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Differential Total Gas Detection for Reservoir Characterization and Reserves Estimation

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ABSTRACT

Conventional mudlogging utilizes a total gas (TG) detector along with a gas chromatograph's C1–C5 gas measurements, which are used for the hydrocarbon-bearing formation evaluation. Differential total gas (DTG) detection system provides a direct measurement of light and heavy gas components calibrated to discriminate formation fluids (water, oil, condensate, wet and dry gas, and coal-bed methane). Combination of TG and DTG measurements leads to better understanding of the reservoir properties such as porosity, permeability, fluid types, and hydrocarbon saturation. It also allows calculating of hydrocarbons in place. Using the real time log, the production capability of the reservoir zone at a fixed pressure drop can be calculated.

This work covers principles of joint interpretation of the TG and DTG curves and examples from a real-time mudlogging conducted on vertical and horizontal wells drilled for both conventional and unconventional reservoirs. They include identification of the water-bearing fault in a horizontal well; oil-water contact; gas-condensate contact; gas-condensate-oil zone; oil-water zone; and tight zone within the reservoir. The case study of the DTG application for shale oil demonstrates the definition of oil production capable intervals and lesser production capable intervals, which is important for an effective fracking design.

Presented examples demonstrate an additional value of including DTG data into petrophysical formation evaluation workflow.

Zamfes, K., V. Egorov, and E. Hasanov, 2021, Differential total gas detection for reservoir characterization and reserves estimation: GeoGulf Transactions, v. 71, p. 317–323.

INTRODUCTION

Conventional mudlogging utilizes a total gas (TG) detector along with a gas chromatograph's (GC) C1–C5 gas measurements, which are applied for the hydrocarbon-bearing formation evaluation. It has been about 70+ yr since the hotwire detector was invented and over 50 yr since the GC is used in the oil and gas industry. The TG and GC combination is a main part of today's mudlogging services provided onsite during the drilling. The TG log is very simple and intuitive for a visual interpretation. If the curve going to the right (increases) it indicates a gas (and, potentially, hydrocarbon) show.

The gas chromatograph measurements are often also simplified down to interpretation of "show – no show," although they provid information of the present gas components, usually C1–C5. The challenges start when one wants to get more information from TG and GC in combination. There are a number of methodologies targeting wetness calculations and various gas components ratios mapping and interpretation. They require additional resources and skills, which may not be available at the wellsite in real time. Note also, that GC readings, as fast as they can be done, are discrete and not continuous. Thus, they have to be interpolated. TG data are usually used to extrapolate the GC values in continuous log presentation. This may inflict additional challenges.

METHODS

To address challenges and limitations of traditional TG–GC data interpretation, the Differential Total Gas (DTG) system was designed (Zamfes and Bearinger, 2000). The system is easily deployed at the drilling site and does not require significant additional resources and training. The output of the DTG system is two log curves: TG and DTG. Both curves are produced by continuous real-time measurements.

The TG curve is the same as a conventional TG indicating the gas show interval and quantity. DTG log comes from an additional gas detection system that quantitatively measures heavy hydrocarbons (C3–C5) in the gas stream resulting in the DTG log. The DTG curve allows differentiating fluid types (gas/condensate/oil/water) and estimate their quantity as well as reveal additional information about reservoir per se. For example, the oil-water contact is determined by the sharp drop of the DTG curve whereas the TG curve has a bell-shaped anomaly (Fig. 1). For a quantitative interpretation a simple ratio of two log values provides an Oil Ratio (OR), where OR = TG / DTG (Fig. 2).

RESULTS

The above-described approach has been implemented successfully on many projects.

Figure 3 shows TG and DTG curves observed during the horizontal drilling through Upper Cretaceous Austin Chalk reservoir in Texas. TG indicates gas show throughout the presented interval. However, the DTG curve is decreasing and becomes negative within the 6880 to 6905 ft interval, indicating that the well is penetrating a water-saturated interval interpreted to be associated with the fault. Notice that TG is increasing within the water-saturated zone due to high concentration of methane in it.

