



## *Horizontal Wells Geosteering and Fluid Characterization by Using Gas Ratio Analysis - A New Approach to minimize well cost in Development Fields.*

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### **Keywords**

Wetness Ratio, Balance Ratio, Character Ratio, Geosteering, Horizontal well.

### **Summary**

The gas chromatography ratios using high speed chromatograph are most applicable to fluid type identification in real-time analysis. These ratios are calculated and plotted in real-time to provide an immediate input of the formation fluid characters while drilling. The values, relationships and separation of these ratio curves are used to determine the hydrocarbon fluid type, relative changes in oil gravity, gas wetness as well as the actual gas/oil and oil/water contacts. The comparison of relative concentrations of the various hydrocarbon species seen in a chromatograph has diagnostic value in estimating the quality of a hydrocarbon reservoir. The data obtained from gas ratio analysis is also useful in stratigraphic correlation using distinct characteristic of hydrocarbons to identify the reservoir boundaries, even when no lithological facies boundary is evident.

The established fluid contacts and the results of gas ratio analysis can be used as an added tool while geosteering to decide the well placement and reduce the well cost drastically by avoiding the Logging While Drilling (LWD) tools in a well known field for a field Development.

### **Introduction**

Using geosteering tools in marginal fields is always critical in view of its high costs incurred, which would improve the recovery of drilled well. Also, identifying various rock layers become difficult in area where formations are cyclic or have identical or similar lithology and log characteristics are similar above & below the zone of interest. To delineate such layers by normal LWD tools for geosteering is a very challenging task.

Every location planned to be drilled are unique; therefore tools, techniques or combinations of tools are designed considering the field's requirements. Sometimes, budgetary considerations become very critical for the fields where return rate is marginal by drilling horizontal wells. Under such circumstances, even using standard geosteering tools become constrains for operator. Hence, cost can be optimized and reservoir productivity can be significantly

increased by drilling long horizontal sections through such reservoir zones by using gas ratio analysis method in known field.

Steering a horizontal well requires identification of lithological changes, reservoir contacts, type of fluid and reservoir quality that can be identified by deploying various Logging While Drilling (LWD) tools. Moreover, drilling a well horizontally in zones having similar lithology, fossils and log responses in layers above and below always warrant to deploy advanced LWD tools, including imaging tools to geosteering the well which will further increase the total cost. The use of LWD tools increases overall well costs, which may not be very lucrative in terms of overall return.

Chromatographic gas ratios analysis obtained from high speed chromatograph provides excellent information regarding fluid type and fluid contacts. Using these data can be viable solution to optimally place the wells in identified zones.

These requirements can be achieved through advanced mud logging techniques by applying detailed analysis of gas ratio analysis, lithological data and ROP.

### **Methodology**

Mud logging companies like Geoservices, Weatherford and Baker Hughes have their advanced gas chromatograph, high speed gas chromatograph – mass spectrometers analyzer or gas systems like FLAIR, GC TRACER etc need to be deployed for recording gas with better accuracy (Fig-1). These Systems Analyzed HC extracted from drilling mud are continuously obtain a quantitative evaluation of component gases C1-C5 and also providing qualitative information on heavier components C6-C8. The recorded gas data is calibrated and corrected for recycle gas, background gas, connection gas and trip gas.

There are different means of using component gases with various algorithms to plot triangular and rectangular diagrams to understand the formation fluid response but the gas ratio analysis method stated below is best for identification of fluid types and fluid contacts.

## Horizontal Wells Geosteering and Fluid Characterization by Using Gas Ratio Analysis

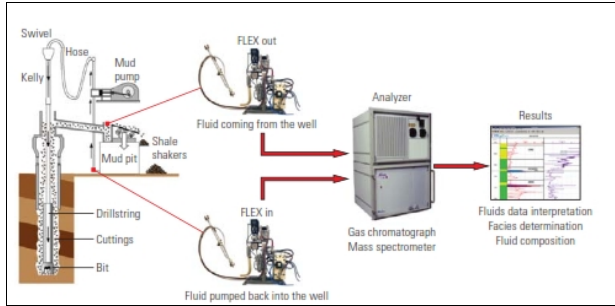


Fig-1: Advance high speed Gas Chromatograph- FLAIR Analysis System (Oil field review-2012)

The high speed chromatography panel deployed in Mudlogging unit provides the necessary depth resolution and accurate gas data. The recorded gas data is used to calculate gas ratios as follows.

