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Application of Real Time Isotope Logging for Reservoir Evaluation in Central Luconia Province

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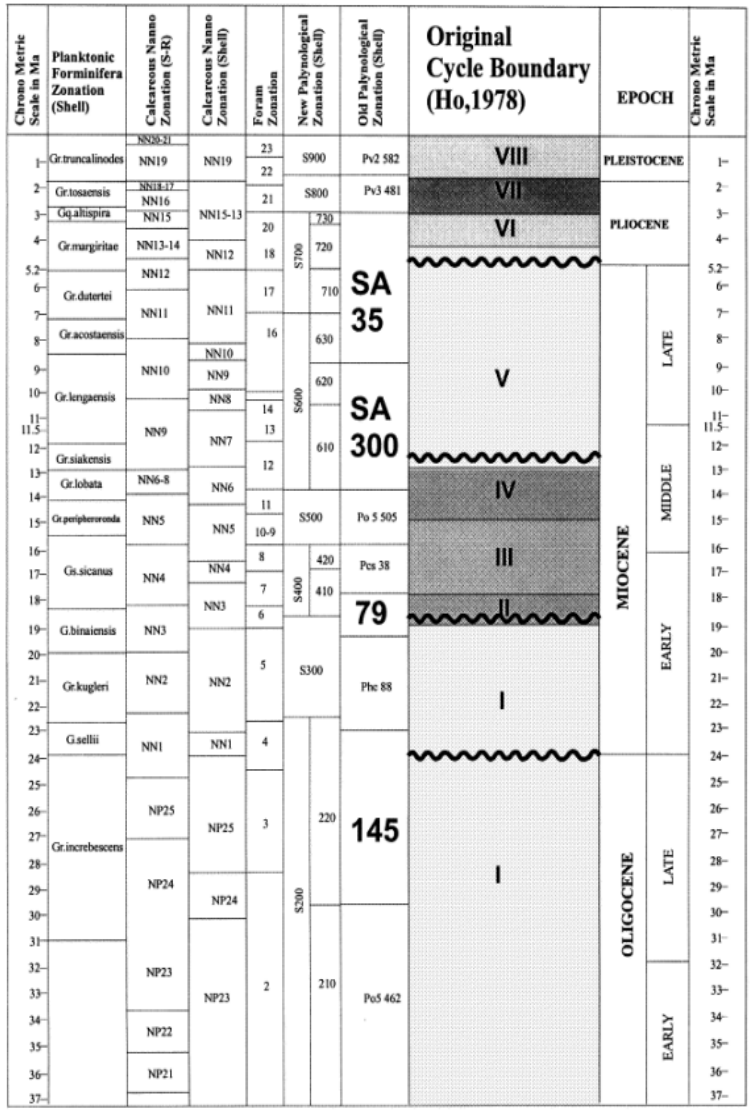
Introduction

- **Central Luconia** is an **important geological province** located **offshore Sarawak**. The main characteristic geologic feature of the Central Luconia province are **reefs and carbonate** build-ups of the **Miocene to recent age**,

- **Cycle V** is known for its **hydrocarbon potential** and pool of gas prone carbonate build.

- The **dominant lithology** of the **carbonate rocks** are mainly **limestone and dolomite**, and these carbonate buildups have high **porosity** some even in excess of **30%**.

- **Column heights** in the field appear to be **controlled** by **several mechanisms**
  - **Charge access** (migration focus),
  - **Aquifer overpressure**
  - **Top seal competency**
  - **Thief zones** interbedded with sealing lithologies.



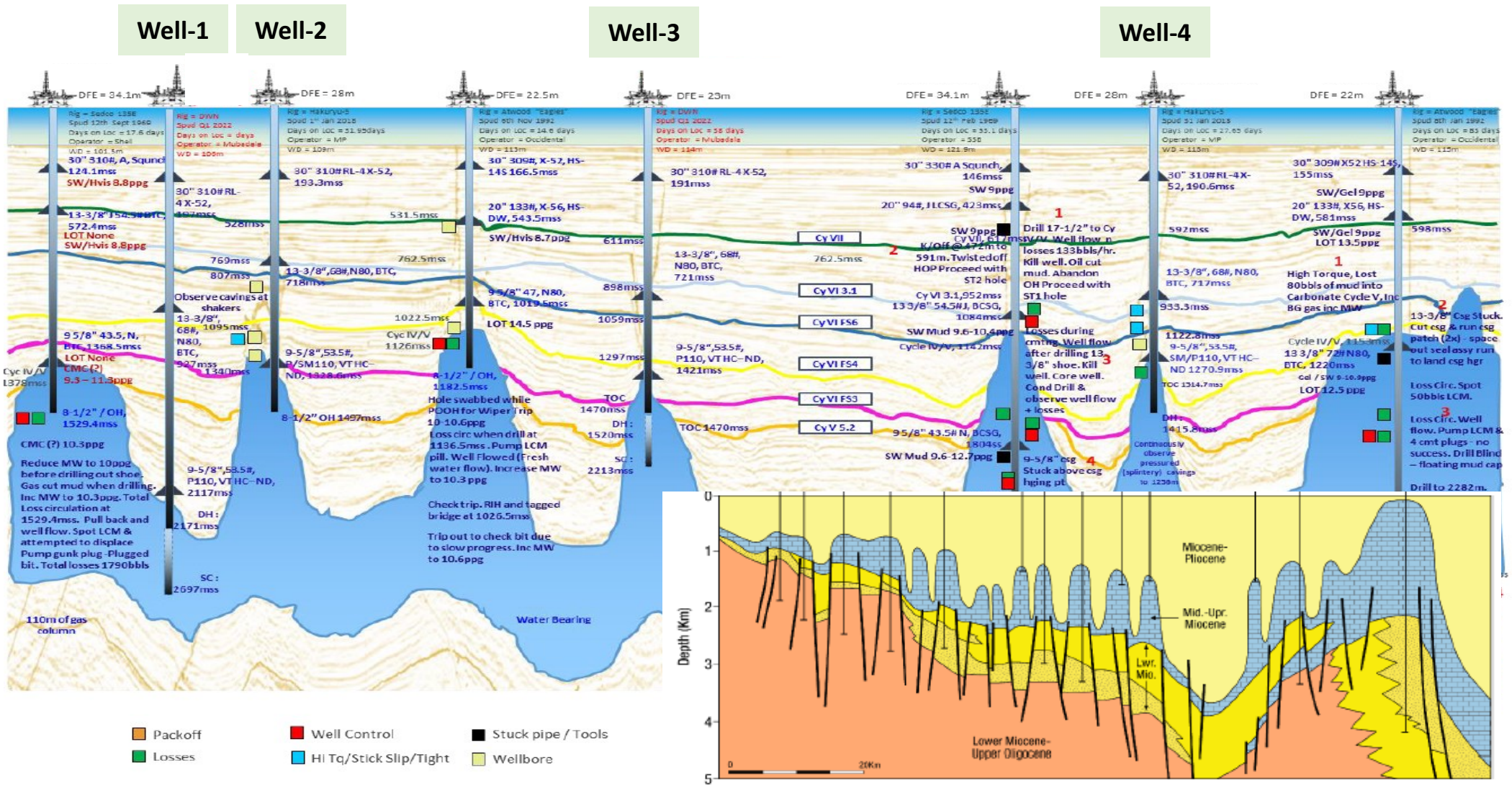
Introduction

- In this study, we propose a **quasi-real-time approach at wellsite** as an alternative to standard Isotubes collection and laboratory analysis, with an **overall gain in terms of response timings and data density**.