Other examples are from the Eastern Shelf of Permian Basin, Texas, where Pennsylvanian sand channels have been the main drilling target. Two reservoir intervals are present and have gross pay zones of approximately 50 and 100 ft. Both intervals are represented by vertically compartmentalized pay zones. Figure 4 shows the upper 6 ft zone for which the DTG and TG both indicate it to be charged with oil. However, below this depth the TG curve still indicates hydrocarbons, while DTG decreases, indicating a tight zone with only traces of gas present within it. Below the tight zone, both DTG and TG behave in accord creating positive gas anomalies with OR = 1.3, which indicates oil-charged reservoir.

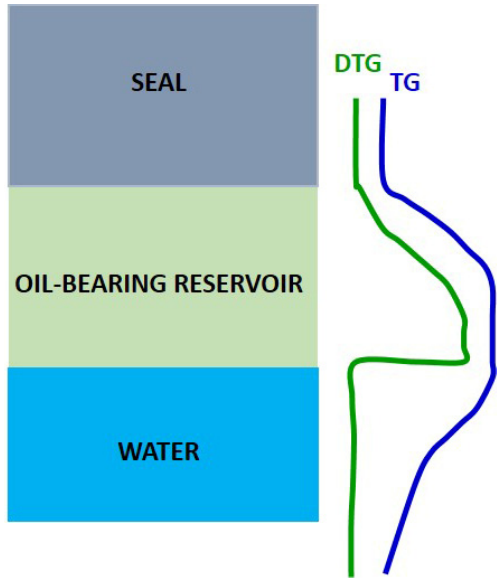
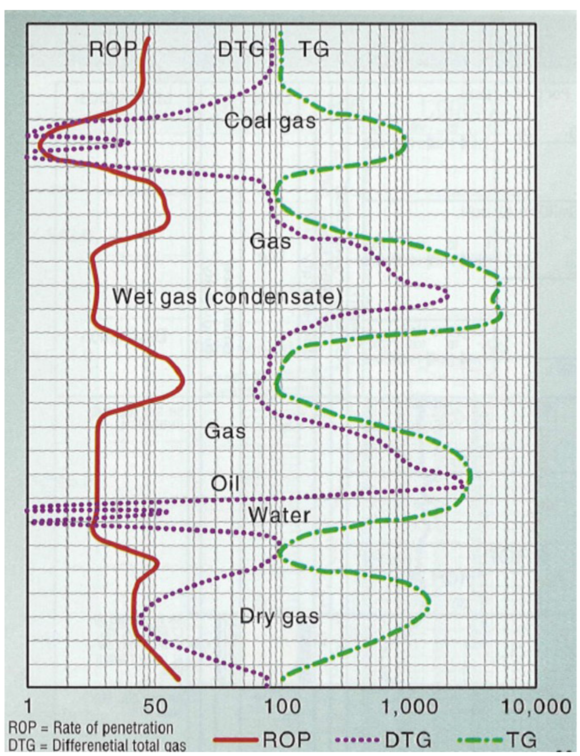


Figure 1. Oil-water contact is indicated by the sharp drop of the DTG curve whereas the TG curve has a bell-shaped anomaly.



Formation fluids and typical DTG-TG responses

Oil Ratio: OR=TG/DTG Interpretation

- 0<OR<3 oil bearing zone
- 3<OR<5 condensate bearing zone
- 5<OR<8 natural gas bearing zone
- 8<OR<10 dry gas bearing zone
- OR<0 oil-water contact, coal bed methane

Figure 2. Differential Total Gas (DTG) and Total Gas (TG) curves interpretation chart and oil ratios differentiating fluid types within the reservoir.

