Geochemistry - A Tool for Identification of Compartmentalization for Pab Sandstone, Sui Gas Field, Pakistan*

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Search and Discovery Article #20138 (2012)
Posted March 12, 2012

*Adapted from oral presentation at PAPG/SPE Annual Technical Conference 2011, Islamabad, Pakistan, November 22-23, 2011

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Abstract

Sui Gas Field, located in the Sulaiman sub-basin of the Indus Basin (Pakistan), was discovered in 1952 and to date 93 wells have been drilled in it. Structurally, the field is located in the first set of folds emerging from the Indus flat planes, west of the Indus River. The major axis of the structure at the surface is about 55 km long and in the east-west direction. The surface dips are gentle and range from 1º to 4º. It is an almost dome-shaped structure, exposing surface rocks down to lower Siwaliks that are marked by the rocky outcrop forming low hills and cliffs all around. Gas has been discovered in three reservoirs to date, with two reservoirs from Ypresian age and one Maastrichtian age. Further hydrocarbon potential, possibly tight gas, exists in the deeper formations.

The two Ypresian reservoirs, Sui Upper Limestone (SUL) and Sui Main Limestone (SML), were discovered in 1952 and contain a major portion of the reserves with 1.28 Tcf in SUL and 12.5 Tcf in SML reservoir. The SUL and SML reservoirs are laterally continuous and are interlain by the laterally continuous Ghazij Shale. The third discovery in the field was made in 1999 in Maastrichtian aged Pab Sandstone reservoir by Sui-87(P) which tested 40 m of gross sand above the gas water contact (GWC). Since then, the Pab reservoir has been tested in five wells out of which three wells, Sui-90(P), Sui-91(P) and Sui-92(U), were drilled inside the GWC identified in the discovery well. Unexpectedly, well Sui-90(P) is in a possible graben, while well Sui-92(U) is in a zone with a shallower GWC, indicating possible compartmentalization of the reservoir. The fourth appraisal well was deepening of existing well Sui-52(U/M), located beyond the identified GWC and was dry.

2D seismic data with an average line density of 1500 to 4000 m is available but is not enough to identify either structural or stratigraphic compartments in the reservoir. In the absence of detailed support from the seismic, we have used geochemical data from the wells supported by the drilling, logging and production data to confirm the existence of compartments in the Pab reservoir. Gas and water

samples from the producing wells Sui-87(P), Sui-91(P) and the downhole gas and water samples collected from the formation tester run in Sui-92(U), suspected to be in a different compartment, were sent for detailed geochemical analysis to ascertain compartmentalization of the Pab reservoir. Gas samples were analyzed for δ13C and hydrogen isotope, while strontium isotope analysis was performed on water samples.

The results show that gas samples from Sui 87(P) and Sui 91(P) have similar isotope values which are significantly different than Sui 92(U) samples. This strongly suggests that Sui 87(P) and Sui 91(P) lie in one compartment different from Sui 92(U), which is further corroborated by formation evaluation data. The isotope results will be used in combination with the 3D seismic data to reduce the risk in appraisal and development of Pab reservoir at Sui Field.

ANNUAL TECHNICAL CONFERENCE
2011

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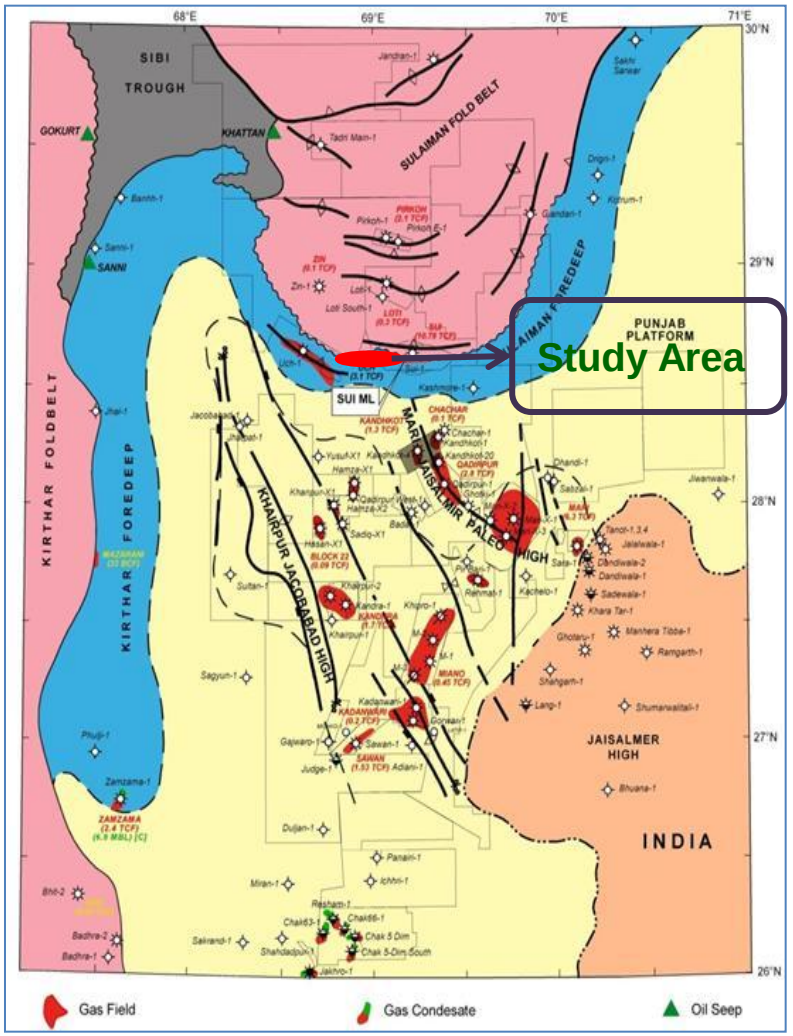
Introduction

Sui Gas Field

- Sui Gas Field, located in the Sulaiman sub-basin of the Indus Basin (Pakistan)
- Discovered in 1952 and to date 93 wells have been drilled in it
- Gas has been discovered in three reservoirs up till now with two reservoirs from Ypresian age (SUL & SML) and one Maastrichtian age (Pab)
- Pab reservoir tested in five wells
  - Sui-87, -91 and -92 drilled inside the GWC
  - Sui-92 encountered shallower GWC than -87 and -91 – indicating possible compartmentalization
  - Unexpectedly Sui-90 was dry – drilled in possible graben
  - Sui-52 located on the eastern flank of the structure deepened to delineate Pab – Encountered Water