A continuous real time isotope

- **Methane isotopes easily distinguish** between **biogenic** and **thermogenic gas**,
- **Degree of mixing**, which is extremely useful in establishing whether **migrating gas has infiltrated the overburden**, and to which **stratigraphic level**.
- Profile through overburden would greatly assist in **differentiating general seal failure due to overpressure**, from **discrete thief beds or absence of thermogenic charge**, in the event of a **dry hole**.
- **High sampling density** , resulting in **very high-resolution isotope log**.
- **Reliable measurements** need **minimum** of hundreds of ppm **HC's**.

Location of Wells



The main **objective** targets are **carbonate pinnacles of Middle-Late Miocene Cycle IV/V** in age.

Gas system configuration - Workflow

MUD GAS EXTRACTION - OUT

Constant Volume Degasser (CVD) OUT

Constant mud Flow
+
Constant sample flow =

Consistent mud gas readings

Gas Distribution System (GDS) -OUT

ARK

TGD - OUT

TOTAL Gas Detector

G5 Service (C_1-C_5) OUT

High Resolution Gas chromatograph C_1-C_5

Geo-Isotope (C1,C2, C3 & CO2)

High Resolution Isotope Analyzer C1,C2, C3 & CO2

MUD GAS OUT DETECTION in MLU

Gas Distribution System (GDS)- IN

TGD - IN

TOTAL Gas Detector

G5 Service (C_1-C_5) IN

High Resolution Gas chromatograph C_1-C_5

MUD GAS IN DETECTION in MLU

MUD GAS EXTRACTION - IN

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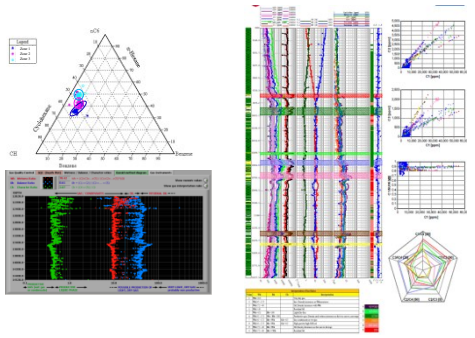
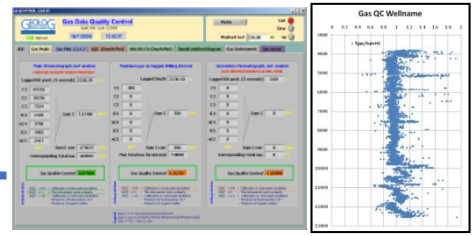
QC and Advanced Fluid Interpretation



Advanced formation fluid interpretation



Rigorous Data QC

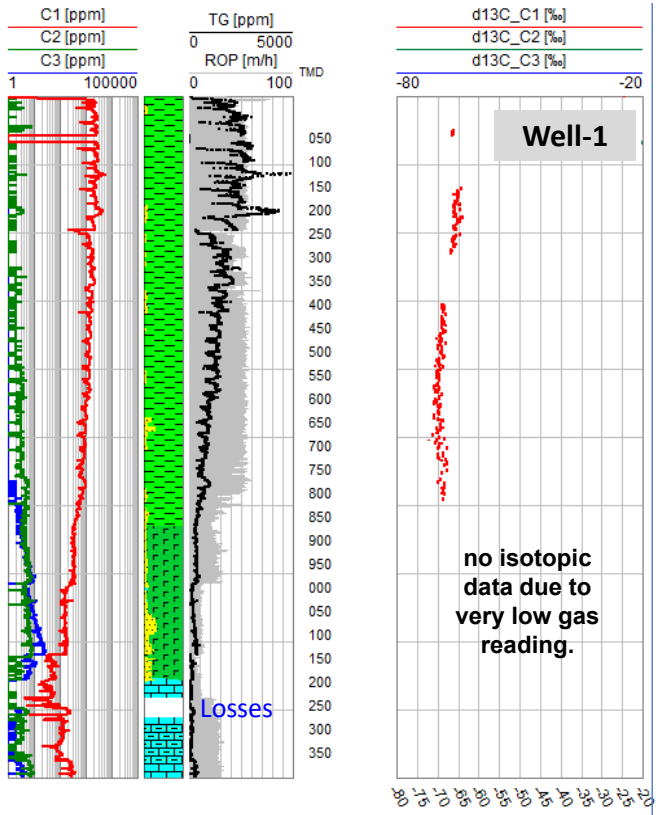
GeoIsotopes Generalities

- Capable of measuring the isotopic ratios (**$^{13}C/^{12}C$**) of Methane, Ethane and Propane. The output is the isotopic ratio compared with the VPDB standard:

$$\delta^{13}C = \left(\frac{\frac{^{13}C_{Sample}}{^{12}C_{Sample}} - \frac{^{13}C_{Standard}}{^{12}C_{Standard}}}{\frac{^{13}C_{Standard}}{^{12}C_{Standard}}} \right) \times 1000‰$$

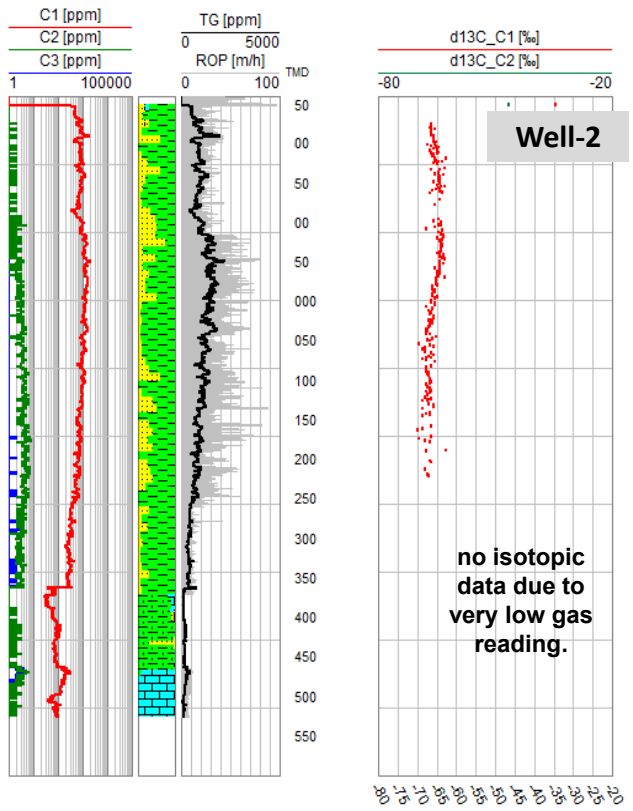
- Two different configurations:
  - C1 and C2 isotopic ratios
  - C1, C2, and C3 isotopic ratios
- Three modules:
  - **IsoChromatograph**
  - **Isotopic Oxidator**
  - **Isotopic Spectrometer**

