Geochemical Tools for Assessment of Tight Oil Reservoirs

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With the astounding success in the U.S.A. from shale-gas production, prices have remained reasonably low particularly when compared to oil prices. Thus, initially while a somewhat serendipitious shift toward shale oil has transformed into a dedicated focus on identifying additional production of oil from tight reservoirs such as shale and closely associated lithofacies. Although considered "new" production from shales or intraformational non-shale lithofacies has a 100+ year history with the Monterey Formation leading the way with over 100 million barrels of production. The ongoing development in the Bakken, Barnett, Niobrara formations for oil in tight reservoirs, whether mudstones or carbonates, provides a premium for oil and helps secure a more independent carbon-bassed energy supply for the U.S.A.

Shale oil production can be from (1) fractured shale, e.g., certain locales for the Monterey and Bakken formation, (2) tight mudstones such as the Barnett Shale, or (3) from hybrid systems where shales are carbonate rich or contain non-mudstone lithofacies such as tight carbonate, sand, or silt, e.g., Bakken formation reservoirs at Elm Coulee or Parshall fields (Fig. 1).
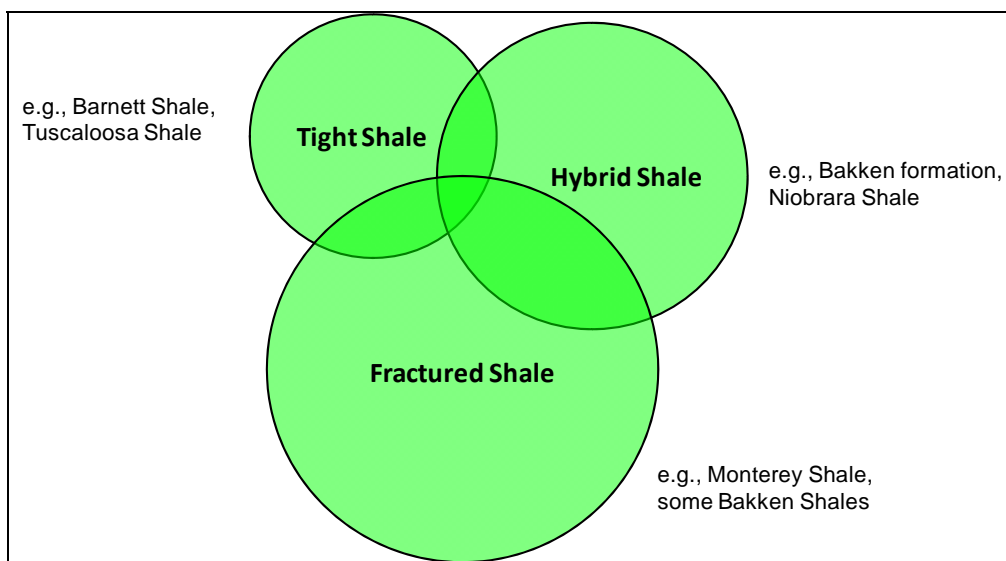

Figure 1. A general classification scheme for shale oil systems.

Prediction of potentially producible shale oil has been utilized in various fields in the Santa Maria and San Joaquin basins. Well site or near well-site work was undertaken to identify zones in the Miocene section that had high oil saturations and had sufficiently high API gravity ($>13^o$API) to have reasonable quality oil (Jarvie et al., 1995). A technique used in the 1950s-1960s to identify high levels of oil saturation was solvent extraction yields normalized by TOC (e.g., Baker, 1962). An offshoot of this technique was the use of Rock-Eval in lieu of solvent extractions (Jarvie and Baker, 1984). As such it provided an inexpensive means of obtaining information about the extent of saturation in a source or reservoir rock. Of course it was and is also important to evaluate oil quality as part of this assessment.

The current work is a modification and addition to prior work of this type to characterize potentially productive tight oil reservoirs for both their oil contents and oil quality including GOR prediction. Using a special pyrolysis program it is possible to predict potential reservoir horizons in shale or other tight reservoirs. Development of an index referred to as the Saturation Index (SI) is used to pinpoint overall units for perforation, stimulation, or horizontal well landing. This technique is combined with a second analytical technique to predict GOR on from well cuttings, SWC, or core chips.

It should be noted that the total oil in a rock particularly a source rock requires analysis of the sample as a whole rock and also as an extracted rock, where the total oil yield is:

$$\text{Total oil yield} = (S1_{\text{whole rock}} - S1_{\text{extracted rock}}) + (S2_{\text{whole rock}} - S2_{\text{extracted rock}}) \quad (\text{Eqtn. 1})$$

This approach has been used to identify and characterize now producing reservoirs in Monterey, Antelope, Barnett, Bakken, and Niobrara formations. A geochemical log from Parshall Field, Mountrail County, Williston Basin shows the effectiveness of this approach, where SI clearly shows the reservoir intervals that are all carbonate rich (Fig. 2). Similarly it shows high saturation in a low thermal maturity shale suggesting that the U. and L. Bakken are, at least in part, expelling hydrocarbons. The dynamics of production for the shale intervals are dramatically different, however, due to the high organic carbon content, which reduces the ability to produce the oil. Thus, a key difference in the SI is whether it is reported on a clay-rich mudstone or other lithofacies such as the Middle Member at Parshall field.

As such these reservoirs vary in character rather significantly from tight mudstones to tight carbonates. The values vary depending on the type of reservoir and reflect different characteristics of the reservoir unit. Source-Reservoirs are characterized by a liquid adsorption threshold that is dependent upon organic richness, thermal maturity, and expulsion. Non-source reservoirs, e.g., intraformational carbonates, have minimal adsorption effects and are more reflective of actual oil saturations such as S_o.

When the SI1 is greater than 100 mg HC/g TOC, producible oil is present and will have $>35^o$API. When SI2 is greater than 100 mg HC/g TOC, producible oil is present, but the oil quality is lower ($<35^o$API).

When oils and rocks are fingerprinted by gas chromatography (GC), prediction of thermal maturity and GOR can be calculated from the C_7 light hydrocarbons. This predicted GOR by sample is based on correlation of Bakken oils across the basin with measured GOR values whereby:

$$\ln \text{GOR} = 1.33 \ln 2MP - 2.81 \ln 3MP + 3.19 \ln 2MH - 0.875 \ln 3MH + 7.20 \quad (\text{Eqtn. 2})$$

where 2MP and 3MP are 2- and 3- methylpentane, and 2MH and 3MH are 2- and 3- methylhexane.

Calculated GOR values for various samples in Sanish Field show good approximation to produced oil GOR values (Fig. 3).

Figure 2. Geochemical log of an EOG well in Parshall Field.

Figure 3. Calculated GOR values from Bakken Shale extracts using high resolution GC results of C_7 methylalkanes. Black bars are U. Bakken Shale and blue bars are L. Bakken Shale results.

References

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