Top Pab Depth Structure Map

(Showing five Pab wells)

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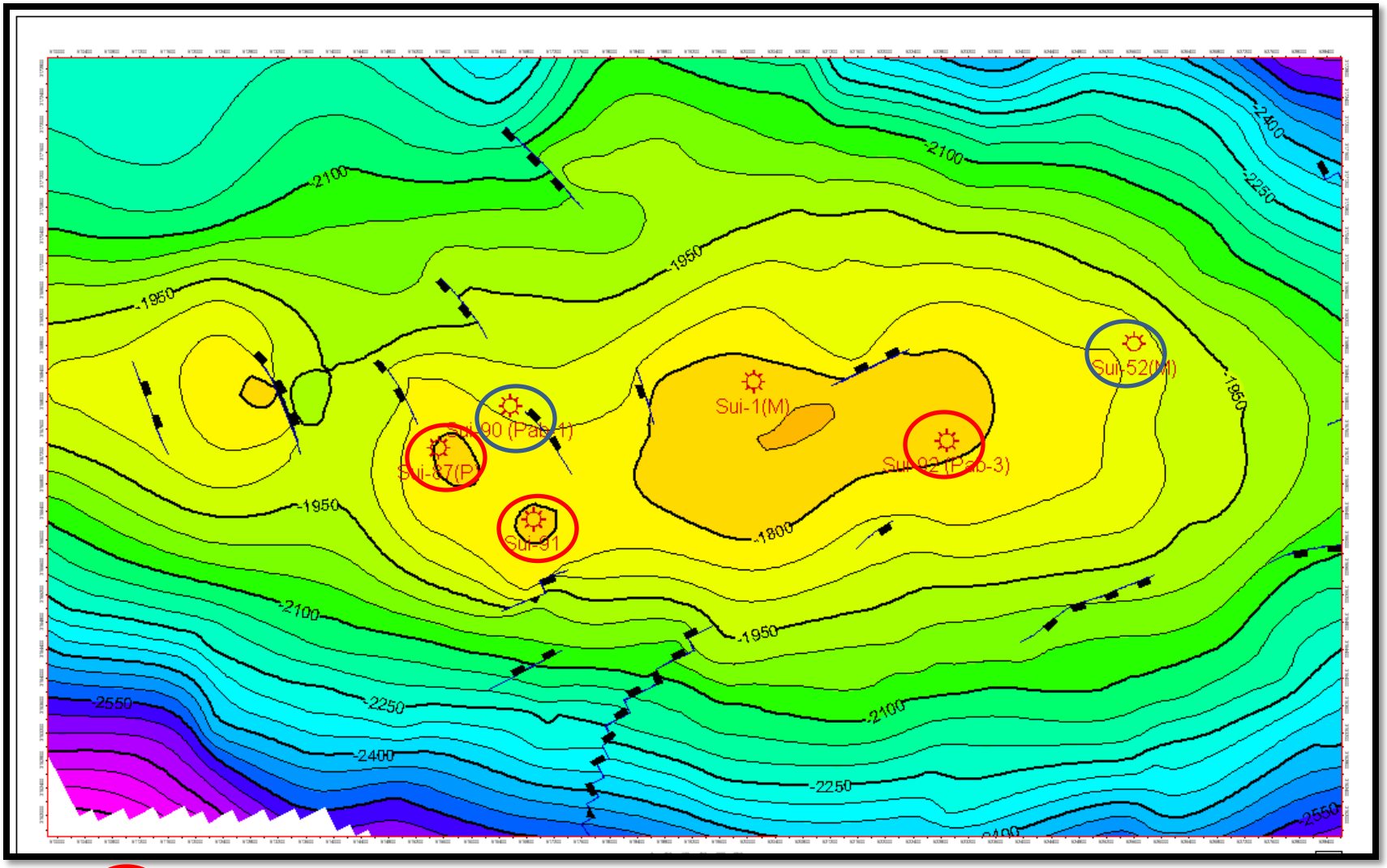