Isotope Log wells



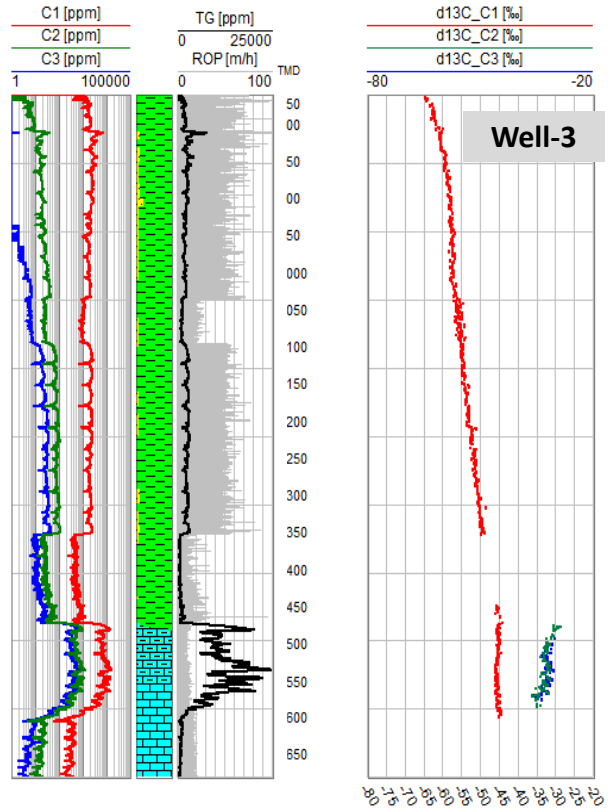
- Silty overburden
- Low gas readings
- Very dry gas
  - C1 <3000 ppm
  - C2 <20 ppm

- Methane isotope of Biogenic origin
- No C2 isotope delta



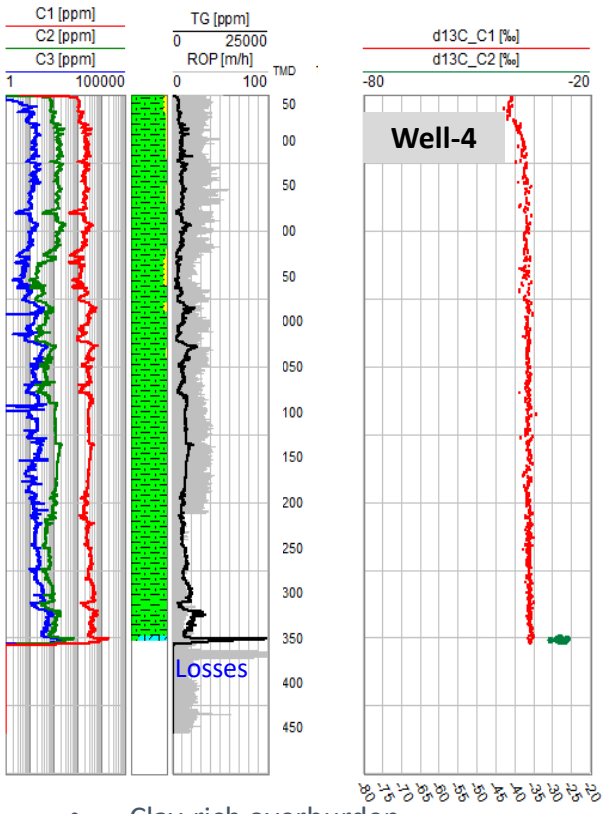
- Silty overburden
- Low gas readings
- Very dry gas
  - C1 <2000 ppm
  - C2 <20 ppm

- Methane isotopes of biogenic origin
- No C2 isotope delta



- Clay-rich overburden
- High gas readings
- Wet gas
  - >5000 ppm C1, 3000-17000 in res
  - >100 ppm C2, 200-1200 in res
  - >40 ppm C3, 150-750 in res

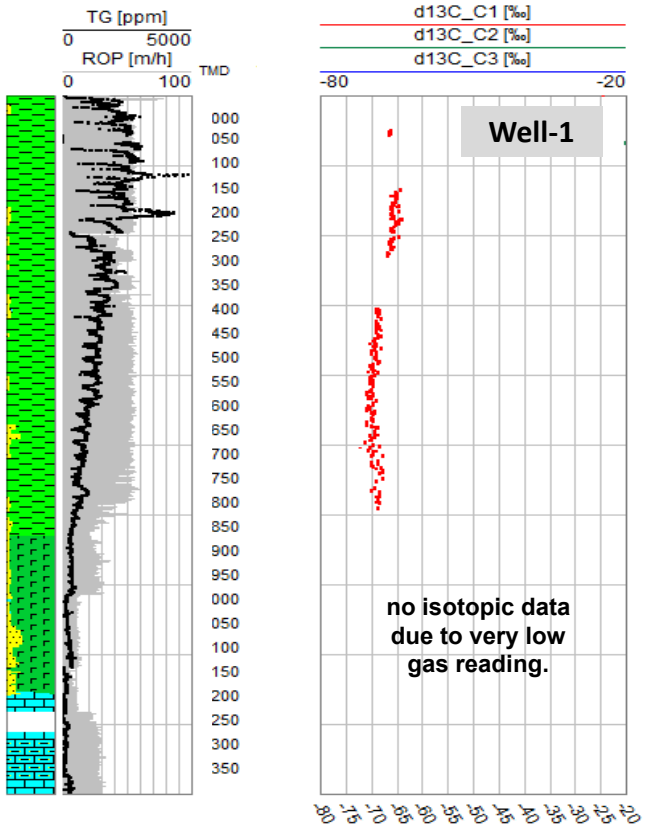
- Thermogenic methane in reservoir.
- C2 and C3 isotopes in reservoir



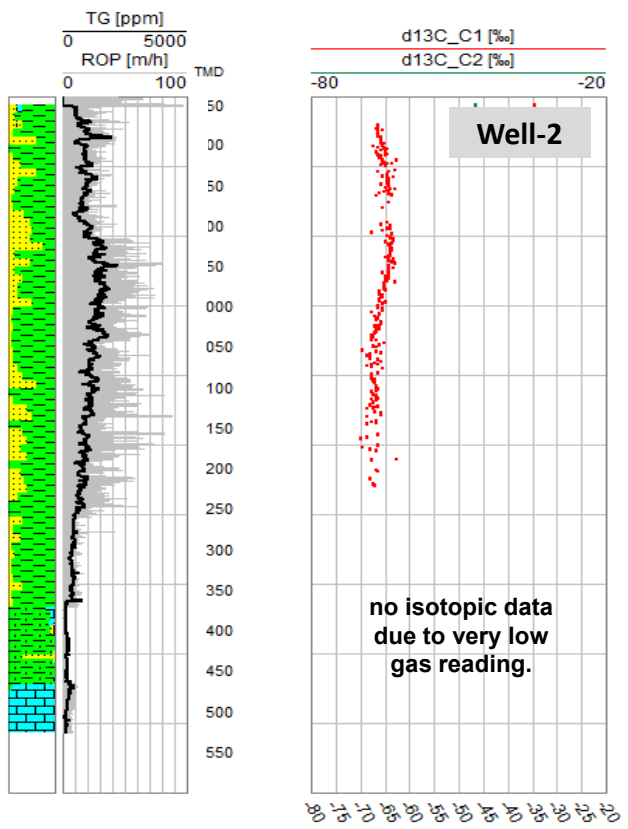
- Clay-rich overburden
- High gas readings
- Wet gas
  - >2000 ppm C1
  - >20 ppm C2
  - >10 ppm C3