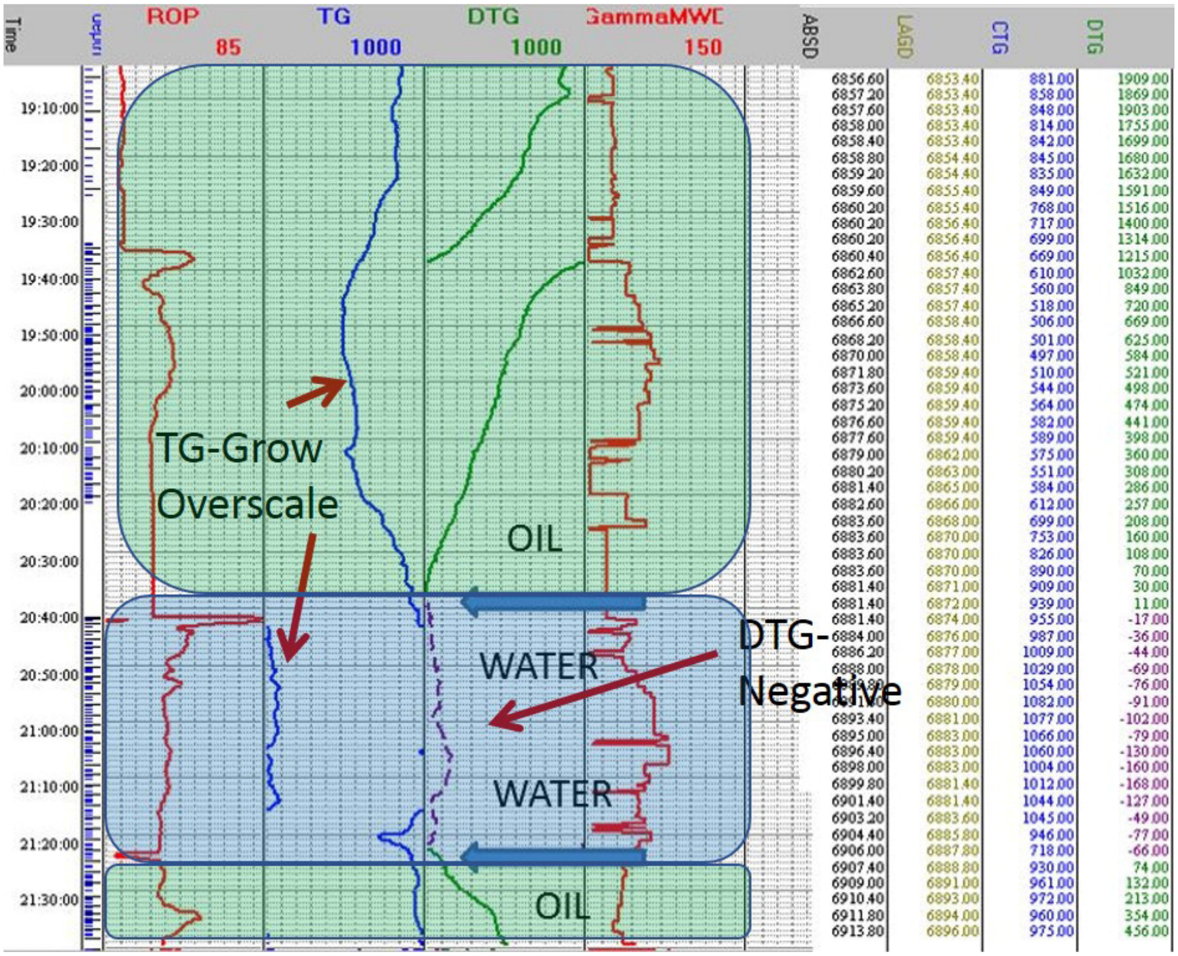


Figure 3. TG and DTG curves observed during the horizontal drilling through Austin Chalk. TG indicates gas show throughout the interval. However, the DTG curve is decreasing and becomes negative within the 6880 to 6905 ft interval, indicating that the well is penetrating a water-saturated interval interpreted to be associated with the fault. Notice that TG is increasing within the water-saturated zone due to the high concentration of methane in it.

Figure 5 shows a second sand interval where TG and DTG also demonstrate vertical compartmentalization, with three pay zones charged with oil as indicated both by the curves' behavior and OR = 1.2. The interpretation of TG and DTG was confirmed by triple-combo logging run after the well had been drilled.