Wells used for Pab Geochemical analysis

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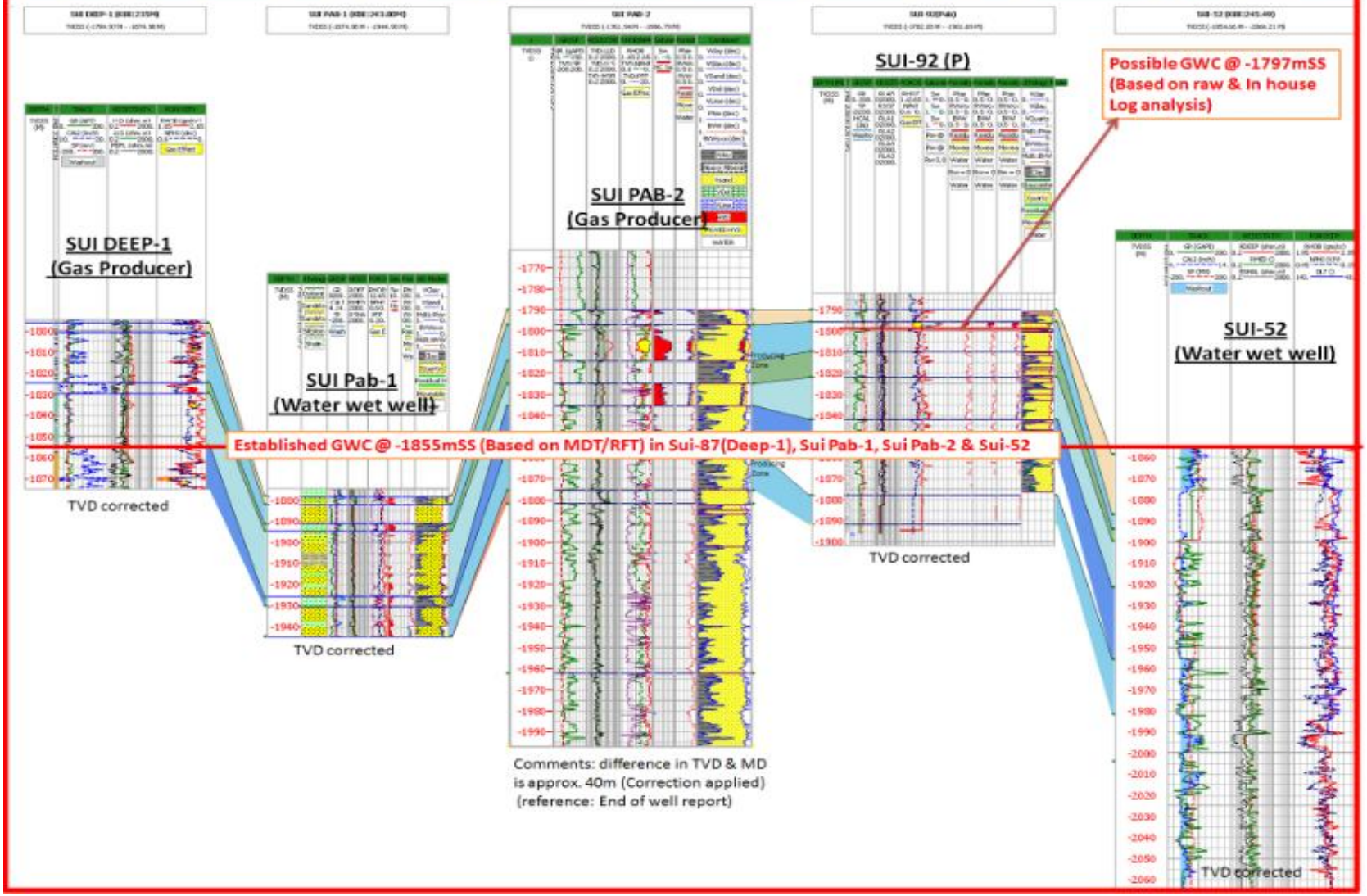
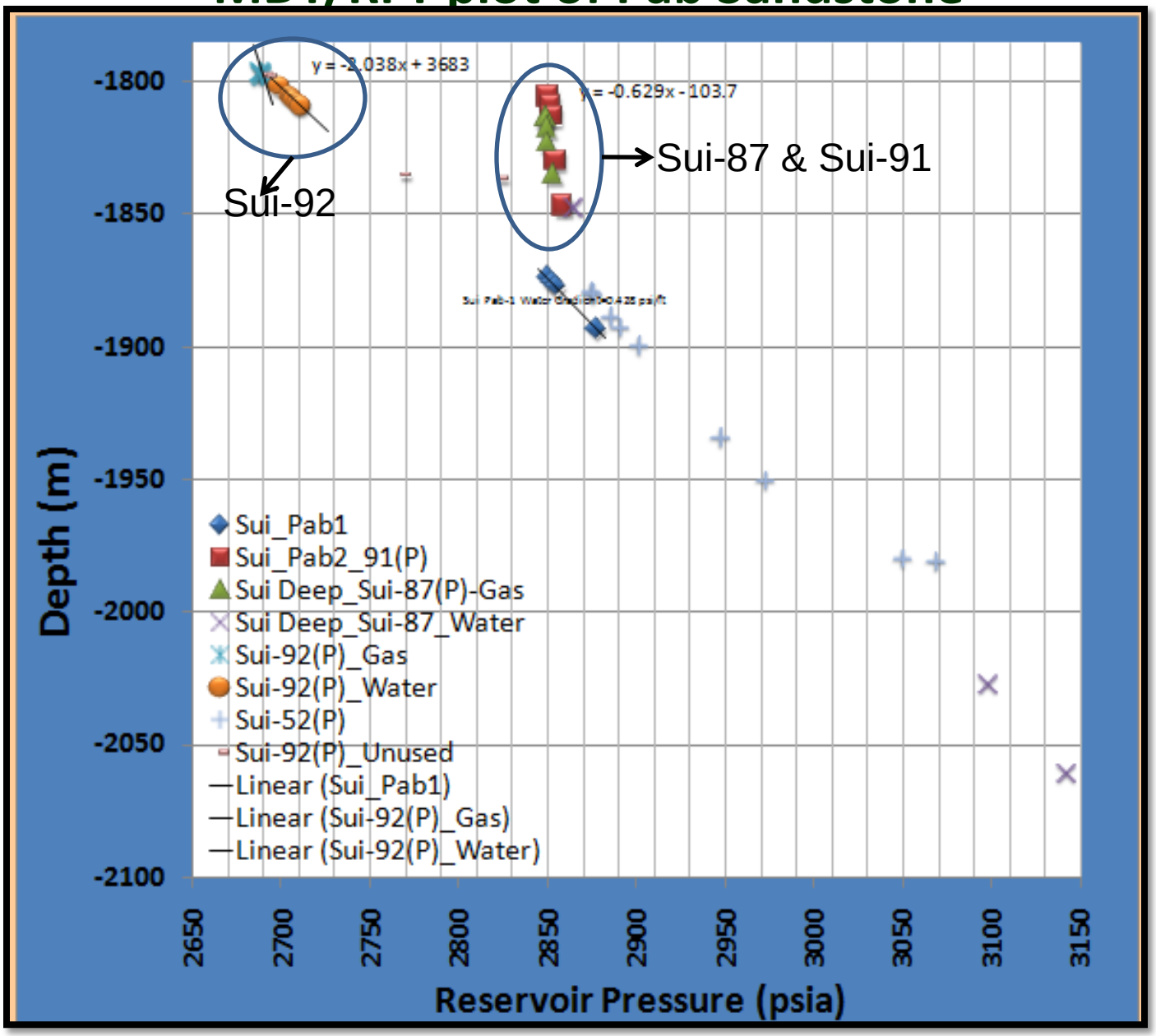
STRUCTURAL WELL LOG CORRELATION OF SUI PAB (UPPER SAND) WELLS



MDT/RFT plot of Pab Sandstone



Objectives of the Study

- Confirm compartmentalization of Maastrichtian aged Pab sandstone reservoir in gas and water legs based on:
  - Geochemical Analysis of Gas and Water samples
  - Logging and Drilling data

Sparse 2D Seismic Data Available – Not suitable to identify Compartments

- Draw Conclusions about
  - Future Appraisal of Pab at Sui
  - Possible Migration Pathways/Charging Direction

Data Set Used

- Gas and water samples from Sui-87, Sui-91 and the downhole gas and water samples collected from the formation tester in Sui-92
- 2D seismic data with an average line density of 1500 to 4000 m low fold data not enough to identify either structural or stratigraphic compartments in the reservoir
- Reservoir data:
  - MDT Sui-92
  - Well head samples of Sui-87 & 91

Workflow, Methodology

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Sample Collection
- MDT Samples
- Well head Samples

