# Identifying Opportunities and Reducing Uncertainty in Development of Bypassed Multilayer Reservoirs through Integrated Mass Spectrometry with Conventional Logs in Dina Terciario Field, Honda Group (La Victoria Formation), Upper Magdalena Basin, Colombia*

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Search and Discovery Article #20211 (2013)
Posted October 21, 2013

*Adapted from extended abstract prepared in conjunction with poster presentation at AAPG International Conference and Exhibition, Cartagena, Colombia, September 8-11, 2013, AAPG©2013

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## Abstract

This article illustrates how the first application in Columbia of innovative technology and principles of geoscience in situ techniques of mass spectrometry integrated with conventional logs can improve the reservoir development and optimize well completions, and identify gas, oil and water zones in multilayer reservoirs while drilling. We discuss the key principle of mass spectrometry (in which $C_1$-$C_5$ components show gas phases, $C_6$-$C_{10}$ components show liquid phases and benzene, hexane, cyclohexane and toluene help to identify water phases) and show that in combination with a petrophysical analysis from conventional logs (with a high uncertainty in water saturation, due to presence of fresh water) have the capability to identify very accurately gas (methane), oil (black oil) and water zones within the reservoir. The application of this principle is illustrated with a case study of northern Dina Terciario Field, operated by Ecopetrol S.A, which produces from a Tertiary structure with multilayer reservoirs, so far under-evaluated in the basin.

The field used for this study is the Dina Terciarios (DT) Field, which has 140 wells and is located in the Upper Magdalena Valley Basin, in the Neiva Sub-Basin, 15 kilometers to the north of the city of Neiva, next to the Neiva Highway that leads to Bogotá (Figure 1).

## Field Description

The DT Field is a structural trap formed by a 3-way closure anticline bounded on the east by a reverse fault (Baché Fault) and has eight different reservoirs (multilayer) (Figure 2). In the DT Field, the La Victoria Formation (Lower Honda Unit) is the main multilayer reservoir and each reservoir, with its own GOC and OWC, is called from base to top Th8, Th7, Th6, Th5, Th4, Th3 and Th2. This formation was deposited in a fluvial environment, based on sedimentologic and petrologic evidence. The lower sands “Areniscas Inferiores and Areniscas Intermedias” are a low gradient-high sinuosity system (Th8, Th7 and Th6 reservoirs) and the upper sand “Areniscas Superiores” is a high gradient-low sinuosity system (Th5, Th4, Th3 and Th2 reservoirs) (Figure 3). Both regimes developed during high volcanic activity resulting in red hematitic floodplain mudstones of montmorillonite, illite-montmorillonite and kaolinite, non-conglomeratic sub-arkosic to arkosic sandbodies.

This main structure has produced since 1963, and in 2010 a smaller anticline was identified three kilometers to the northeast of the main structure. This smaller structure was drilled by three wells in the early 1960’s with production of 80 BOPD each, but the wells were quickly abandoned. In 2011, Ecopetrol drilled three wells in the highest part of the smaller anticline which now have commercial production of oil and gas (130 BOPD each and DN-16 produces 800 KSCFT).

## Example

The conventional mud logging and wireline analysis of these new wells were showing poor potential for economic production of hydrocarbons. Gas chromatography data with conventional ratio analysis was indicating non-productive gas. Conventional logs showed high uncertainty in water saturation prediction. ADT log predicted residual oil saturation. Dipolar Sonic logs showed gas in the base of the formation. And pressure points displayed non-conclusive gradients.

Mass spectrometry was run at near DT Field wells Dina 14 ST and Dina 16 within the La Victoria Formation. The purpose of using mass spectrometry was to complement wireline logging due to presence of fresh water in the reservoir sections which makes petrophysical evaluation somewhat cumbersome in terms of water saturation prediction based on historical behavior of the Dina Terciarios Field.

A quadrupole mass spectrometer (FIT-dq1000) was deployed at the rig site for drilling of the above mentioned wells. This equipment is able to detect a wide range of chemical species, well beyond conventional gas chromatography ($C_1$ to $C_5$), from 1 to 140 AMU (atomic mass units), can detect paraffins ($C_1$ up to $C_{10}$), aromatics (benzene, ethyl benzene, toluene, xylene), naphthalenes, sulfur compounds ($H_2S$, $SO_2$, SO), noble gases (helium, argon), inorganic species (hydrogen, nitrogen, $CO_2$)), among others. Also, a FIT Gas Cannibal constant volume trap was used to improve quality of gas sampling from the possum belly to the gas analyzer. The equipment was set at the directional drilling cabin with a minor footprint and it was operated by one dedicated technician and data was broadcast real-time to Ecopetrol headquarters in Bogota for quality control and evaluation while drilling.