- Isotopes exclusively thermogenic.
- C2 isotopes in reservoir

Isotope Log wells



- Methane Isotopic Ratio -65‰ to -70 ‰
- Methane of Biogenic nature in the overburden.
- No C2 isotopes



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- Methane of Biogenic nature in the overburden.
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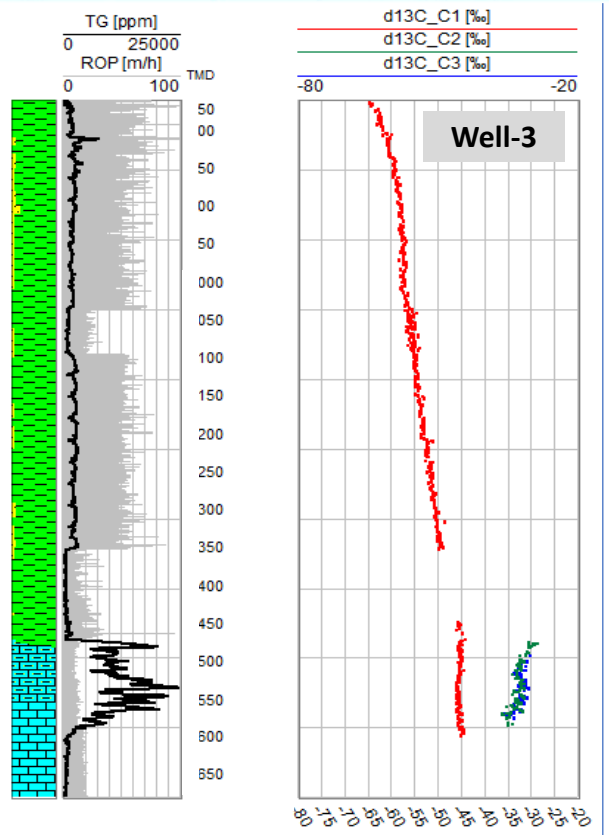
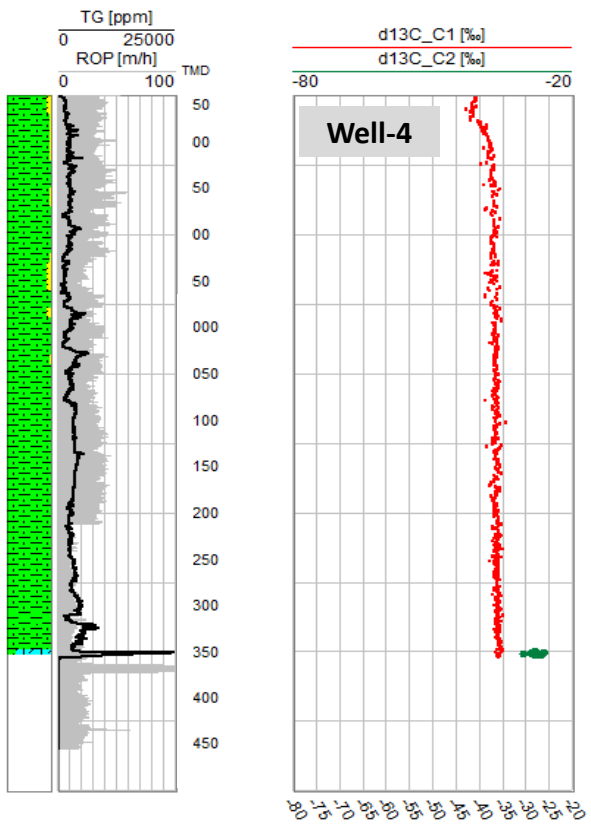


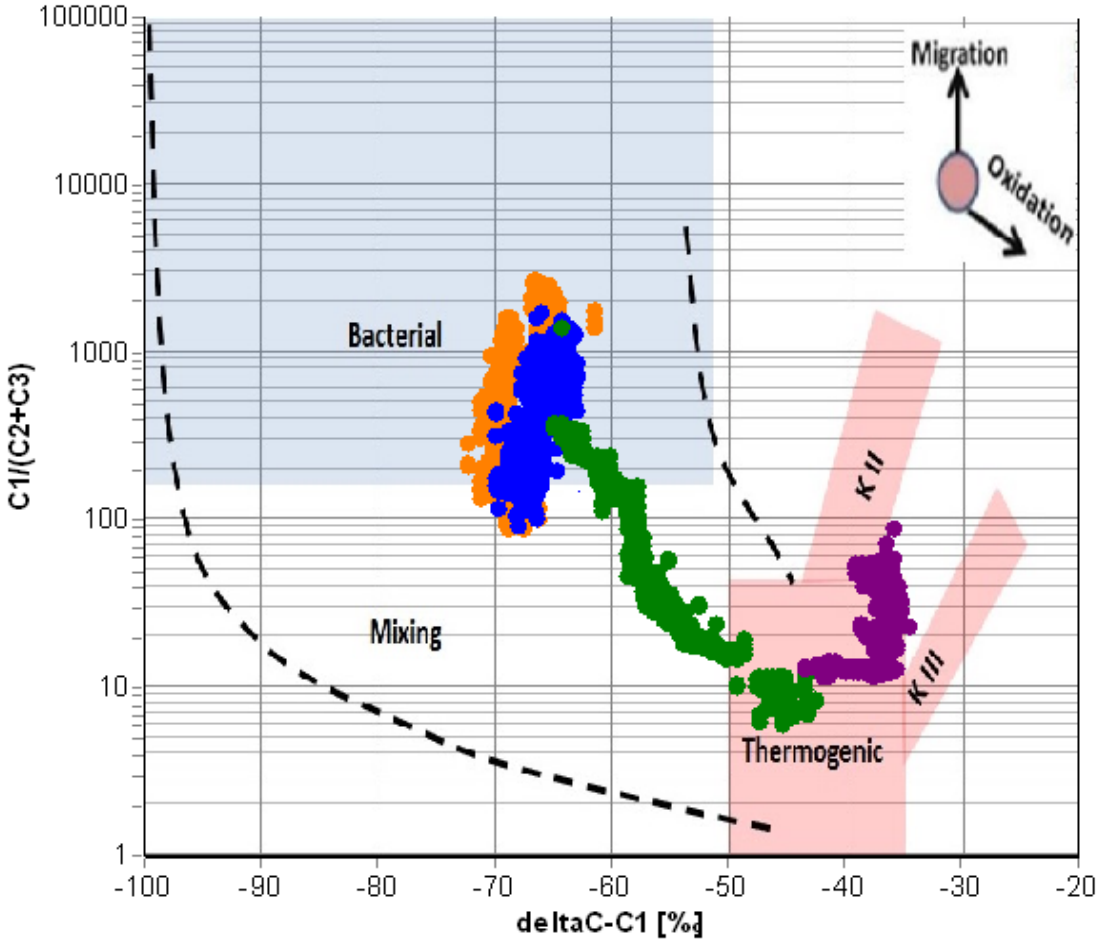
- Methane Isotopic delta -64‰ to -44 ‰
- in the overburden, diffusion of thermogenic methane from reservoir.
- C2 isotope delta in reservoir -36‰ to -29‰
- C3 isotope delta in reservoir -36‰ to -30‰