QC/VC of Samples
- Initial Compositional Analysis on the gas samples

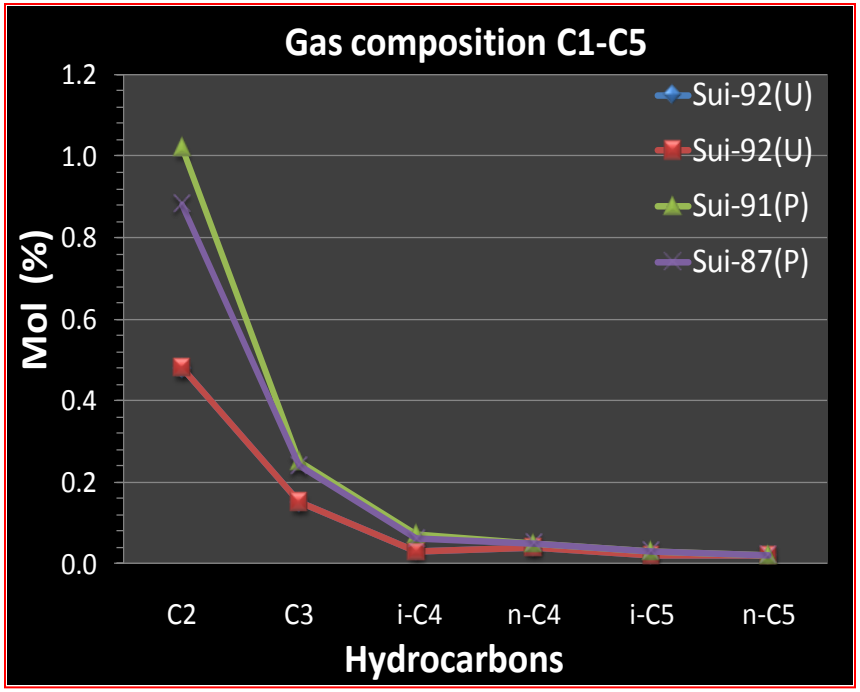
Sample preparation for Geochemistry Analysis

Gas Isotope analysis results on Wellhead & MDT Gas samples

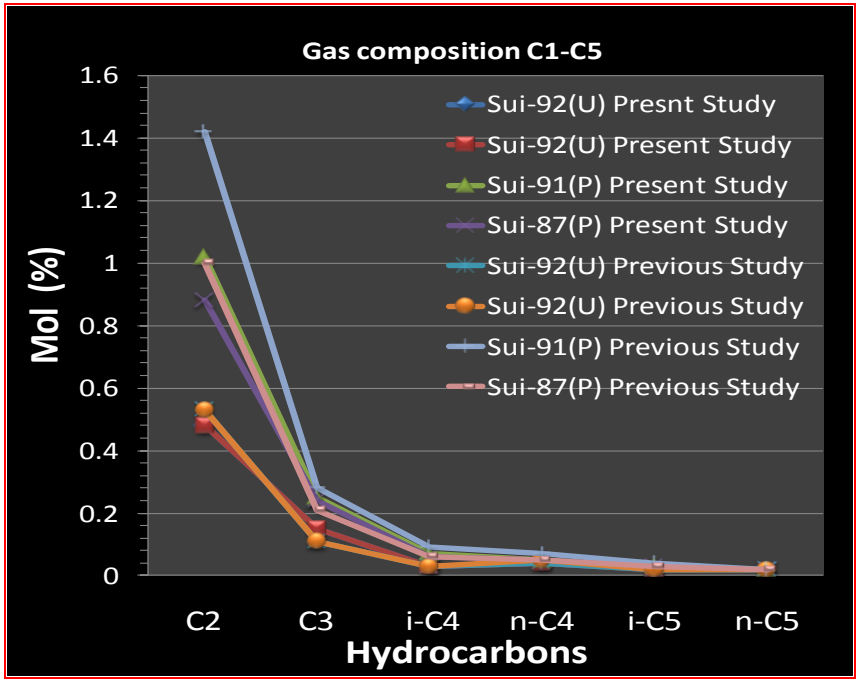
Isotope & Ionic Analysis on MDT & Well head water samples

Results / Discussion

- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92 wells



The relative abundance of hydrocarbon gases from C2 to C5 (Compositional analyses)



Comparison of composition of the hydrocarbon gases

Results / Discussion

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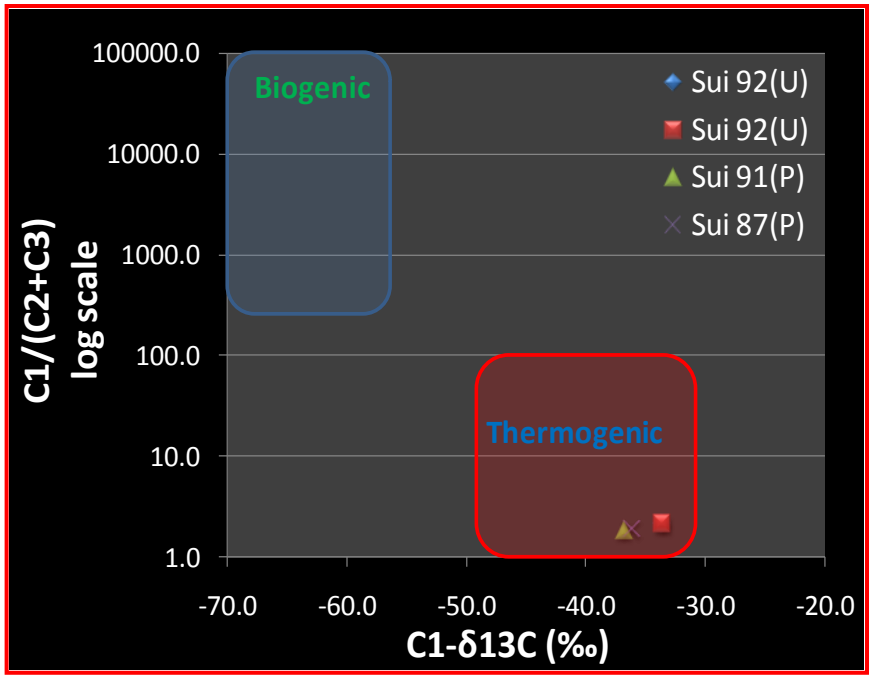
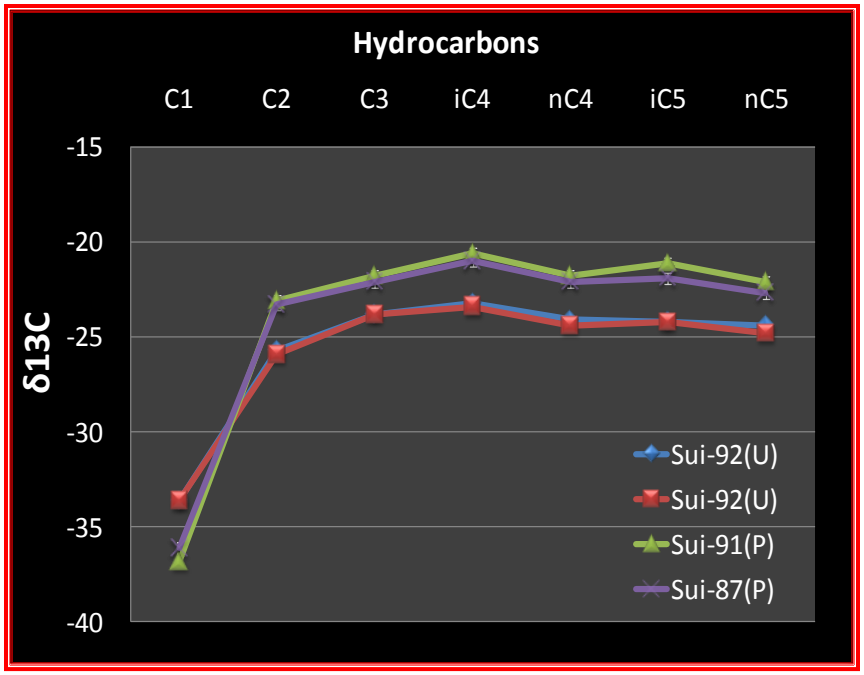
- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92 wells