## Results and Conclusions

The results of this technique were encouraging since the data was able to predict fluid type compared later with downhole fluid testing and production. Moreover, data revealed that Honda TH7 has an exogenous and deeper charge of methane that is associated with the presence of helium. The helium anomaly was first seen during drilling of Dina 14ST well and later during Dina 16 which confirmed the anomaly.

Initial fluid prediction while drilling was oil in Th3 and Th5, oil and gas in Th6, and presence of gas in Th7 and Th8, which was corroborated with Dipole Sonic logging (Figure 4). Data revealed that Honda Th6, Th7 and Th8 have an exogenous charge of methane, probably from a deeper source migrating through fractures that are associated with the presence of helium.

The integration of the petrophysical analysis with the mass spectrometry gas data acquired while drilling permitted an easier identification of gas, oil and water zones (Figure 5). In addition to this tool, several bottom hole fluid samples were taken from the new wells and analyzed in the laboratory.

Results were compared with the spectrometry data obtained during drilling. The results showed that there is a relationship in terms of composition between the fluid samples and the mass spectrometry data, mainly for black oil and for methane.  In this case, the mass spectrometry data showed a good calibration to identify this type of hydrocarbon. The production of the wells shows that there are additional drilling opportunities. Based on reservoir engineering best practices, detailed reservoir studies and low cost and higher economic benefits, mass spectrometry is one of the innovative technologies available while drilling. It can help geologists and engineers in a quick and reliable identification of gas, oil and water zones in a reservoir.

## References Cited


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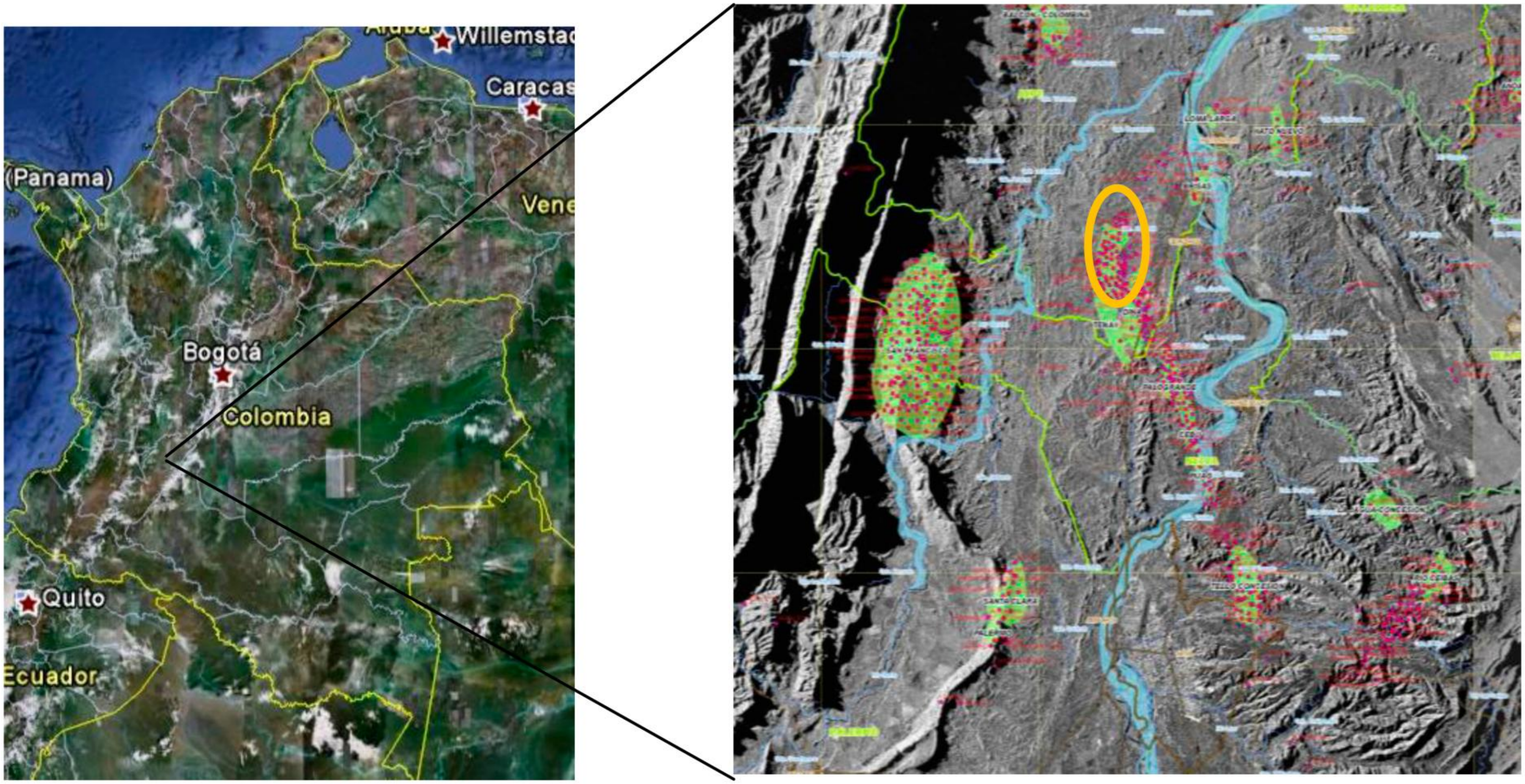