**Wetness Ratio (Wh) =**

$$\left[ \frac{(C2+C3+C4+C5)}{(C1+C2+C3+C4+C5)} \right] \times 100$$

The wetness ratio shows an increasing trend as gas and oil density increases, i.e. as the amount of heavy gas components increase proportionally against the lighter gases.

**Balance Ratio (Bh) =  $\left[ \frac{(C1+C2)}{(C3+C4+C5)} \right]$**

The balance ratio is a direct comparison of light to heavy hydrocarbons for interpretative purposes; the balance ratio is used together with the wetness ratio. If the balance ratio is greater than the wetness ratio, the accumulated of gas is being predicted. The closer of wetness ratio and balance ratio curves indicates the presence of dense gas and more likely to be produced.

**Character Ratio Ch =  $\frac{(C4+C5)}{C3}$**

The character ratio confirms whether a gas prediction is indeed a gas zone or whether the gas is associated with oil. The significance of comparing these three compounds is that C3 will typically be more predominant in a gas reservoir with lower amounts of C4/C5. All the heavier components will increase as the fluid density increases where C4 and C5 will increase proportionally in case of light oils. In addition to this C1, C2, C3, and C4 ratios are also useful for identification of pay zones and fluid types

### Case Study

The study area fall within Tarapur tectonic block of Cambay Basin, Gujarat, India (Fig-2). The regional litho facies analysis indicates the development of clastic reservoirs at Paleocene, Middle Eocene, Late Eocene, Oligocene and Miocene levels. The Eocene and Oligocene sands are good producers of oil and gas for the past three decades. The Kalol formation was deposited conformably over the Cambay shale in Middle Eocene having

gross thickness 90-120 m with 20-30m net of reservoir. The Kalol reservoir displays an overall regressive -transgressive - regressive nature; the regressive depositional system is comprised of sandstones, siltstones, carbonaceous shales, shales and coals. The case study well was drilled to encounter prospective reservoir targeted at structure top of Kalol formation.

A vertical well in a study area drilled up to 1940m was terminated in Cambay shale formation. The reservoir encountered is divided into units by a thin layer of shale section, which was tested conventionally produced considerable amount of oil and gas. In order to increase the production, all the data obtained from wells were reviewed and considering the zones lateral continuity on seismic (Fig-4) it was planned to drill the reservoir horizontally under the best exploitation strategy.

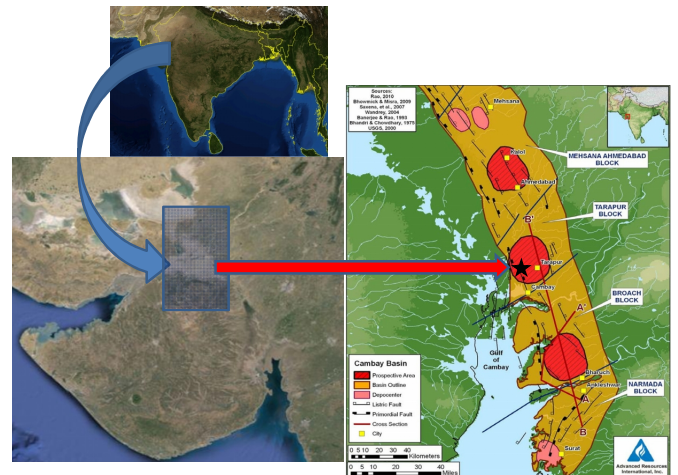


Fig-2: Tectonic Blocks and Location Map of Study Area

Considering the similarities in cuttings and log response between upper and lower reservoir, the cost of geosteering for using advanced LWD tools to identify the fluid types, fluid contacts and the numbers of well required be drilled to exploit this reservoir optimally, it become a very challenging task to define the most economical way out.

Considering the above said limitations, it was decided that gas ratio analysis method is the most suitable one to address all these problems.