Distinction between biogenic and thermogenic methane



Carbon isotope composition ($\delta^{13}C$) of C1-C5

Results / Discussion

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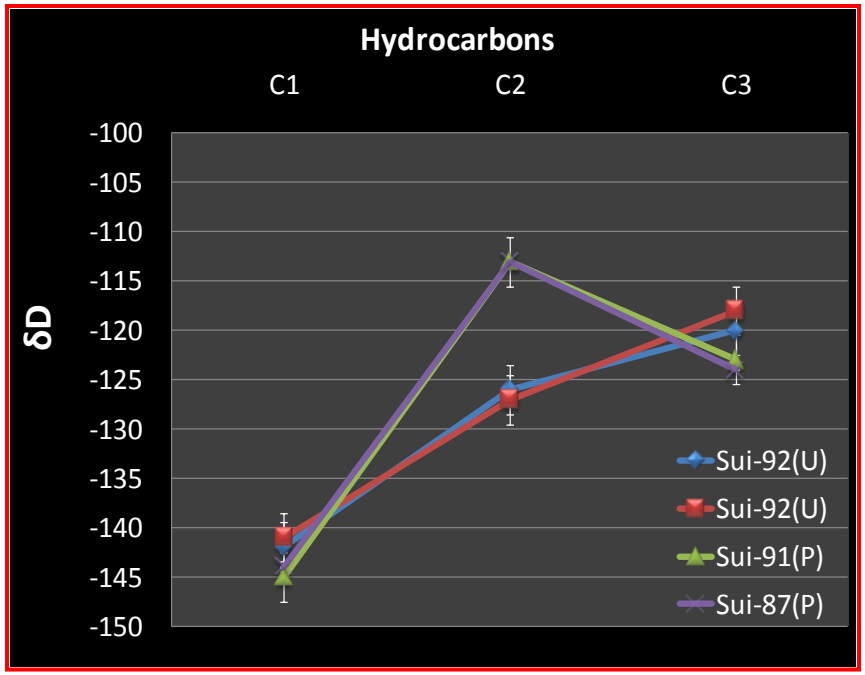
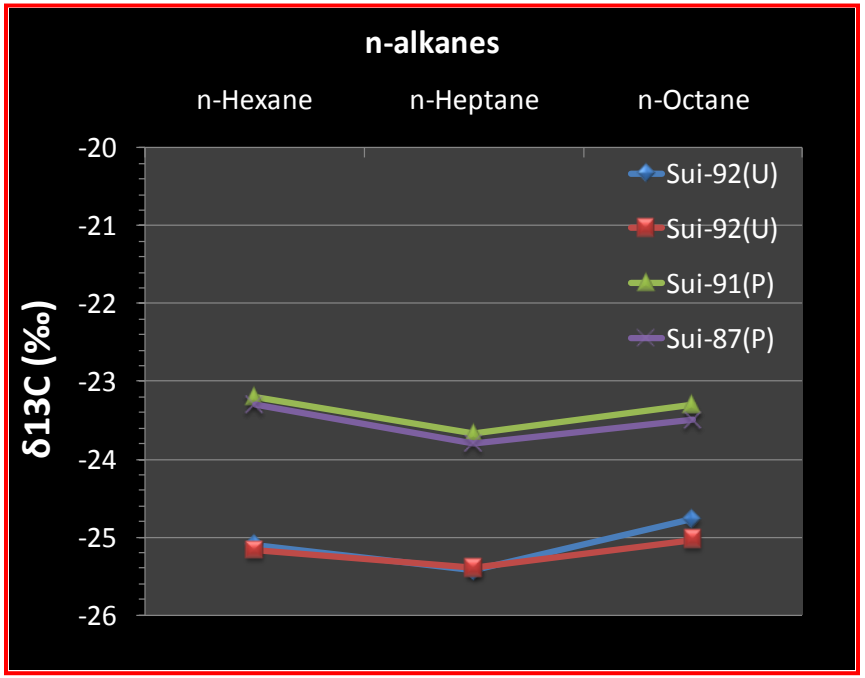
- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92 wells