Figure 1. Location of Dina Terciarios Field. The yellow oval shows the location of the Dina Terciarios Field.

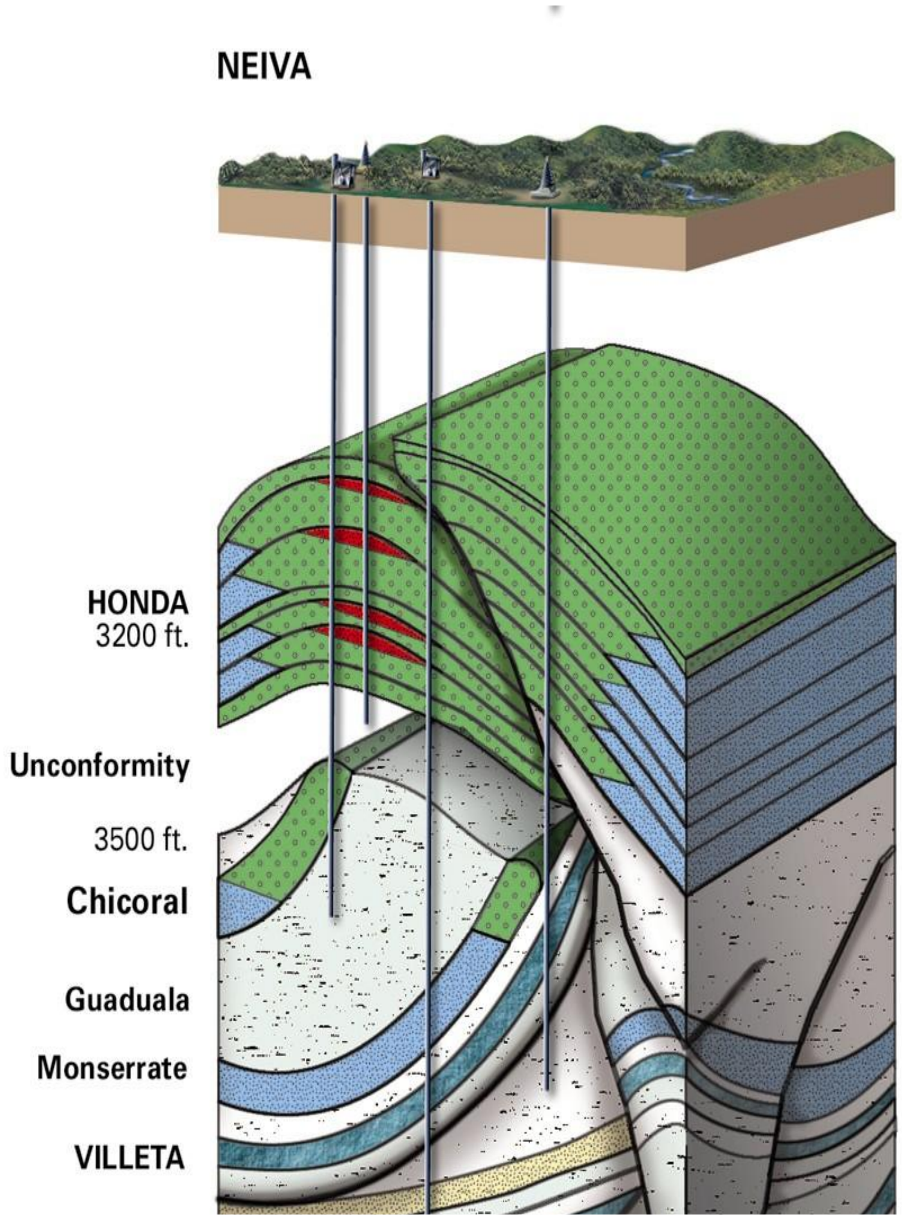



Figure 2. Schematic of the different producing formations from Honda in Dina Terciarios Field. Each layer