- Methane Isotopic delta -40‰ to -35 ‰.
- Thermogenic gas in the overburden.
- C2 isotope delta in reservoir -27‰ to -30‰

Bernard Diagram

Well-1
Well-2
Well-3
Well-4

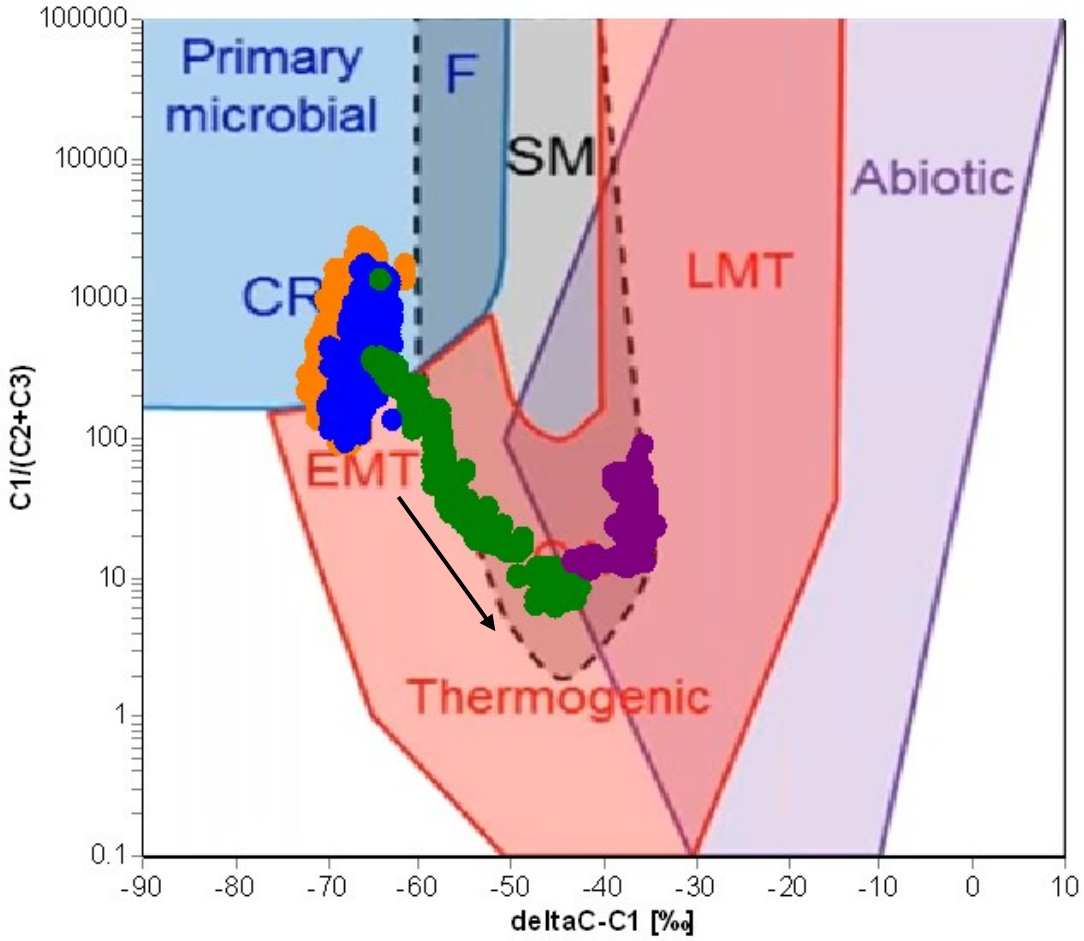


- **Well-1 and Well-2** shows Biogenic origin of Methane (Bacterial Activity) .
- **Well-3** Methane isotope show a gradual trend to thermogenic gas, possible diffusion effect by leakage of Thermogenic gas from the deeper Reservoir (vertical migration).
- **Well-4** Methane isotope of thermogenic origin, late Mature.

Modify Bernard Diagram by Milkov

As per Modify Bernard Diagram by Milkov;

