Petroleum Geology Conference and Exhibition 2008
14th – 15th January 2008 • Kuala Lumpur Convention Center, Kuala Lumpur, Malaysia

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ADVANCED MUD GAS LOGGING TECHNOLOGY: APPLICATION FOR FLUID IDENTIFICATION AND CHARACTERISATION, OFFSHORE SARAWAK, MALAYSIA

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Conventional mud gas data has been available for a long time from mudlogging operations. For several reasons, it has been under-utilised for fluid characterisation, although still acquired routinely in the drilling of oil and gas wells. However, the introduction of some advanced mud gas logging methods like FLAIR (Fluid Logging and Analysis in Real-Time) by Geoservices have made near real-time geochemical analysis of mud gas data possible. Advanced mud gas logging is also referred as Gas While Drilling (GWD) in some literature.

This article will describe how such mud gas data are utilised to identify and characterise different fluid types encountered by wells drilled in Shell operations. Two wells drilled offshore Sarawak in 2006-2007 are presented as examples (see Figure 1). The first example is an appraisal well while the second is a development well. The appraisal well was drilled to appraise the stacked sand reservoirs of Late Miocene age within the Baram Delta Province while the development well was drilled to produce gas from a sour (high H2S and CO2) carbonate reservoir in the eastern part of Central Luconia Province.

Corrected FLAIR data are analysed in-house by Shell geochemists in a data analysis package called Spotfire DecisionSite. Typically, n-alkanes (C1, C2, C3, iC4, nC4, iC5, nC5, nC6, nC7), aromatics (benzene, C6H6 and toluene, C7H8) and cyclo-hexane (methylcyclohexane) components are measured. The geochemist has to be aware of the type of drilling mud used to identify possible contamination from hydrocarbons from the mud itself. In the development well example, a pilot attempt was also carried out to measure mercaptanes to indirectly detect H2S in the carbonate reservoir. The mercaptanes measured were methyl mercaptane (CH4S), ethyl mercaptane (C2H6S), and propyl mercaptane (C3H8S).

Data interpretation is carried out by plotting various geochemical cross-plots and depth plots (see Figure 2). Hydrocarbon zones are identified by certain methane (C1) cut-off values, usually at 10,000 ppm. Hydrocarbon and water-bearing zones clearly show different trends on C1/C2 vs. C1/C2+ plots. Oil-bearing zones have relatively higher toluene/nC7 and methylcyclohexane/nC7 ratios compared to gas-bearing intervals. Biodegraded oil can be identified where sudden increases or spikes in iC5/nC5 ratios are observed; bacteria preferably consume the normal alkanes first (nC5), thus the sudden increase in this ratio.

A very useful geochemical plot that we created from our Sarawak experience is the log balance vs. log wetness plot (see Figure 3). Plotted on logarithmic scales for both axes, this plot would enable the different fluid types (dry gas, wet gas, oil, biodegraded oil or water) to be distinguished when properly calibrated. This plot is first applied in Sarawak as the conventional wetness-balance cross-over plot used in the Gulf of Mexico is not locally applicable.

In the case of the appraisal well example, the analysis of the mud gas data using methods described earlier helped the asset team pick fluid sampling points of different fluid types in various intervals. Several fluid types were identified from the mud gas data; wet gas/condensates, oil, biodegraded oil and water. Gradational changes in fluid character can be clearly observed in the various plots. Good data was also obtained within the cored intervals. It was later revealed that 4 out of 4 the fluid types interpreted from the mud gas data match the PVT analysis results.

In the development well example, the pilot attempt to measure mercaptanes (to indirectly measure H_2S) and CO_2 failed due to the use of H^2S scavengers in the drilling mud. However, ratios of the heavier to lighter n-alkane components decrease with increasing H_2S levels (see Figure 4). These ratios include (C4+C5+C6)/(C1+C2+C3) and (C2+C3+C4+C5+C6/C1). This is probably because H_2S preferentially reacts with heavier n-alkanes first, thus lower heavier n-alkane/lighter n-alkane ratios are observed where H_2S is higher in concentration. This behaviour still needs further investigation, as more data is required to further validate this observation. The mud gas data, together with LWD data can also be used to identify possible baffles/tight zones within the carbonate reservoir.