Figure 6 shows an oil-bearing interval with a downward oil saturation decrease until it reaches an oil-water contact, where the DTG becomes negative within a free water filled zone. TG still shows elevated values and GC shows heavy gas components are slightly increased not indicating the oil-water contact position.

The last example is from shale oil in an Upper Cretaceous Woodbine reservoir in East Texas. Figure 7 illustrates that DTG and TG curves behave identically within a sand part of the well. However, within the shale oil interval, DTG clearly increases while the TG curve does not and in fact in places it decreases.

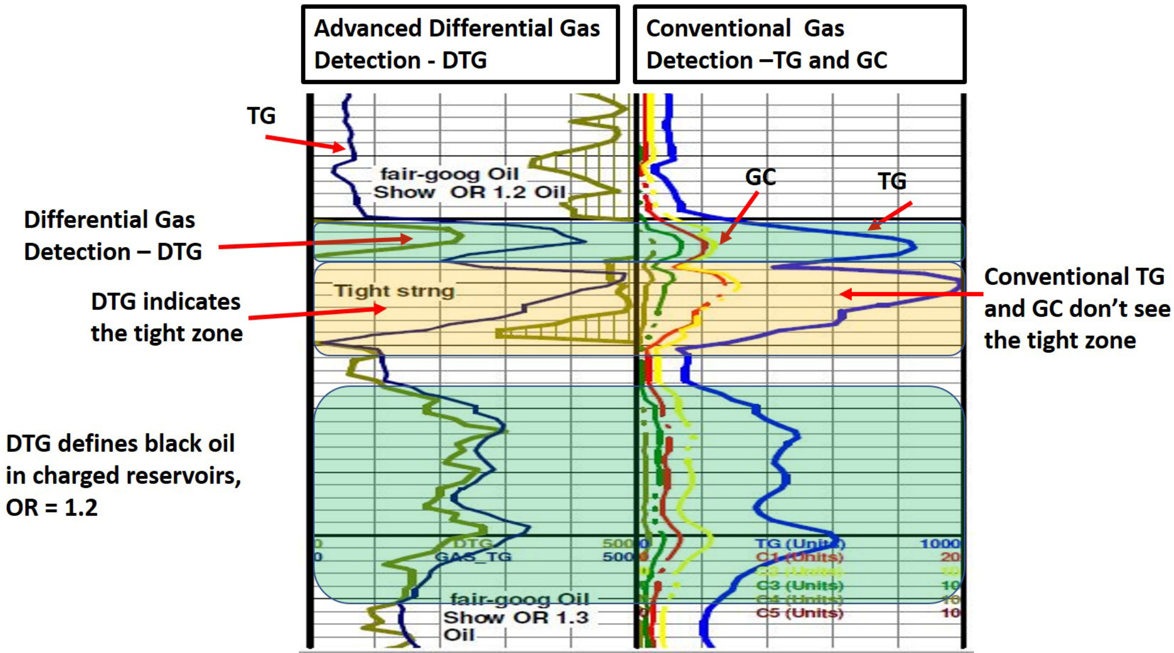


Figure 4. Upper 6 ft zone of the reservoir with the DTG and TG indicating it to be charged with oil. Below this interval, the TG curve still indicates a gas show, while the DTG is decreasing, indicating a tight zone with only gas present within it. Below the tight zone, both the DTG and TG curves behave in accord creating positive gas anomalies with OR=1.3, which indicates oil-charged reservoir.