Well-1	
Well-2	
Well-3	
Well-4	

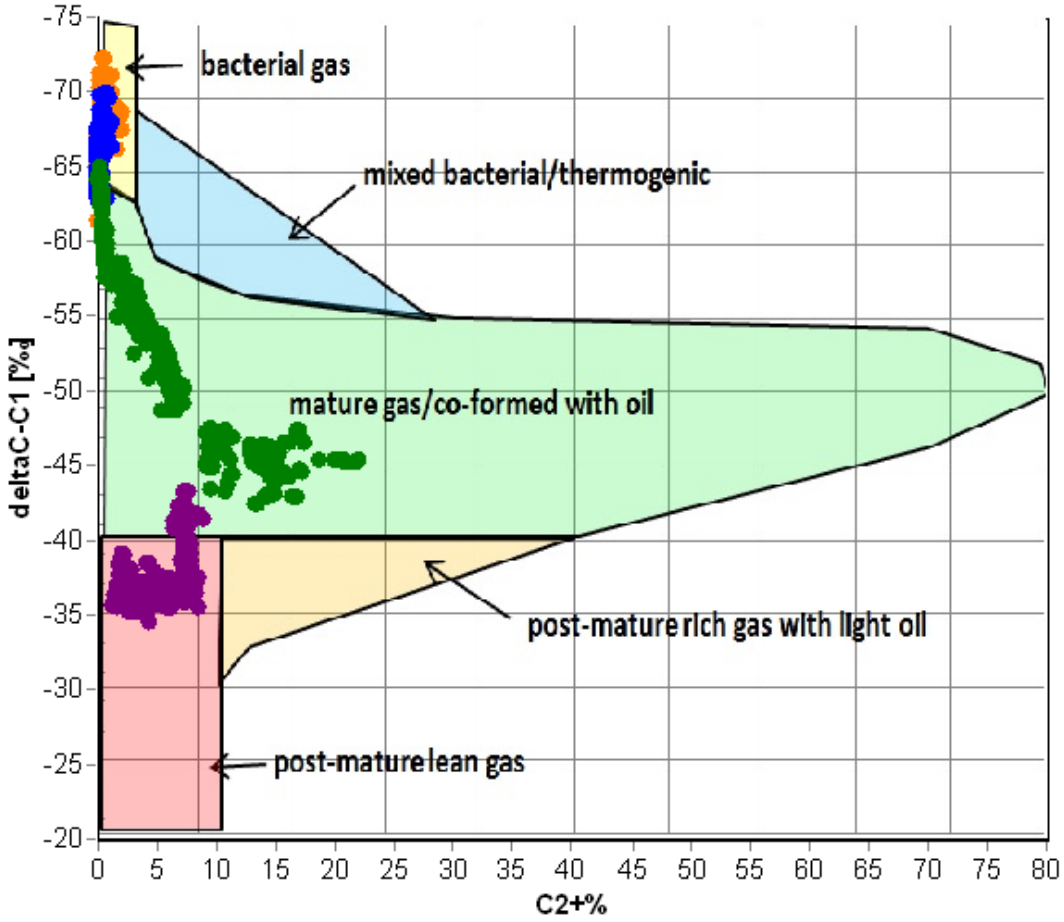


- **Well-1 and Well-2** Show Methane isotope of Biogenic origin (Bacterial Activity) .
- **Well-3** Methane isotope show a gradual trend to thermogenic, possible diffusion effect by leakage of Thermogenic gas from the deeper Reservoir (vertical migration).
- **Well-4** Presence of Methane of thermogenic origin.

Gas Isotope Classifications- Schoell Chart

As per Gas Isotope Classifications- Schoell Chart;

Well-1
Well-2
Well-3
Well-4

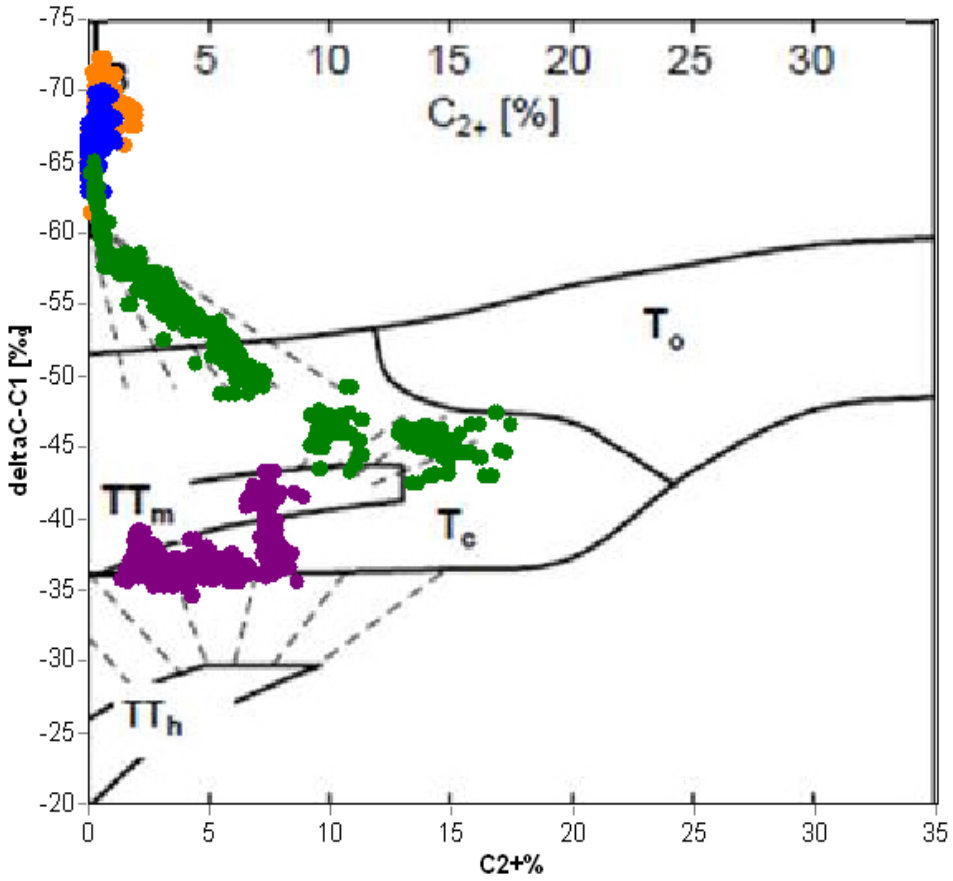


- **Well-1 and Well-2** Presence of Biogenic gas along the whole section drilled.
- **Well-3** The isotopic trend along the overburden suggest a diffusion effect due to leakage from the thermogenic gas of the deeper reservoir section, ‘’mature gas’’.
- **Well-4** late mature Thermogenic gas along the section.

Schoell Maturity Chart

As per Schoell Maturity Chart;

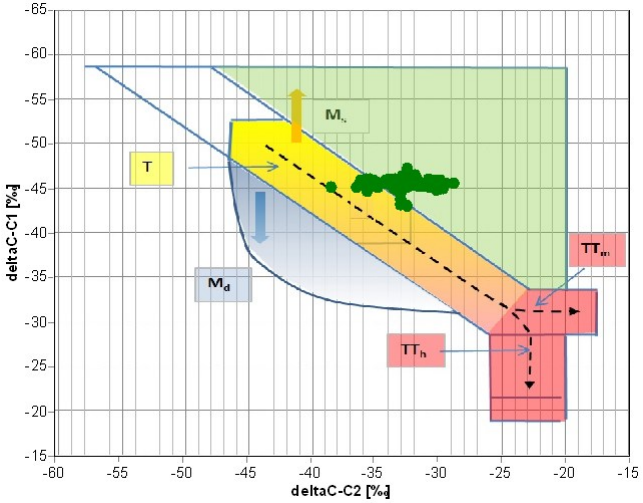
Well-1	
Well-2	
Well-3	
Well-4	

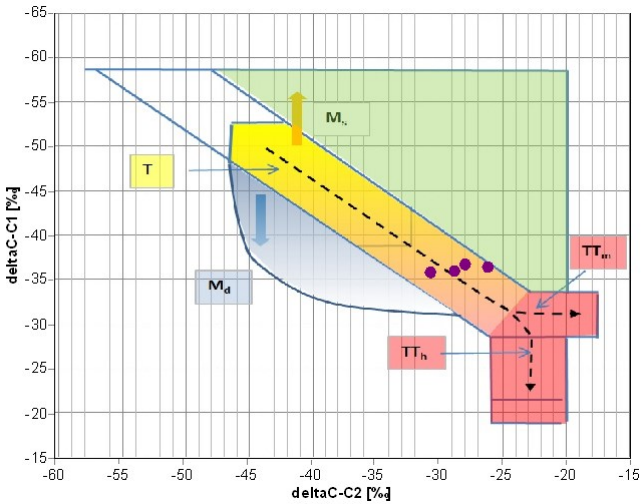


- **Well-1 and Well-2** Biogenic origin of the gas throughout out All Sections.
- **Well-3** Mixing trend between a thermogenic and biogenic end member, in reservoir section data fall in ''TC'' area suggesting that the gas could be associated with Condensate.
- **Well-4** late Mature Thermogenic gas.

