Evaluation of Parameters Affecting Gas-in-Mud Quantification and their Use in Formation Evaluation Utilising Surface Gas Logging

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Introduction

Surface gas mud logging has long been overlooked as a critical real-time tool for accurate formation evaluation, despite the potential cost and operational benefits which could be derived. This is due to a perceived inability to yield reliable, quantitative data that truly reflects real gas-in-mud values and subsequently the reservoir fluids. However, recent developments in gas extraction technology have taken place that allows more quantitative gas-in-mud data to be generated[1].
The most recent advance in gas extraction at wellsite utilises diffusion of hydrocarbon and non-hydrocarbon gases across a semi-permeable membrane as its extraction technique (Figure 1). The less soluble a gas is within a given mud, the higher partial pressure that is exerted on the membrane leading to a higher rate of diffusion (Henry's law). Previous investigations have shown that extraction of gases from the drilling fluid across the membrane varies in relation to the properties of the drilling fluid, with fluid type and temperature being the most significant factors affecting gas solubility. In modelling the relationship between fluid type, temperature and the specific gas components it has been possible to obtain gas-in-mud values suitable for formation evaluation purposes in a wide variety of situations[2]. However, during the drilling of a well the mud system is subject to many other changes that will influence the take up of gas within the system and the retention time therein. In order to provide improved quantification of the gas values present within the mud, further investigation into the relative importance of other mud rheology factors was deemed necessary. A test rig was constructed to investigate the effect of these fatctors on gas extraction across a semi-permeable membrane. In addition to a range of mud types, the mud rheology parameters investigated included temperature, flow, pH, oil/water ratio, viscosity and salinity.

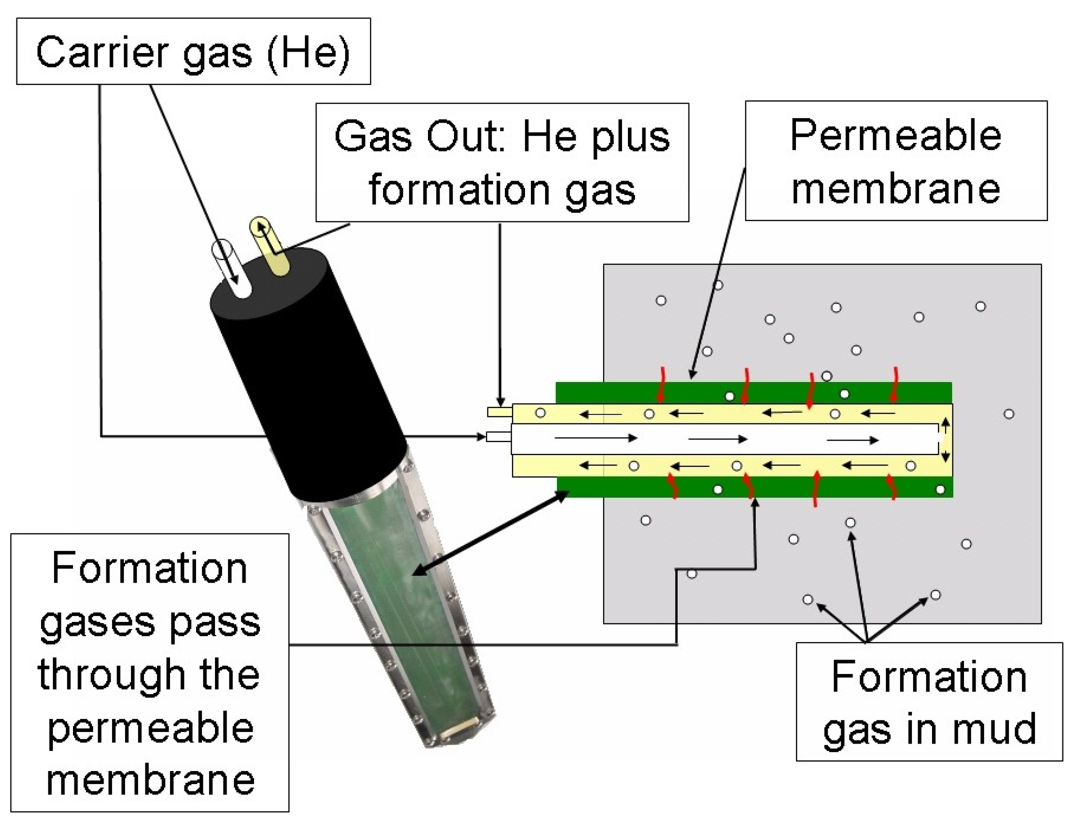

Figure 1: Gas dissolved in the drilling mud diffuses across a semi-permeable membrane, in accordance with Henry's law, and is transported to a gas chromatograph