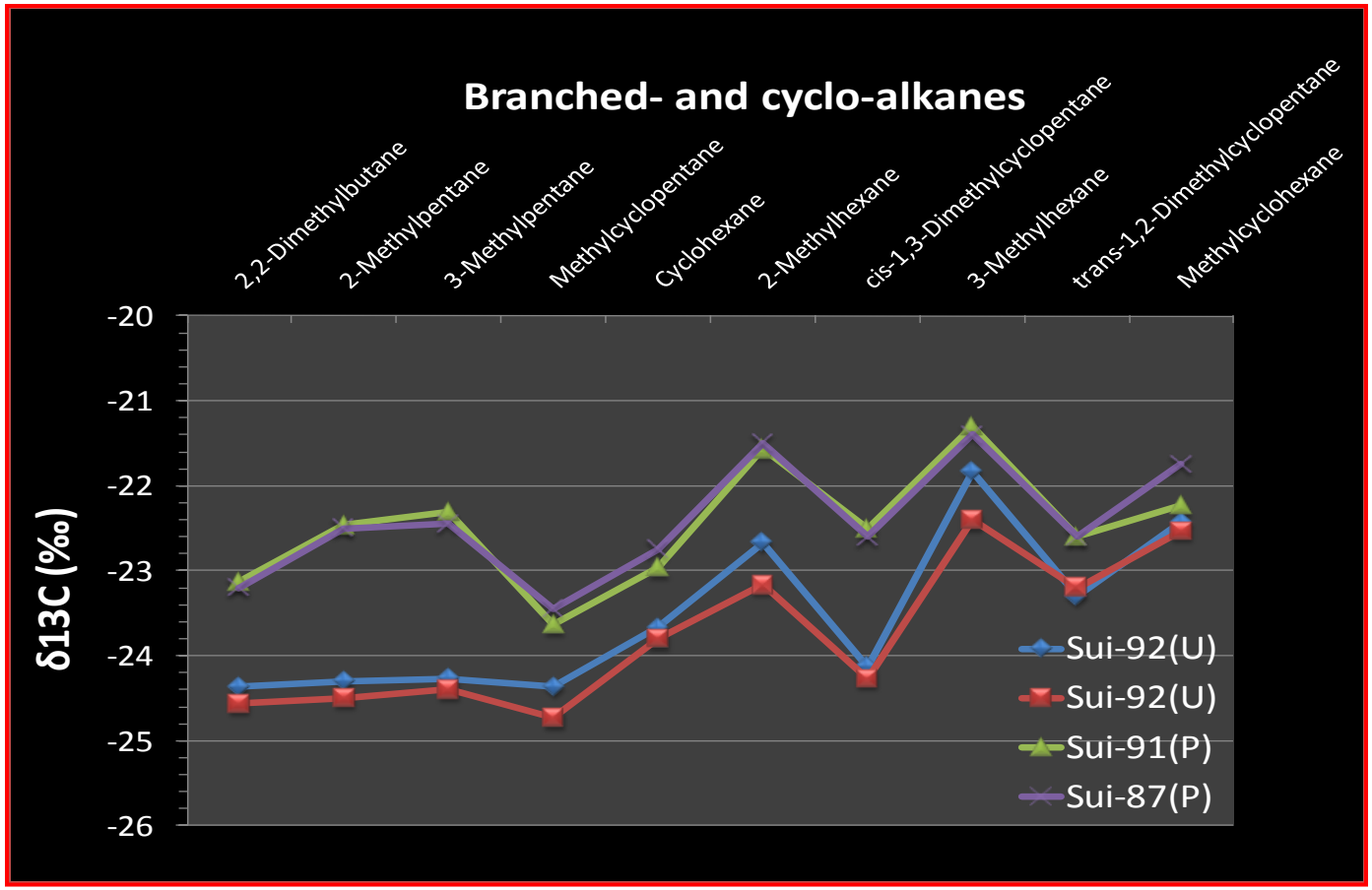
Hydrogen isotope composition (δD) of C1-C3



Carbon isotope composition ($\delta^{13}C$) of C6-C8 n-alkanes

Results / Discussion

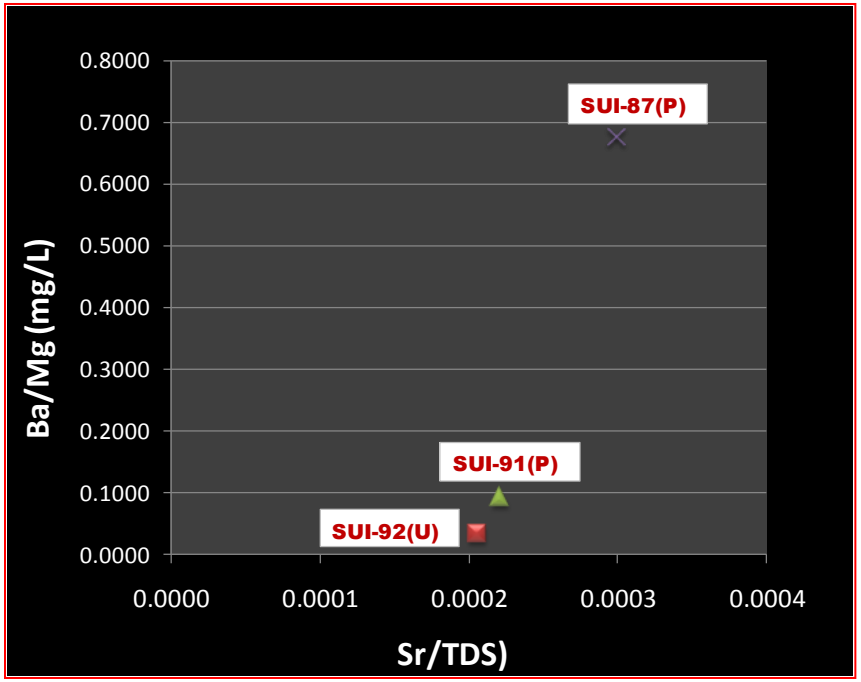
- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87,91 and 92 wells



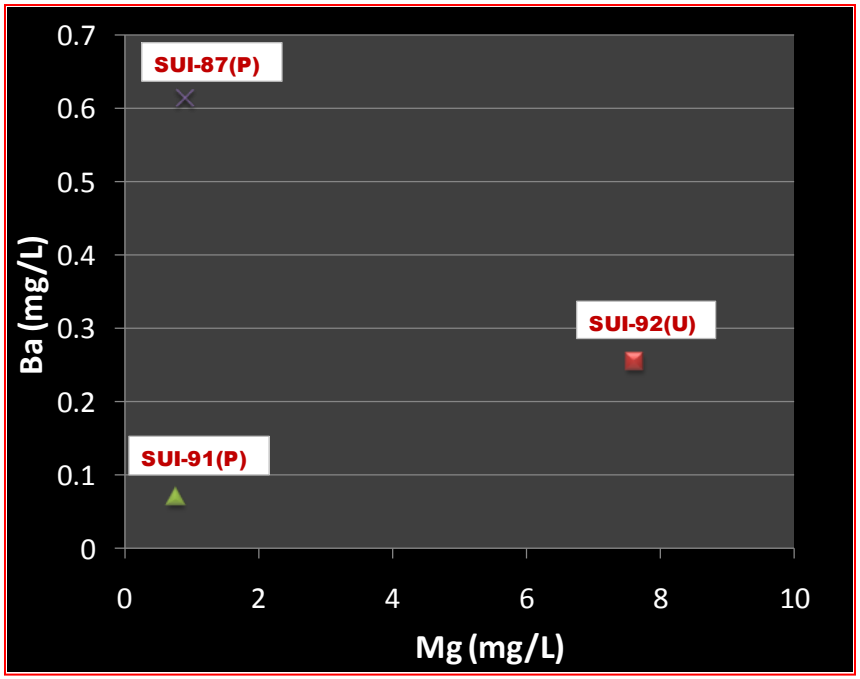
Carbon isotope composition ($\delta^{13}C$) of C6-C7 branched and cycloalkanes