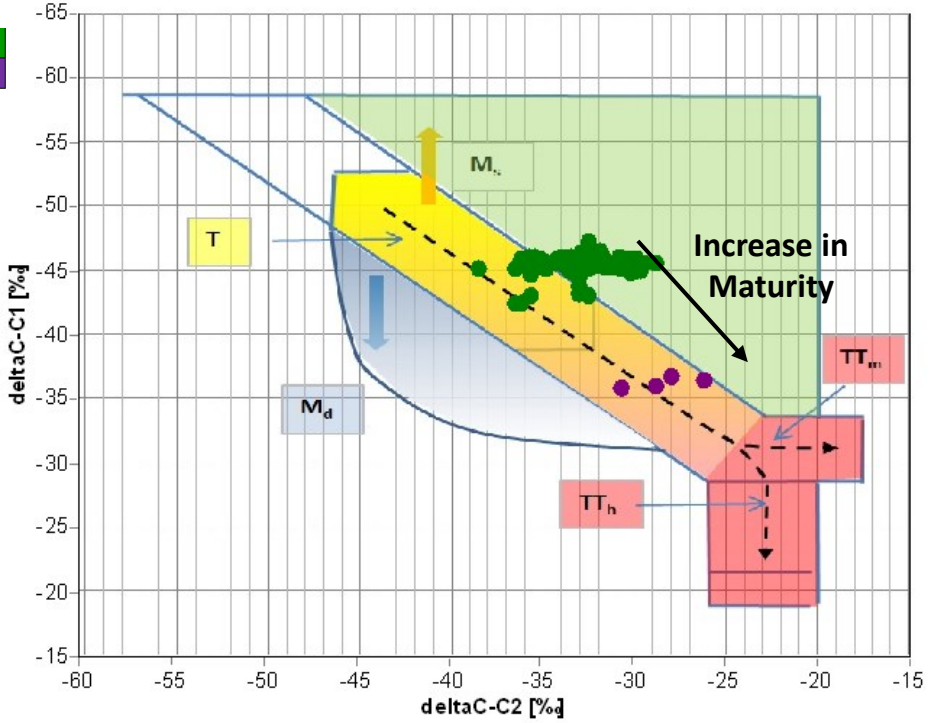
Schoell Cross plot

As per Schoell cross plots;





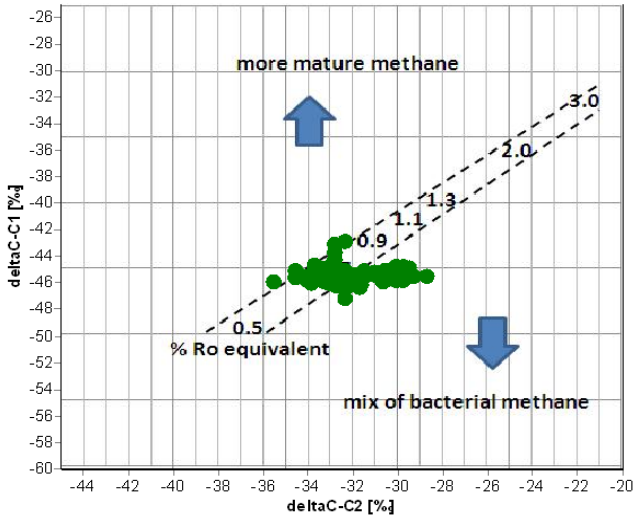
Well-3
Well-4

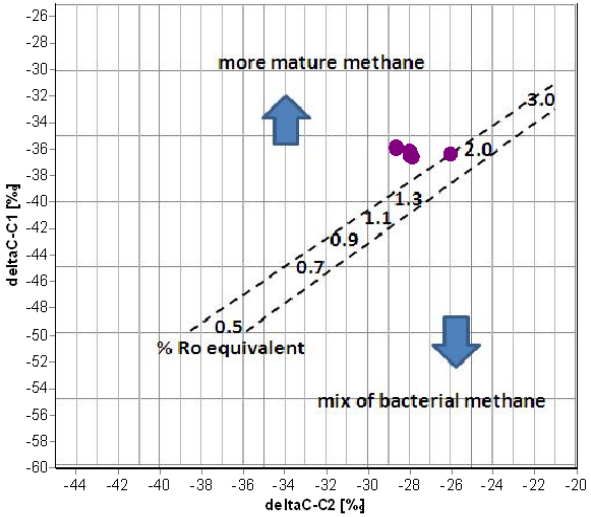


Schoell Cross plots of δ 13C-C1 and δ 13C-C2 indicate ;

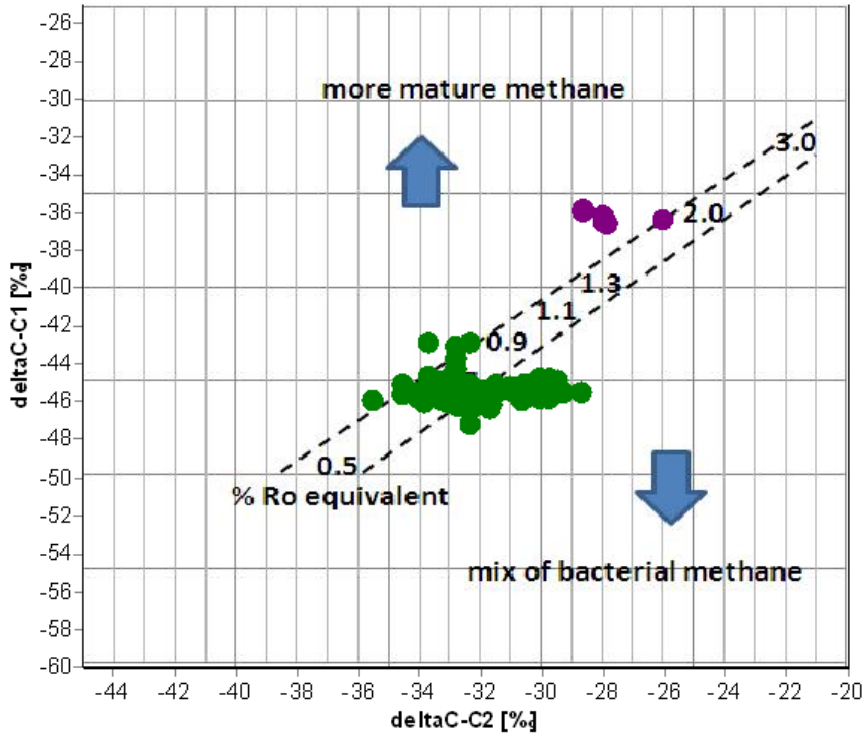
- Well-3 , suggesting associated gas/ dry gas (mixing with bacterial Methane) in green zone but for Well-4 associated gas-highly mature dry gas in yellow zone.