In summary, advanced mud gas logging has proven to be valuable as a first pass/initial fluid characterisation tool. Continuous fluid identification and characterisation from the mud gas data will provide up-to-date fluid data throughout the drilling operations up to target depth, and serve as a practical back-up when other fluid characterisation methods fail

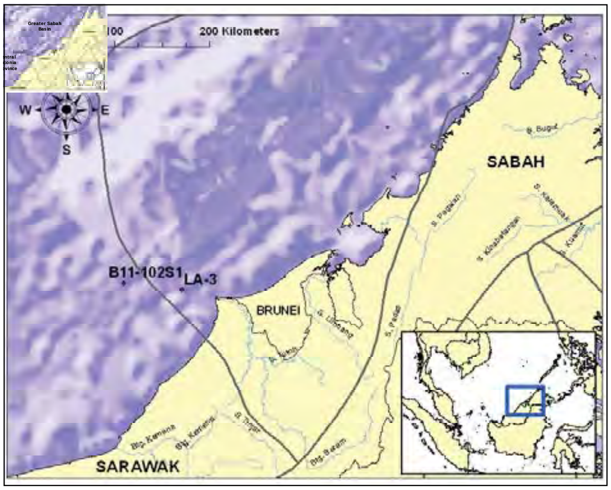

Figure 1: Location of the development and appraisal wells in Central Luconia and West Baram Delta Provinces (western part of the Greater Sabah Basin) respectively, offshore Sarawak, Malaysia.

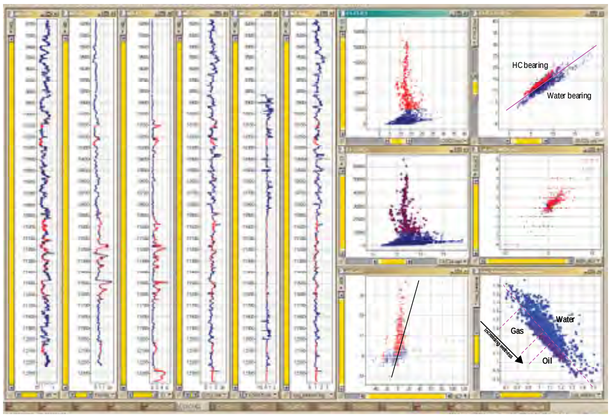

Figure 2: Mud gas data interpretation plots used by Shell geochemists. Analysis/interpretation is done in Spotfire.

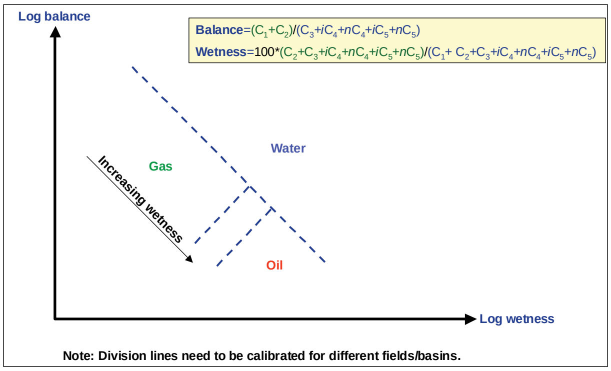

Figure 3: Log balance vs. log wetness plot used to aid the geochemist to distinguish different fluid types from mud gas data. The plot needs to be calibrated first before being applied to a particular well/field/basin.

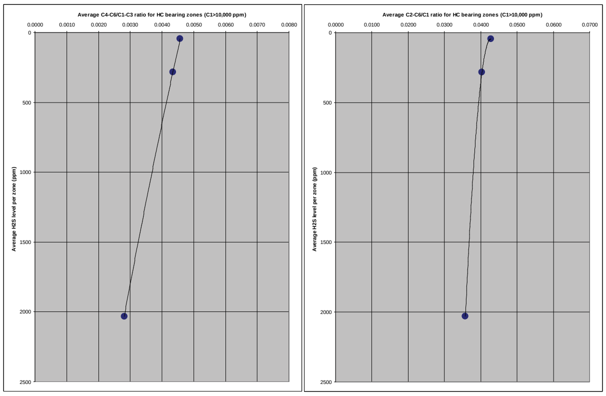

Figure 4: Changes in hydrocarbon ratios with increasing H2S levels in the reservoir.