Results / Discussion

- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92 wells



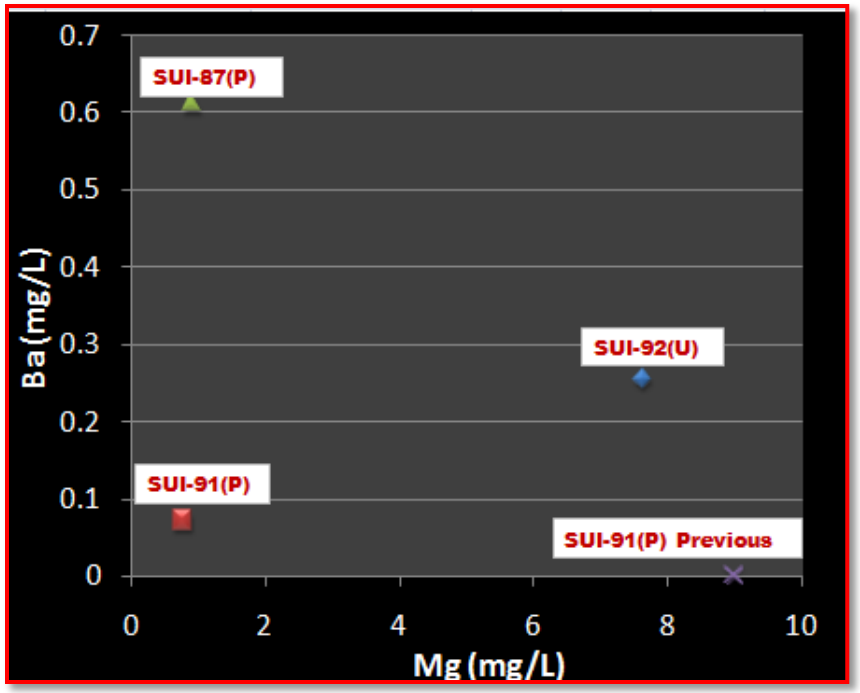
Ba/Mg versus Sr/TDS ratios



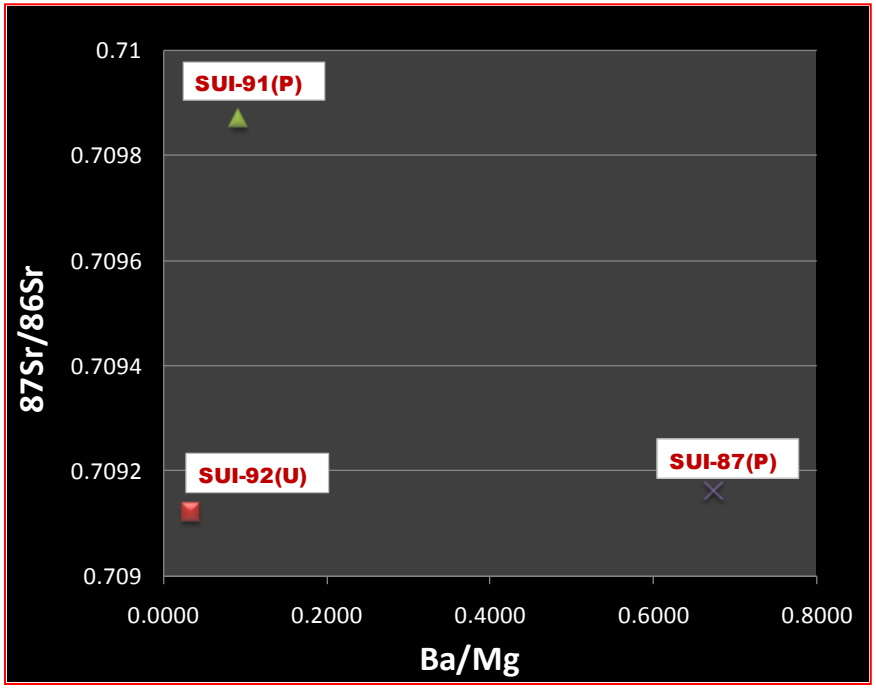
Ba versus Mg

Results / Discussion

- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92



Ba versus Mg contents of water samples from wells Sui-87,91 and 92 (this study) and well Sui-91 (Pab-2) (historical data)



$^{87}Sr/^{86}Sr$ versus Ba/Mg ratios

Results / Discussion

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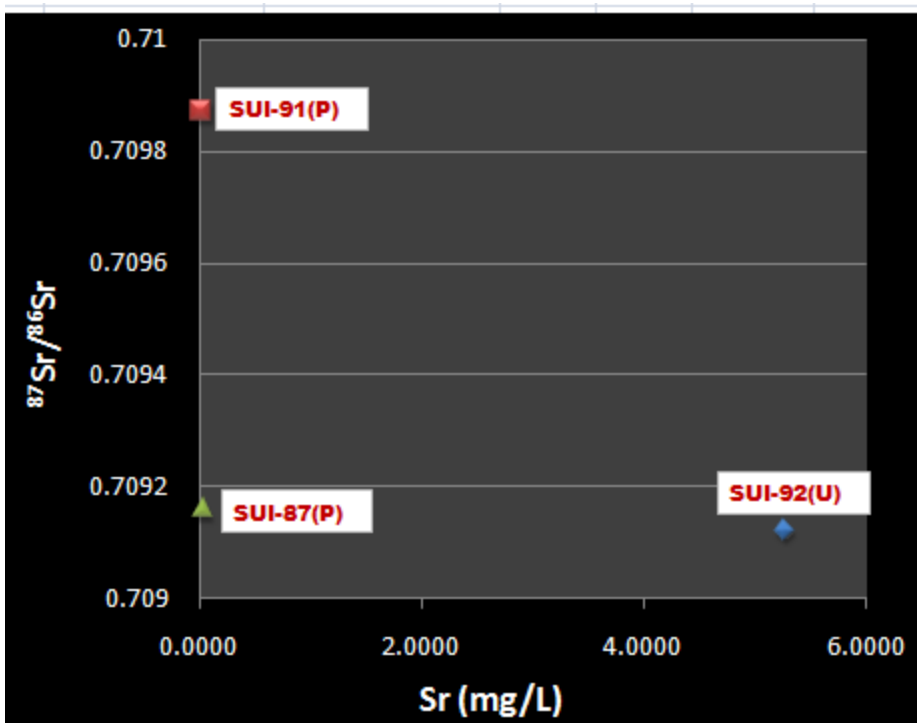
- Compositional Analysis of MDT and Wellhead Gas Samples from Sui-87, 91 and 92 Wells