has its own GWC and OWC (from Evaluacion Integrada de Yacimientos campo DT año, 2002).

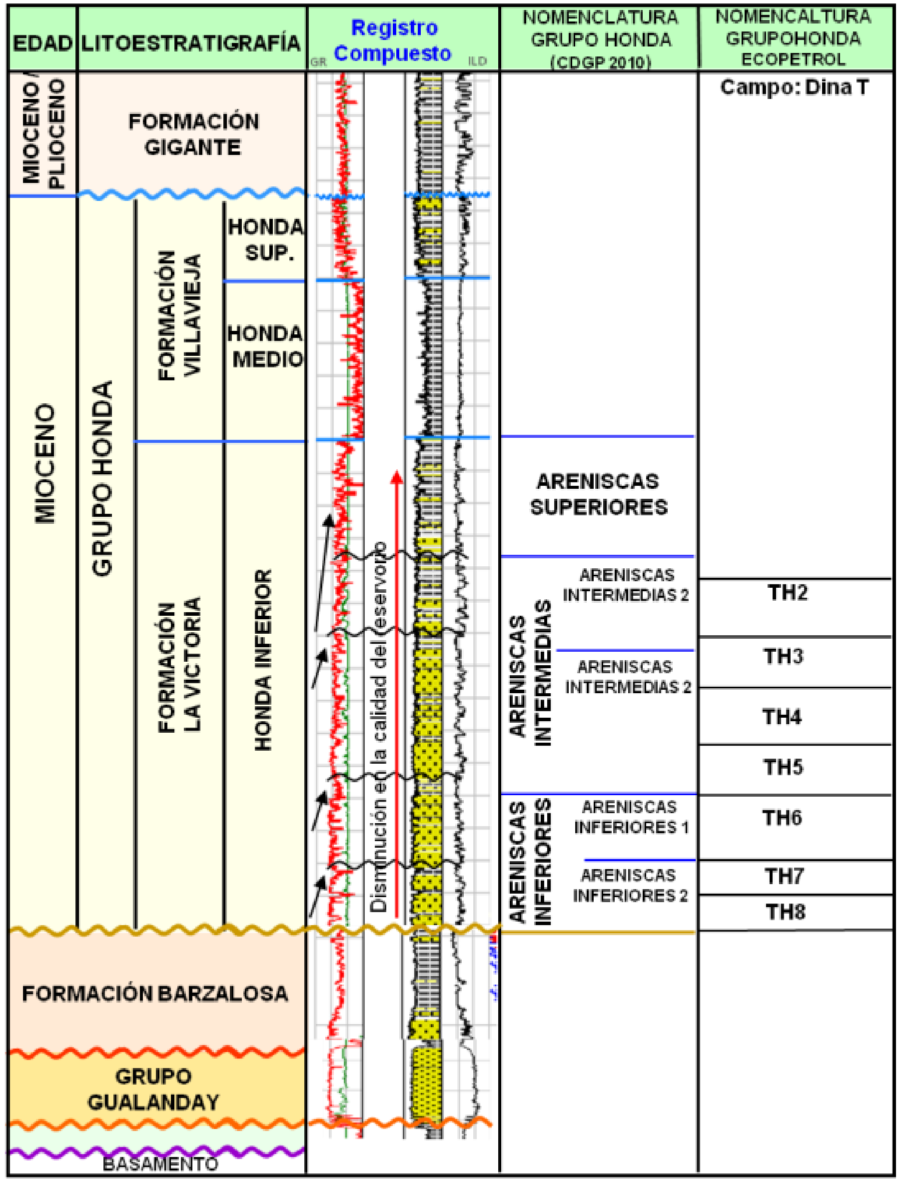



Figure 3. Stratigraphic column of Honda Group in Dina Terciarios Field (from Ecopetrol - CDGP Halliburton, December 2010).