Methods

A test rig consisting of 2" stainless steel pipe was constructed to circulate drilling fluids, into which known amounts of gas were injected (Figure 2). The semi-permeable membrane was attached to a probe and transported the gases to a gas chromatograph. Algorithms were constructed based on the relationship between the known amount of gas injected, the amount measured and the other properties of the drilling mud.
The test rig controlled the mud velocity and also the mud temperature. Other properties of the mud, e.g. pH, viscosity, were altered by the addition of additives to the drilling mud. Properties of the mud were measured in real-time by an array of sensors integrated into the test rig system.
A synthetic oil-based mud and a caesium-potassium formate were two of the muds tested. The gases tested were the alkanes C_1-C_8, the aromatics Benzene and Toluene, methylcyclohexane and the non-hydrocarbons CO_2, N_2 and SF_6.

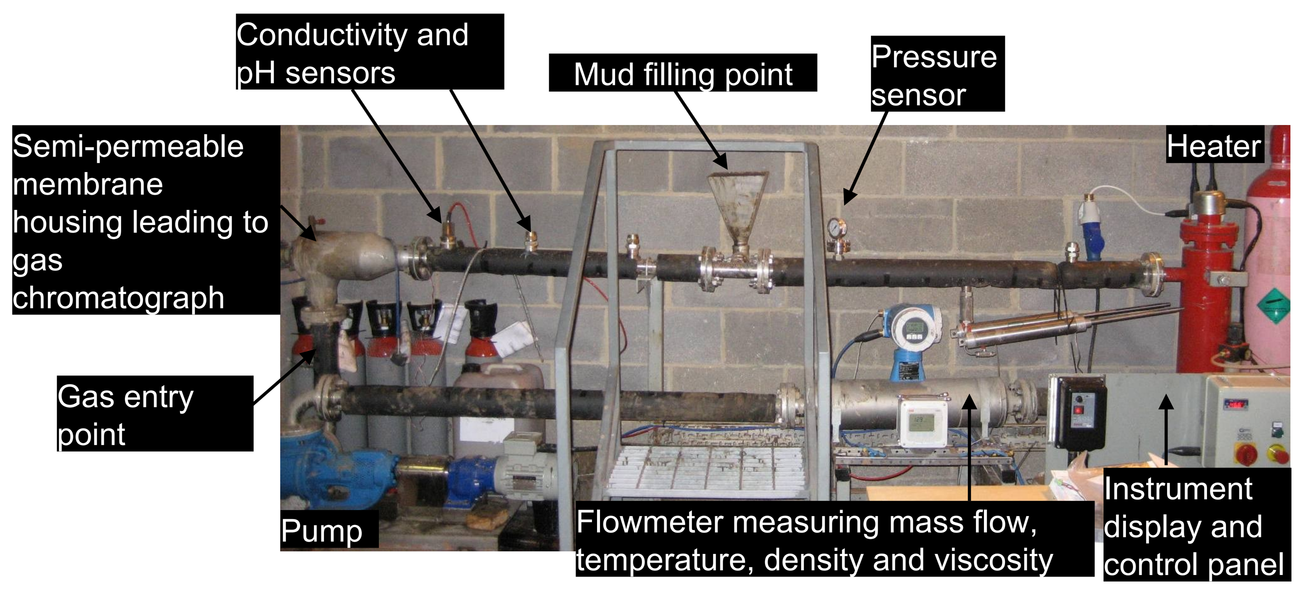

Figure 2: Test rig showing the various controls and sensors. The rig performance is monitored and slight modifications are made to the attachments/configuration to optimise performance and also as additional sensors are added.

Acknowledgements

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Results

In addition to gas concentration, the factors shown to have affected solubility/partial pressure include mud temperature, pressure and mud flow rate (Figure 3).
As gas concentration increases the chromatograph shows a positive linear response. For pressure and temperature the response is exponential. The flow rate relationship is more compex. In all instances, the less soluble gases, e.g. the lighter hydrocarbons, show a greater response for any given change in a parameter.