$^{87}Sr/^{86}Sr$ ratios versus Sr contents

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STRUCTURAL CROSS SECTION OF PAB RESERVOIR

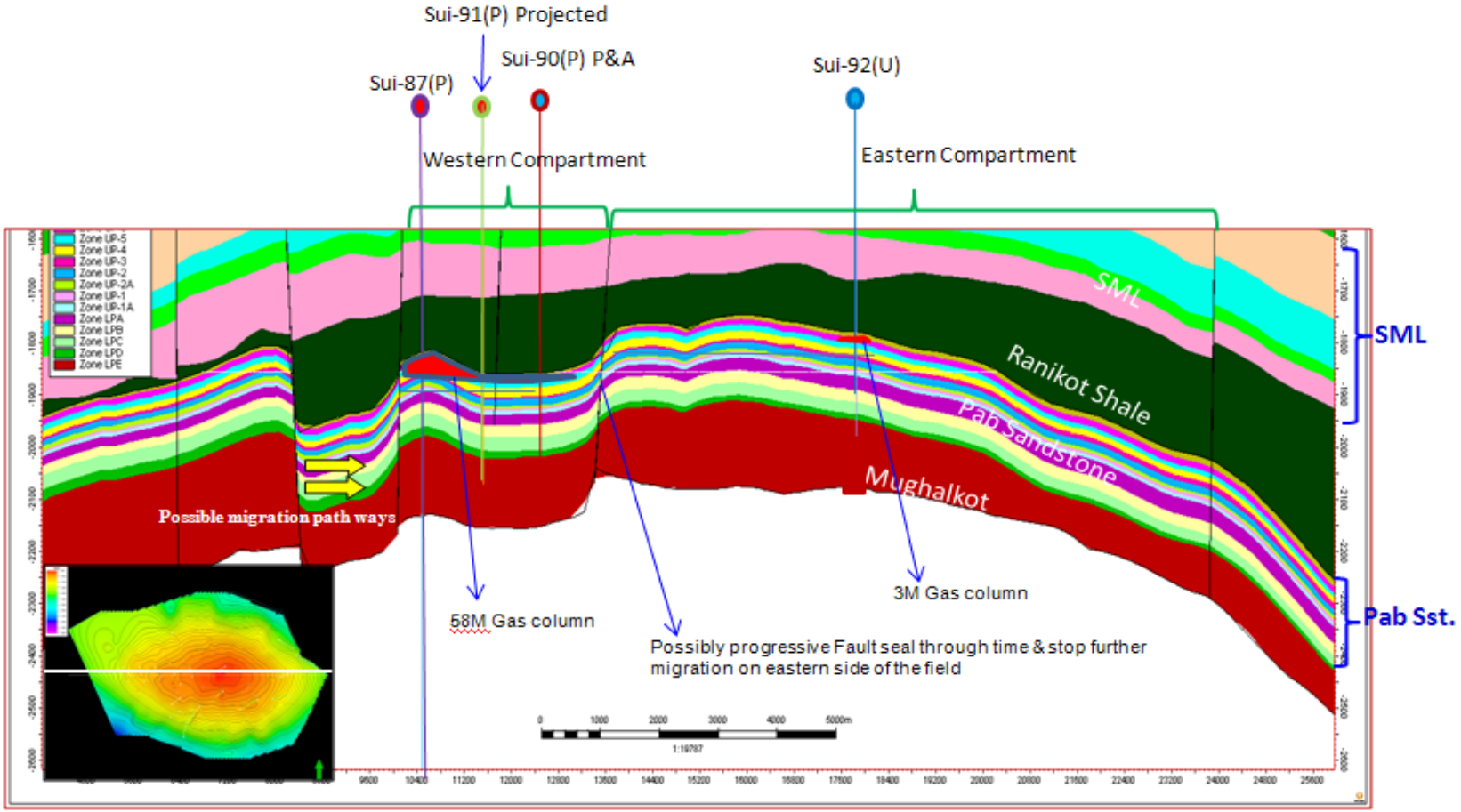

Figure 15: Cross sectional view of Pab reservoir & possible Post Eocene charge of the structure from West based on available data

Conclusions

1. Analysis suggest possible mixing of hydrocarbons generated by more than one facies or source rock
   a. Sui-87 and 91 have higher abundance of C_2-C_5 as compared to 92
   b. Sui-87 and 91 have heavier $\delta^{13}C$ values (~2‰) for C_2 to C_8
2. Analyzed gas samples confirm mostly thermogenic origin based on hydrocarbon gas carbon isotope distribution and composition.
3. Geo-chemical analysis corroborate well with pressure and log data from Sui-87, 91 and 92 which shows 87 and 91 to be in different compartment as compared to 92
4. High resolution 3D seismic data is required to define the source of compartmentalization

Implications for Pab Appraisal/Development

1. It is understood that the reservoir gas is predominantly from hydrocarbon charge from west to east, that took place in late Tertiary time, i.e. after the major structural configuration with some minor throw adjustments in faults at Pab level had taken place.
2. This may therefore mean that the compartments at Pab reservoir level in the crestal part of the structure need to be evaluated with particular care as the crestal compartments may have successively less hydrocarbon column as one moves towards the crest.
3. Compartments down dip of the shallowest producing compartment may be considered as interesting exploration target at Pab level.

Acknowledgement

We are thankful to Pakistan Petroleum Limited for providing the data for the study and permitting to publish it. In addition we are also thankful to Mr. Khursheed Akhtar & Syed Manshoor Ali for improving the quality of the paper during the review session

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THANK YOU