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Application of Gas Geochemistry in Production Allocation and Well Performance Monitoring

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In this paper, we present results and methodology showing the application of gas composition and stable carbon isotope geochemistry data from co-mingled Mesozoic sandstone reservoirs (Sand A and Sand B) used for production allocation. Gas composition and isotope data indicate that the end-member gases from Sand A are dry (>90% methane) with isotopically heavier carbon atoms in the $\delta^{13}C$ for C_1 to C_{6+} hydrocarbons. Results indicate that these gases have been generated from a Type II source rock at ~2.0 %Ro maturity. End-member gas samples from Sand B are wet (83% methane), isotopically lighter and believed to have been generated from a Type II source rock at ~1.2%Ro maturity. The gas composition and isotope data help constrain the end members in the allocation study and serve as the basis for production allocation of wellhead gas samples.

Our data indicate a good agreement between production allocation results derived from gas composition and carbon isotope data; however, methane data tend to be less reliable than ethane and propane. Results from this study also showed that this method is robust with a high degree of repeatability. We establish the capability of this approach in predicting production allocation within ±2% of allocation results derived from other methods such as mechanical spinners and decline curve computations.

The application of low cost geochemical methods for production allocation studies especially in co-mingled reservoirs help to identify reservoir performance problems at any point in the life of a given well. The performance of this method unlike other conventional methods is not limited by the direction or orientation of the well whether it is vertical, horizontal or deviated. This approach also provides avenues for assessing uncertainty and standard errors estimations in the production allocation results which is useful for modeling production outputs critical to economic decision making. To this end we present results showing the applications of gas geochemistry (composition and isotope) in production allocation in two co-mingled pay zones (Sands A and B) separated by the laterally extensive thick shale seal in the basin.

Methodology and Results

Using gas geochemistry for production allocation or monitoring well performance only requires a natural occurring chemical difference in the end members to exploit. To a large extent understanding the reason for the chemical difference is often technically not required to be known in order to perform allocation. However, understanding the reason for a chemical difference is important in order to determine the requirement for end member selection; or in other words the validity of an end member geographically. If the chemical difference is related to thermal maturity of the gas or differences in organic facies of the source, these differences are often manifested in relatively long wavelength chemical differences; thus resulting in end members that can be used over a longer distance. Chemical differences that arise due to in-reservoir processes (e.g. mixing or biodegradation) often results in short wavelength changes in chemistry and thus require more local end member determination. Long wavelength variation in chemistry can be overcome by using end member samples at a shorter wavelength than the regional trend; whereas, short wavelength variation in chemistry can only be overcome by extremely proximal end member sampling (e.g. same well) or by use of parameters not affected by the short wavelength mechanism. In this study we discuss the methodologies for proper selection of end members. In general, for the study area we found the gases to be controlled predominately by a regional variation in source thermal maturity with some local variability due to lower maturity dry methane gas contribution.

This study was carried out over a 55 sq mi area where over 60 gas samples were collected from ~18 well heads using IsoTubes in deviated and horizontal wells over a 15 months interval. Each of these samples were subject to gas composition analyses (C_1 to C_{6+}) using a gas chromatograph (GC). In addition concentrations of CO_2, N_2, O_2 + Ar and CO are also obtained from the gas analyses. The same sets of gas samples are also analyzed using a coupled gas chromatograph-isotope ratio mass spectrometer (GC-IRMS) to evaluate the stable carbon isotope signatures of the light hydrocarbon gases (C_1 to C_{6+}).

For most of the samples, the cross plot of N_2 vs. O_2 + Ar show a gradient between 3.8 and 4.1. These derived gradients are similar to those found in air suggesting that there are no external streams of contaminants in the collected samples. A few samples contained relatively higher amounts of N_2. This is derived from the N_2 enriched fluids used in the fracture stimulation during well completion. This does not significantly affect the results of the allocation since only hydrocarbon concentrations normalized to total hydrocarbon concentrations was applied in the allocation.

Two geochemical based allocation approaches were carried out in this study. The first uses gas composition data only where the normalized concentrations of the hydrocarbon gases to the total hydrocarbon is applied in the production allocation algorithm. The second uses the carbon isotope data combined with the normalized gas composition. Our allocation results show good agreements between these two different gas geochemical methodologies, predicting allocation result within an error range of ± 2% (Figure 1). Results of average allocation derived from the normalized composition and C-isotope methodology also showed good agreements with allocation results derived from other methods such as spinner and decline curve analysis (Figure 2). An additional application of the gas geochemistry is well performance surveillance were we track the reservoir allocation of individual wells on a quarterly basis.

Conclusions:

- Data indicate a good agreement between production allocation results derived from gas composition and gas isotope data and the method is robust with a high degree of repeatability.
- We establish the capability of the gas geochemistry approach in predicting production allocation result within ±2% of allocation results derived from other methods such as mechanical spinners and decline curve computations.
- Gas geochemistry is low cost and allows for easy surveillance monitoring of reservoir contribution over time.