While drilling, gas trap is usually located near the entrance of the flow line on the shale shaker. The drilling fluid carries gas from well bore to shale shaker along with formation fluids and drill cuttings which are analyzed in Mud logging unit. The gas traps agitate the drilling fluid in an enclosed space, thereby releasing the gas from the drilling fluid, which is then extracted, by vacuum, from the enclosed space. All these data are being recorded in mud logging unit and analyzed thoroughly in real-time. The Gas panel

## Horizontal Wells Geosteering and Fluid Characterization by Using Gas Ratio Analysis

is calibrated for all contaminated gas such as mud additive gas, trip gas, connection gas and recycled gas etc. The pay zone intervals were identified based on gas ratio analysis encountered in the interval 1630-1666m MD matched with the zones identified from wire line logs. The total gas (TG) and component gas (C1-nC4) observed in pay zone during drilling are given in Table-1.

A detailed gas analysis of Chart-1, the Wetness, Balance and Character Ratios in the Study Well, the wetness ratio is greater than 17.5, less than 40 and Balance ratio is less than Wetness ratio is indicating productive oil bearing zone. The Gas Oil Contact (GOC) was established at 1630.5m MD and Residual Oil Contact at 1657m MD (Fig-4 & Table-1) respectively.

Depth	C1	C2	C3	IC4	NC4	WH Ratio	Bh Ratio	Ch Ratio
	ppm	ppm	ppm	ppm	ppm			
1628	11200	500	300	150	0	7.818	26	0.5
1629	130500	10200	500	300	150	7.871	28	0.9
1630	18800	2800	1400	800	400	22.314	8.30	0.85
1631	228000	33800	16900	5100	0	19.661	11.9	0.3
1632	292400	44400	22200	7400	3600	20.972	10.14	0.495
1633	108200	17100	8500	2800	1400	21.594	9.866	0.49
1634	96400	15200	7600	2500	1300	21.626	9.78	0.5
1635	98700	45600	7800	2600	1300	36.73	12.33	0.5
1636	100400	15900	7900	2600	1300	21.623	9.85	0.49
1637	98300	15500	7800	2600	1300	21.673	9.72	0.5
1638	118000	18600	9300	3100	1500	21.594	9.82	0.49
1639	114100	18000	9000	3000	1500	21.634	9.78	0.5
1640	116500	18400	9200	3100	1500	21.654	9.77	0.5

Table-1: The fluid characterization using the Wetness, Balance and Character Ratios in the Study Well, the green colour indicating the zone of interest, which shows  $17.5 < Wh < 40$  and  $BH < WH$ , result Oil bearing.

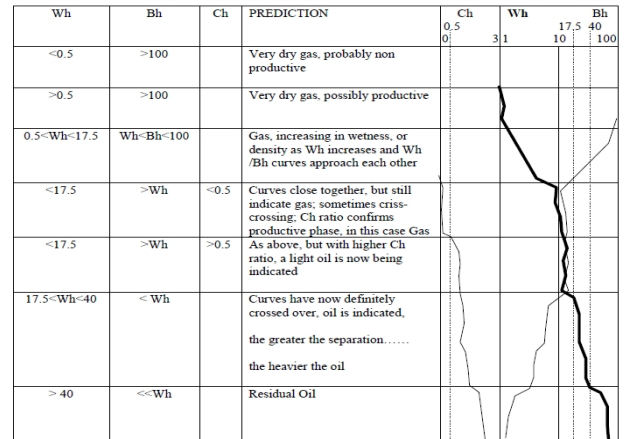


Chart-1: Chart of Guidelines to fluid characterization using the Wetness, Balance and Character Ratios (D.P.Hawker-1999).

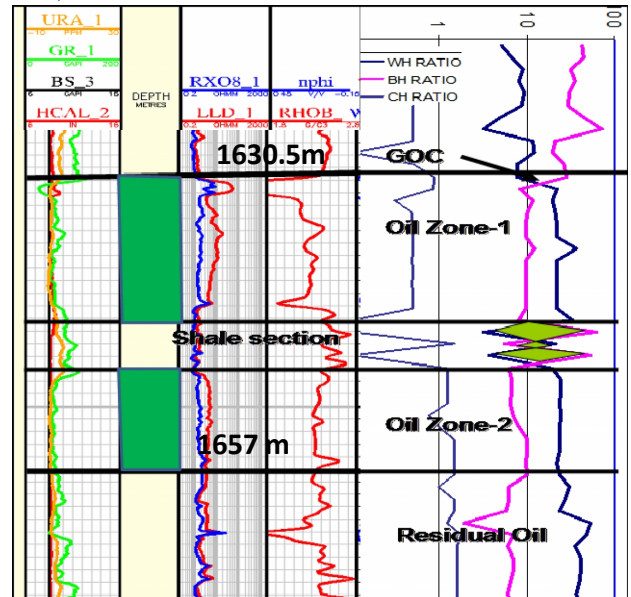


Fig-3: The results  $17.5 < Wh < 40$  and  $BH < WH$  is indicating Oil bearing. The GOC, Residual Oil Contact in pay zone.