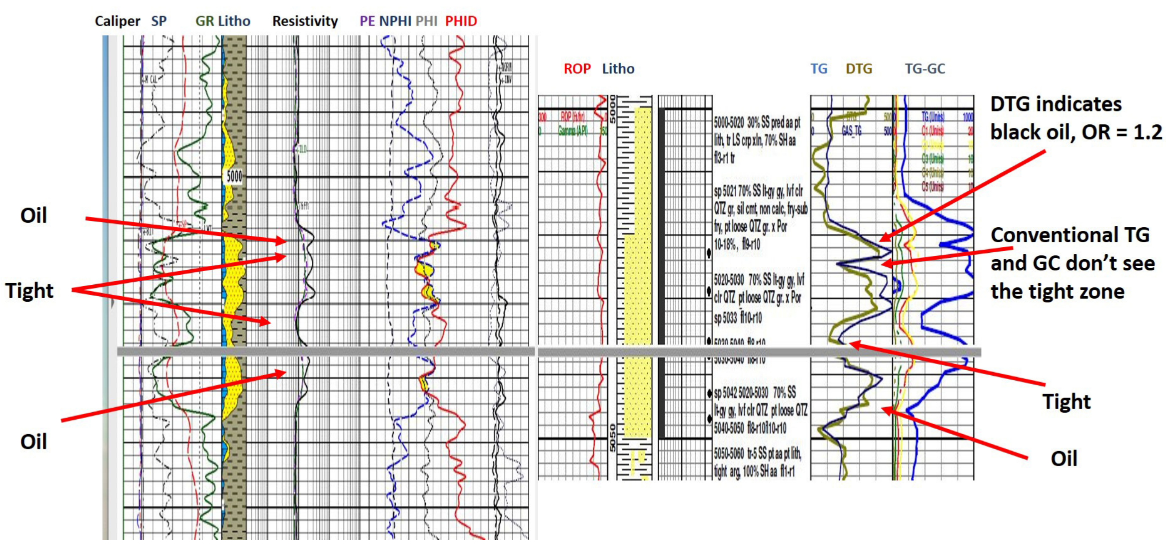


Figure 5. TG and DTG demonstrate vertical compartmentalization of the reservoir, with three pay zones charged with oil as indicated by both the curves' behavior and OR = 1.2. The interpretation of TG and DTG was confirmed by triple-combo logging run after the well had been drilled.

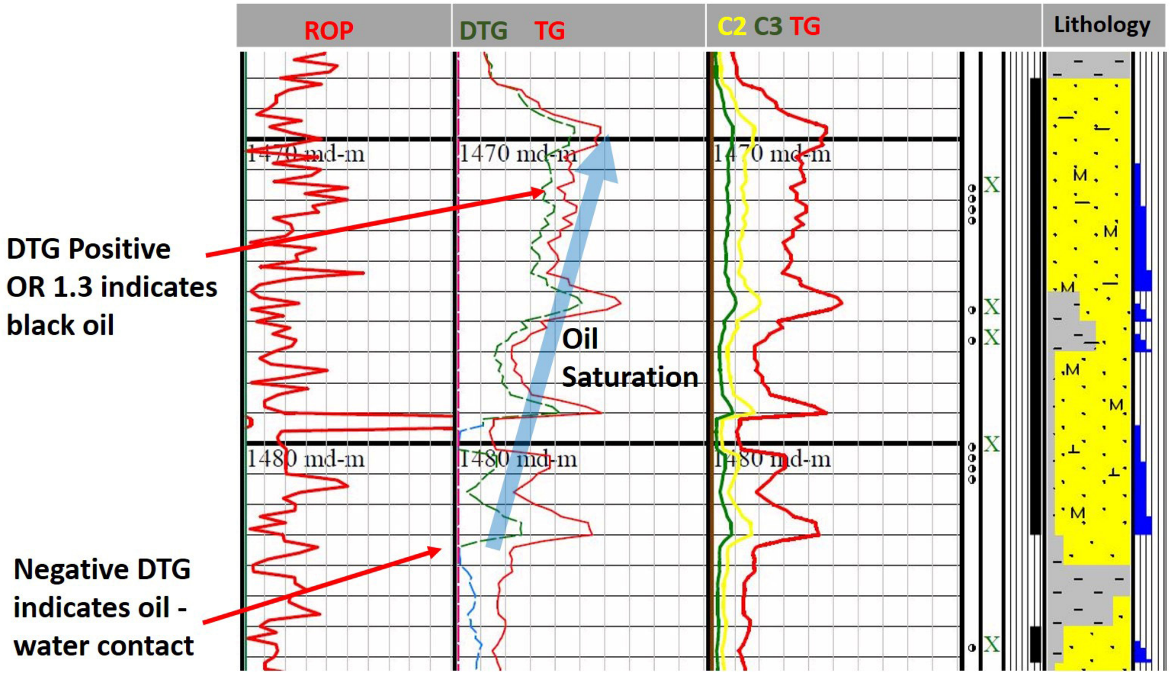


Figure 6. Oil-bearing interval with a downward oil-saturation decrease trend until it reaches the oil-water contact, where DTG becomes negative within the free-water filled zone. TG still shows elevated values and GC shows heavy gas components are slightly increased not indicating the oil-water contact position.