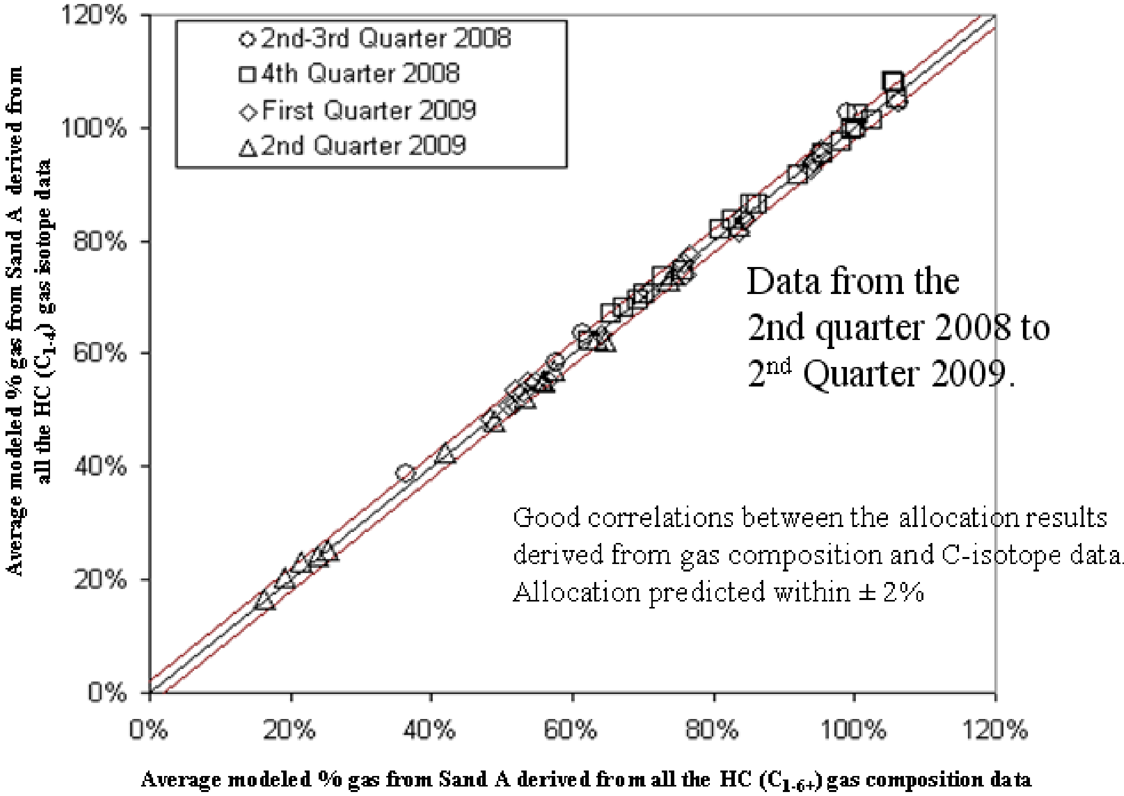

Figure 1. Comparison of production allocation (% gas from Sand A) results derived from gas composition and carbon isotope data for samples collected from the study area.

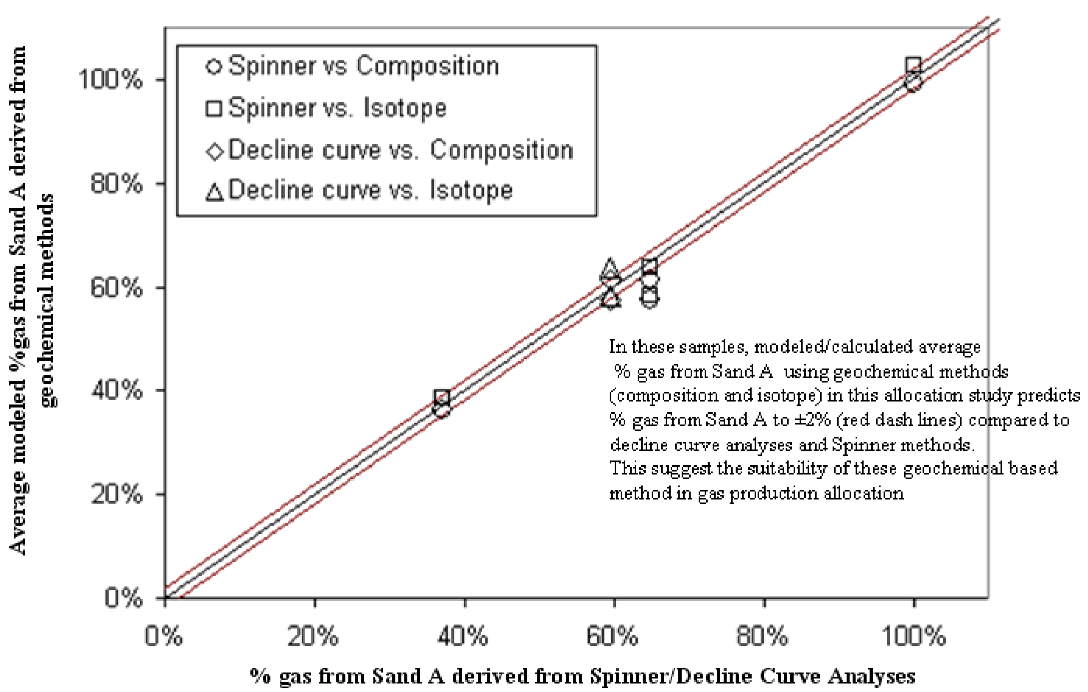

Figure 2. Comparison of allocation results derived from gas geochemical methods and other production allocation methods in the study area.