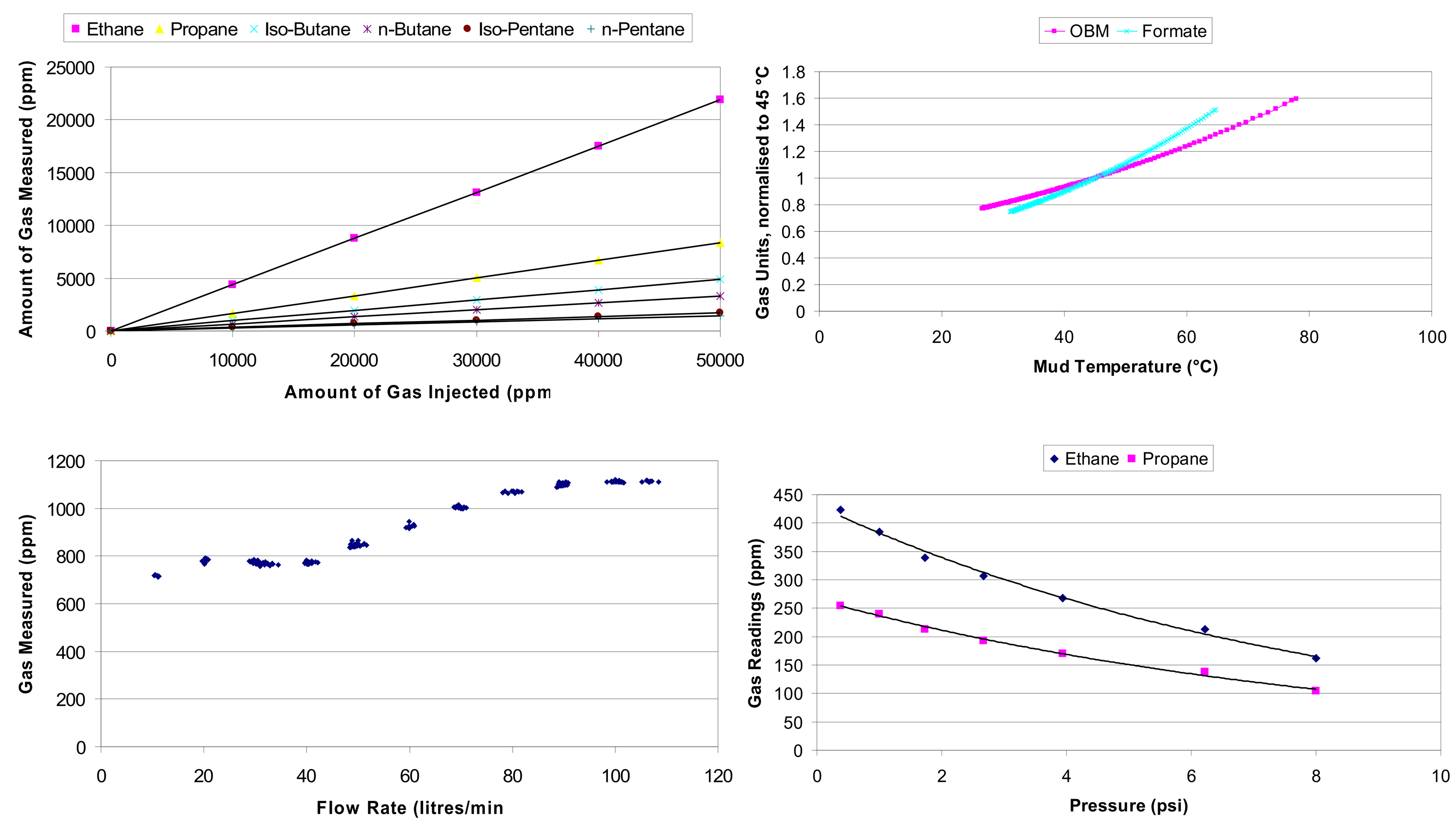

Figure 3: Test rig results showing the effect of various parameters on gas chromatograph readings. Clockwise from top left: effect of increasing concentration; effect of temperature on methane for two different mud types; effect of pressure; effect of flow rate on methane readings.

Field Trial

The results obtained from the test rig allowed the resulting algorithms to be tested in a well with a high flow regime in a close flow line. The presence of high amounts of gas resulted in free-phase gas within the flow line. The gas chromatograph results obtained via the semi-permeable membrane were re-calculated to account for mud velocity, temperature, pressure and mud type, The unmodified and modified data are presented below (Figure 4).