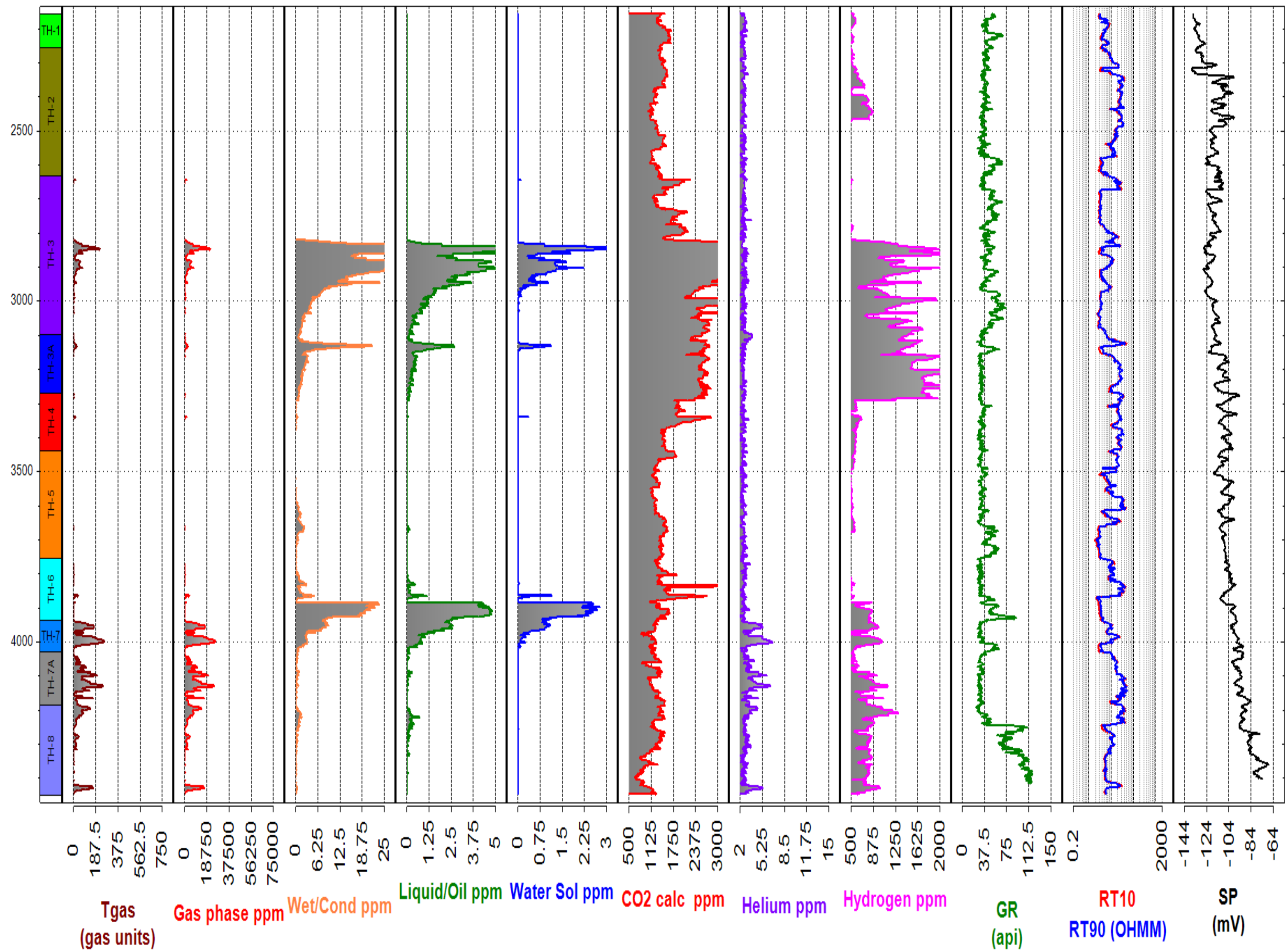
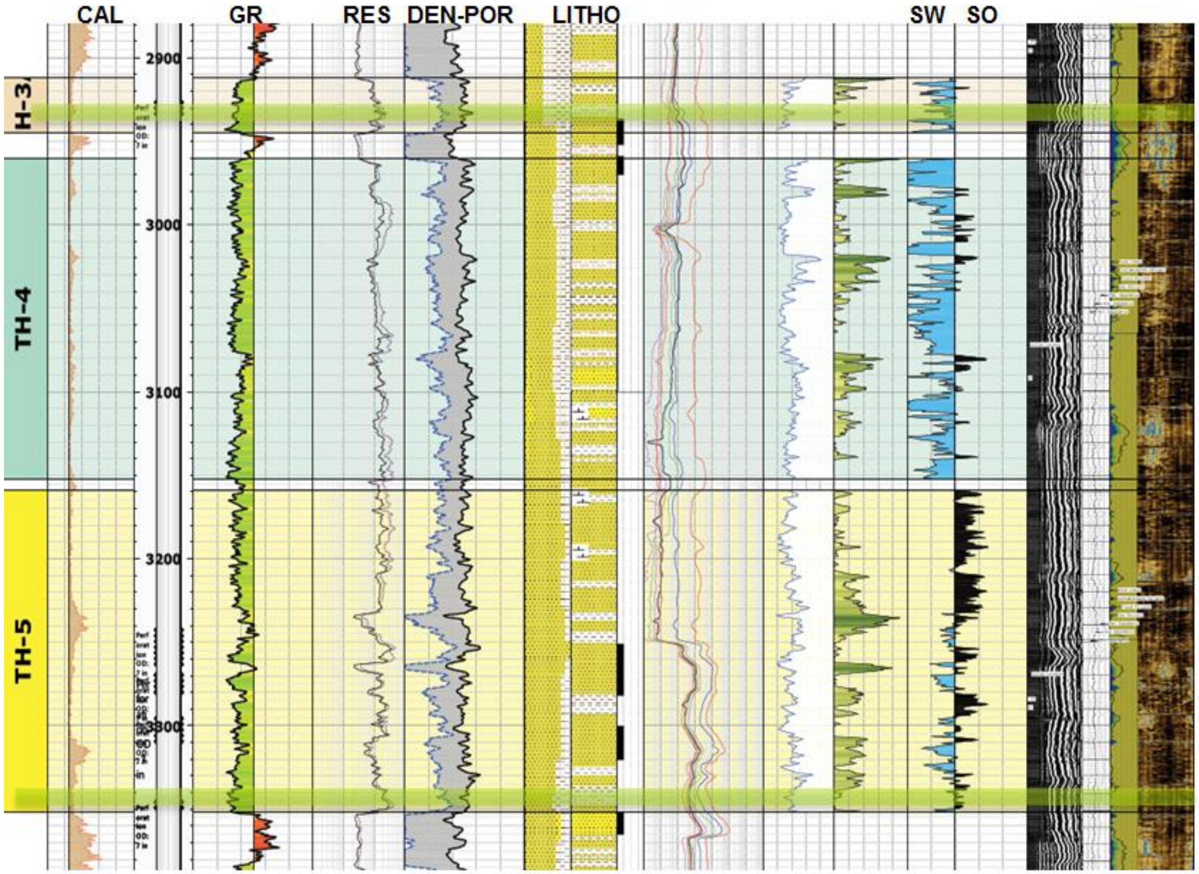