SUMMARY AND CONCLUSIONS

Adding DTG measurements and interpretation along with an accurate drilling cuttings sampling and analysis provide reliable and ground-truth confirmed interpretation. They often demonstrate higher-resolution than standard petrophysical logs and certainly remove ambiguity in the interpretation of the latter. DTG allows real-time evaluation of the fluid types penetrated by the wells. Besides vertical well drilling, it is definitely useful to be implemented for horizontal well drilling when the traditional open hole logs are too expensive or impossible to run.

REFERENCE CITED

Zamfes, K., and D. Bearinger, 2000, Mudlogging technology I: Gas-detection technology defines oil-gas-water contacts: Oil & Gas Journal, February 24 issue, p. 32–38.

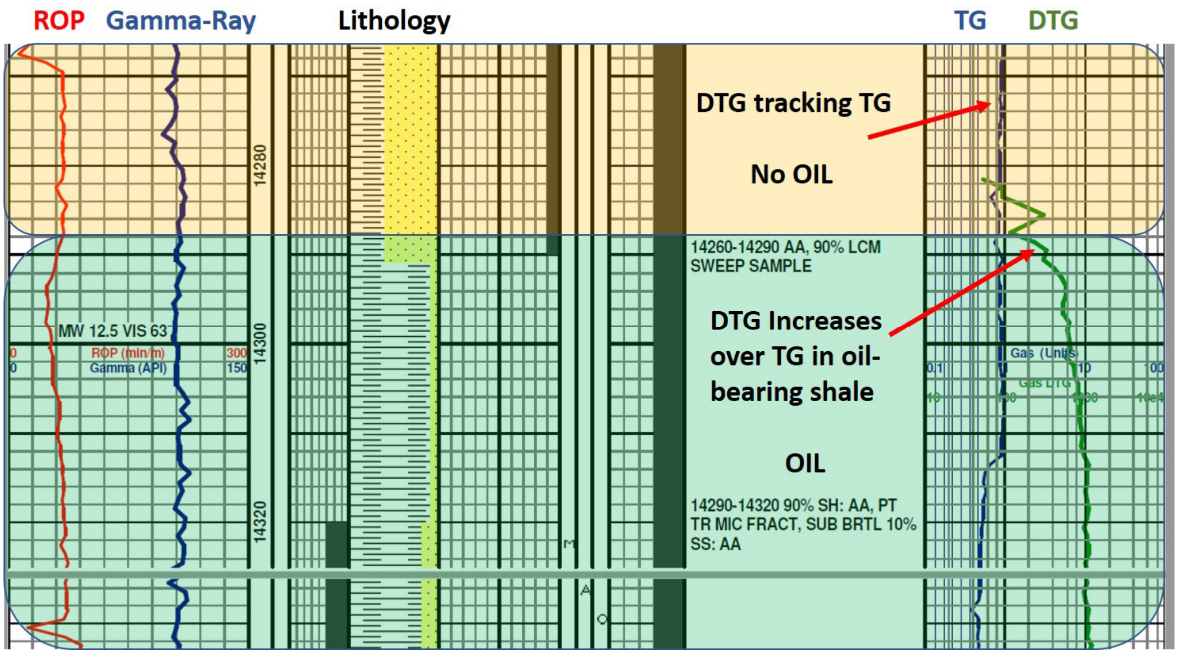


Figure 7. DTG and TG curves behave identically within the sand part of the well. However, within the shale oil interval DTG clearly increases while TG curve does not go up and at places TG readings even decrease.

NOTES