Whiticar Chart δ 13C-C1 and δ 13C-C2





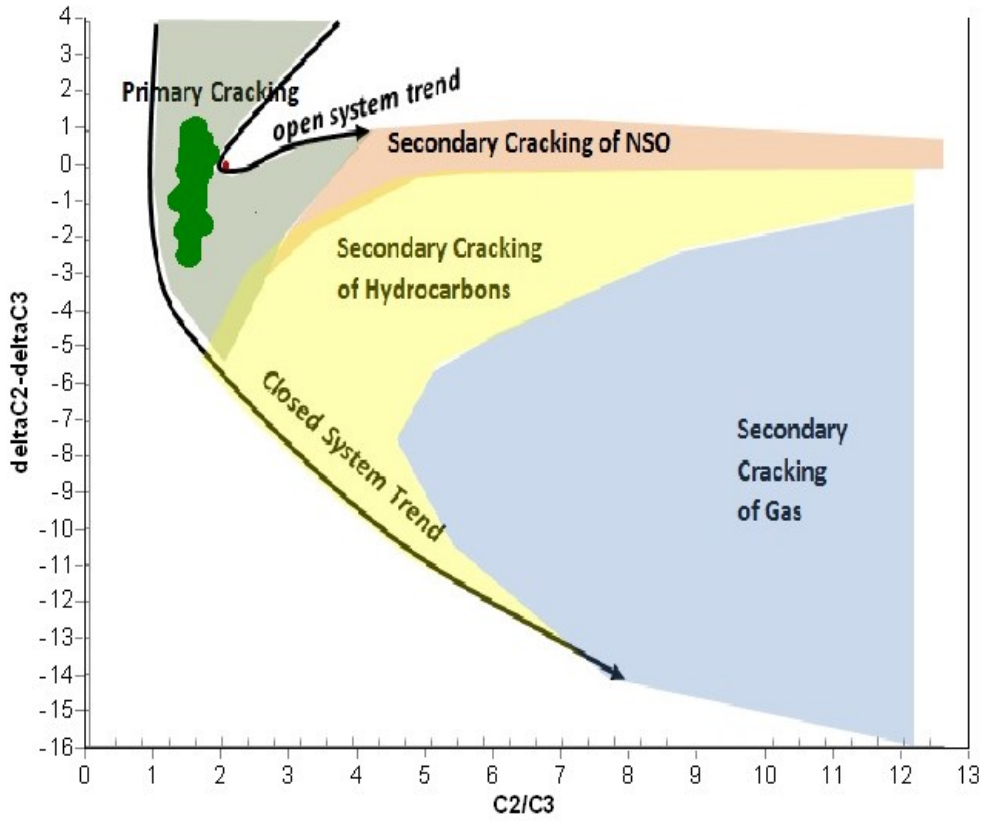
Well-3	
Well-4	



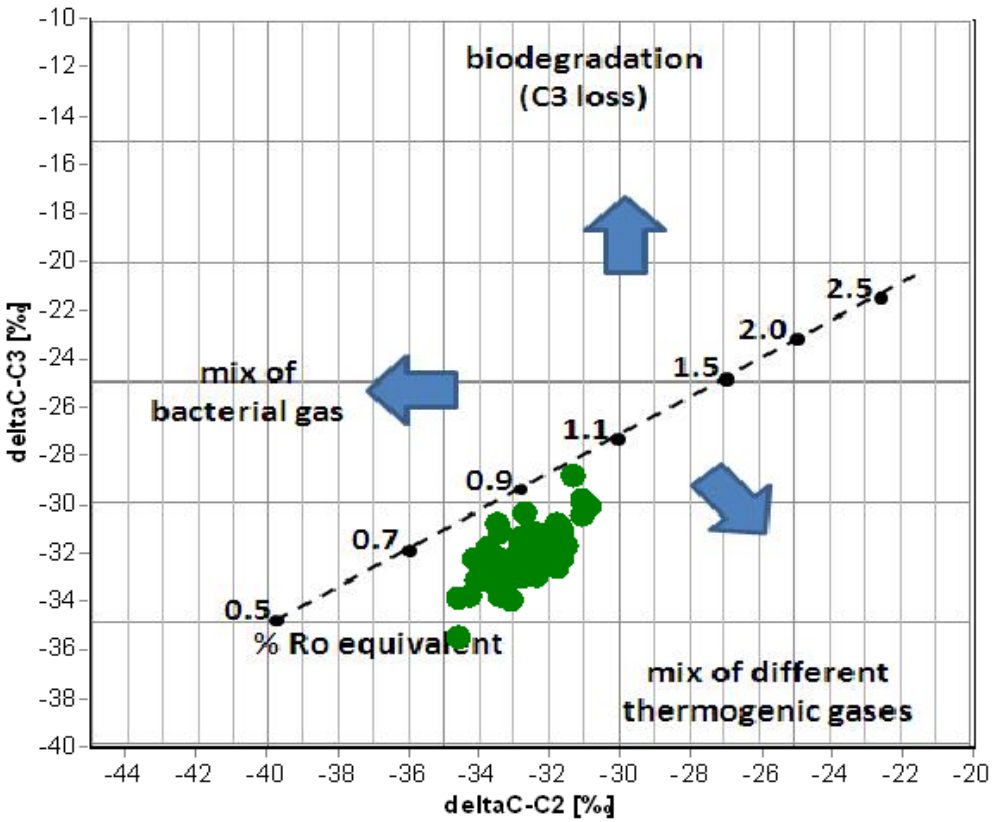
Whiticar Chart of δ 13C-C1 and δ 13C-C2, indicate a Vitrinite reflectance %Ro;

- 0.8-0.9 maturity for Well-3, suggesting a fluid between wet gas and Condensate window. The well Well-4 shows a more mature (%Ro 2) trending to late Mature Gas.

Whiticar Chart δ 13C-C2 and δ 13C-C3 and Lorant Diagram



Well-3



- Lorand Diagram showing isotopic ratio of reservoir gas as result of primary cracking process.

- Whiticar Chart of δ 13C-C2 and δ 13C-C3, indicate a Vitrinite reflectance %Ro is 0.8-1 maturity, suggesting a fluid between wet gas and Condensate window.

Conclusions

- The proposed methodology was applied in **four wells** in a Far East province, which resulted in **two gas discoveries** and **two dry holes.**

- **Gas isotope profiles** in seal sediments can be **integrated with the basin model** to provide insight into **plumbing and failure mechanisms during post-well analysis**, e.g., understanding the **mechanism that controls the pinnacle reef reservoirs type** or the **sealing capacity of the overlying succession**, in order to **facilitate charge de-risking in undrilled targets**.

- Using this information, it was **possible to carefully decide the final drilling depth** of the well and **secure the well without further drilling related risks**. This process allowed the asset team to **decide on drop open-hole logs for both dry wells** and **enabled optimized sampling for further laboratory analyses in the other two wells**, which lead to **significant cost savings**.

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