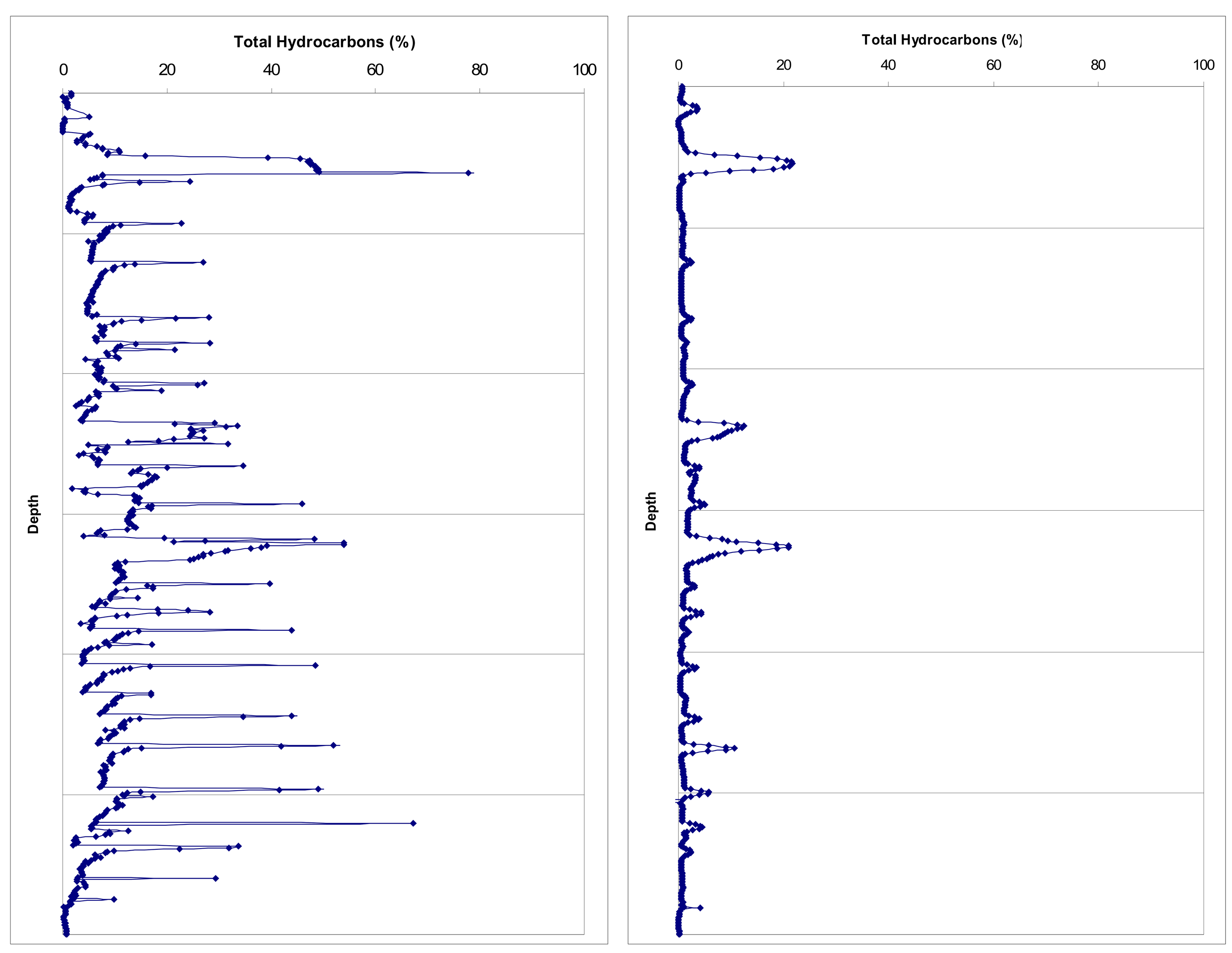

Figure 4: Total hydrocarbon volumes obtained from a semi-permeable membrane. Results on the left are the unmodified gas chromatograph results; those on the right are the re-calculated values accounting for flow rate, temperature, pressure and mud type. Initial feedback suggest that the latter results are more representative of the actual formation conditions.

Conclusions

A number of factors – including gas concentration, temperature, pressure, flow rate – are shown to affect gas solubility and therefore extraction of gases across a semi-permeable membrane. Through quantification of these relationships it is possible to produce results which can be used, in a quantitative manner, for formation evaluation purposes.
Work is currently continuing to quantify the effect of other mud properties on gas solubility for a range of different mud types.

References

[1] Brumboiu, A.O., Hawker, D.P. (2000) SPE 62525, West. Reg. Meeting June 19-23, 2000.
[2] Pinna, G. N. & Law, D. J. (2008). SPWLA 49th Annual Symposium, May 25-28, 2008.