Figure 4. Common view of the mass spectrometry data adquired during drilling. The different colors on the left side show the eight different reservoirs. The blue ellipsoids show oil zones and the orange ellipsoid shows gas.




Intervalos Abiertos:
2925-2934 (9)

Intervalos Abiertos:
3344-3350 (6)
Prueba Swabbing
*23 hrs, 130 bls fluido de formación recuperado 5,5 bls/hr

22,9° API @ 92 °F, 2% BSW
*7560 PPM CL
*No se observa gas

*Se recuperan dos muestras de fondo Análisis PVT.

| Tope (pies MD) | Base (pies MD) | Espesor (pies MD) | UNIDAD | Densidad TPP | Diametro | TIPO | Fase | COMENTARIOS |
|---|---|---|---|---|---|---|---|---|
| 3344 | 3350 | 6 | TH-5 | 6 | 4 5/8" | BIGHOLE | 60° | Antes de Fractura |
| 2925 | 2934 | 9 | TH-3A | 6 | 4 5/8" | BIGHOLE | 60° | Antes de Fractura |

Figure 5. Petrophysical analysis from Dn-14ST well showing the intervals tested. The shallower interval opened in Th3a shows water in the petrophysical analysis but produced oil during swabbing (2.5 bls/hr) The deeper interval opened in Th5 showed poor oil concentration in the petrophysical analysis, but during swabbing produced oil (5.5 bls/hr).