The Wireline log response of the zones in study well having very similar characteristics that makes it very difficult to demarcate the fluid contacts based on log response. Further, very close proximity and great lithological resemblances between the reservoir and non reservoir zones make it difficult to precisely identify that whether drilling is on in upper or lower zone (Fig-3).

## Horizontal Wells Geosteering and Fluid Characterization by Using Gas Ratio Analysis

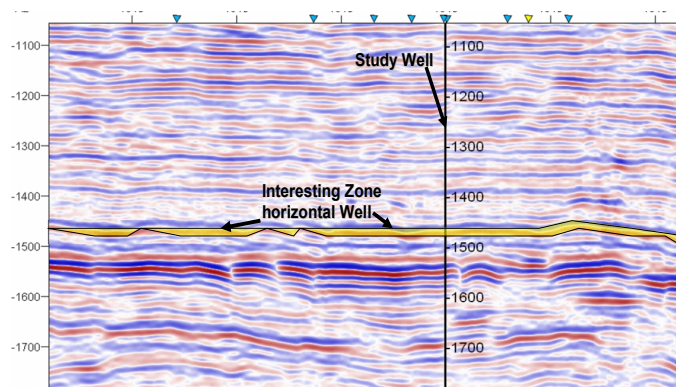


Fig-4: Seismic section showing continuity of Zone of Interest

Considering such a close lithological and Wireline log resemblances between zones vis-à-vis LWD tools cost, it is planned to geosteer the next well horizontally by using Gas Ratio Analysis method. As per gas ratio analysis, horizontal drilling was planned in two different layers viz. 1632-1642m MD and 1646-1657m MD (Fig-3,4 & Table-1).

### Limitation:

In order to geosteering the well using gas ratio analysis method, the basic requirement will be advanced mud logging unit having a high speed chromatograph and real time data transmission to take necessary corrective actions immediately in real-time while geosteering the wells.

### Conclusion:

In most of the cases gas ratio analysis can be used to identify hydrocarbon pay zone, fluid type, and fluid contacts. This analysis will help in geosteering the wells to maximizing production of reservoirs having limited thickness in a known field. The fluid contacts can be properly established using gas ratio methodology which will help to controls the well path for geosteering purposes.(Fig-5).

Even in zones having very identical lithological and Wireline characteristics which may not be possible to identify with normal LWD tools; thereby this technique is most effective in shallow development field wells and would requires effective calibration in deeper wells.

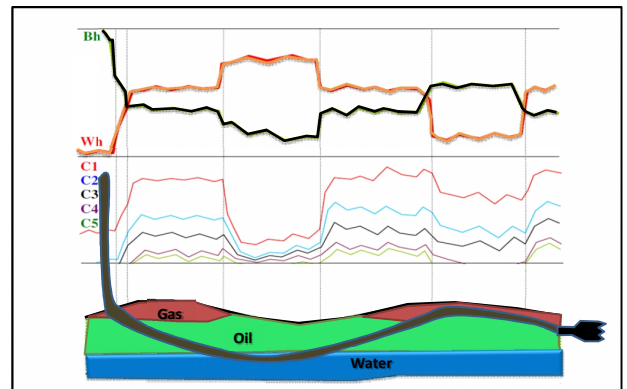


Fig-5: Schematic Diagram of Gas responses in different fluid contacts in a reservoir

### Acknowledgements:

The author wish to acknowledge Mr. Samir Biswal (Director-Exploration) and Mr. Satyesh Bhandari (GM – Exploration) for their able guidance and active support to materialize this technical paper. Authors also wish to acknowledge GSPC management for providing necessary facilities for preparing the manuscript.

### Abbreviations:

GOC	Gas oil Contact
MD	Measured Depth
OWC	Oil Water Contact
TG	Total Gas

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