significant volumes of kerogen.

At the onset of thermogenic oil generation an expulsion threshold must be obtained prior to the initiation of expulsion and migration, even in source rocks with extremely high expulsion efficiencies. To a large degree this can be attributed to the oleophilic nature of the kerogen which will readily absorb and adsorb the generated hydrocarbons until a point is reached when the kerogen matrix is completely saturated by its own hydrocarbon byproducts. This fraction of absorbed/adsorbed oil is effectively immobile and is not associated with the porosity network that facilitates flow and production of liquid hydrocarbons from the rock matrix. It is also worth mentioning that even in immature source rocks (that have yet to undergo thermogenic oil generation) there exists some volume of “oil” in the kerogen, sourced from the original organic biomass precursors that were preserved in the sediment.

Bitumen is defined as that fraction of organic carbon that is soluble in an organic solvent, thus oil is a constituent of bitumen. When utilizing solvent extraction techniques (like the GRI method) to quantify fluid saturations all soluble hydrocarbons are removed, to include the fraction entrained in the kerogen and any other immobile heavy molecular weight bitumen components. On the other hand thermal techniques like retort or pyrolysis only measure the mass of hydrocarbons that volatilize at some predetermined isothermal temperature.

For example let's consider programmed pyrolysis. The S1 peak is defined as the free oil content of a given rock sample. In reality the S1 peak is only the result of the volatilization of all hydrocarbons at an isothermal temperature of 300°C. Simplistically, this is equivalent to the volatilization of C5 to about C20 (b.p. of C20 is about 338°C). The oven temperature is then ramped slowly (25°C/min) from 300°C to a final temperature of 600°C. During this temperature ramp the S2 peak is generated which is defined as the remaining hydrocarbon generative

potential. However, in reality the S2 peak can frequently display a “shoulder” or behave bimodally due to the volatilization of preexisting high molecular weight hydrocarbons (i.e. oil/bitumen) rather than the pyrolyzation of kerogen.

The Bakken produces oil at 36-44 API gravity (ND Petroleum Council), the Eagleford produces oil at 42-60 API (Platts Special Report, 2012), and the Niobrara produces oil ranging from 35-58 API (Daily Finance, 2013) which is roughly equivalent to oils with molecular weights ranging from 100 lbmol to 200 lbmol. If you convert this range of molecular weights to a corresponding carbon number for simple alkanes (C_nH_{n+2}) it is equivalent to oils consisting of hydrocarbons ranging from approximately C7-C15. These computations are clearly an oversimplification but readily suggest that only the lighter, low viscosity components are produced, which only makes sense considering the extremely low permeabilities associated with tight oil reservoirs.

Considering all of this it becomes apparent that when attempting to calculate producible OIP estimates in tight oil reservoirs solvent extraction techniques will frequently result in a gross overestimation as the resulting volumes represent a total oil (bitumen) to include immobile oil adsorbed within the kerogen as well as a potential fraction of “free” oil that separates from the original composition due to mole sieve effects. Conversely thermal analytical methods have the potential to underestimate OIP (S2 peak carry over) but to a lesser degree.

Methodology and analytical techniques used to assess OIP estimates in tight oil reservoirs will be discussed. Additionally, comparative data will be presented to highlight the disparity of OIP estimates that result from various analytical methods.