PS Integration of Time Lapse Seismic and Dynamic Reservoir Model Facilitate EOR Immiscible Water Alternating Gas (IWAG) Programme in Oil Field, Offshore Peninsular Malaysia *

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Abstract

The integration of geoscientific and reservoir engineering data is critical for reservoir characterization and management in the mature oil field. The flood front movement monitoring through Immiscible Water Alternating Gas (IWAG) injection is a major challenge due to sparse well locations and reservoir heterogeneity. The selected field was discovered in 1981 and is on production since 1991 with cumulative production around 20% of STOIIP. A pilot IWAG injection project was carried out in the sub-block of the main reservoirs for a period of four years successfully as one of initiatives for enhanced oil recovery (EOR). As a result, full field injection plan has been formulated.

For effective reservoir management, it is very important to detect and monitor IWAG injection effect. In order to understand the potential uncertainty and for effective planning prior to actual project implementation, a time-lapse seismic feasibility study was carried out. Rock physics modeling played a critical role for establishing the relationship between elastic properties and pressure/saturation effects simulated in dynamic reservoir modeling. It has been observed that two years IWAG injection cycles may lead to cumulative acoustic impedance changes of 6%-8%. The present study identifies the factors contributing to the chances of success (COS) of the project. The time-lapse seismic feasibility outcome ensured both technical and economics success and further prompted for monitoring of full field implementation IWAG injection.

INTEGRATION OF TIME LAPSE SEISMIC AND DYNAMIC RESERVOIR MODEL FACILITATE EOR IMMISCIBLE WATER ALTERNATING GAS (IWAG) PROGRAMME IN OIL FIELD, OFFSHORE PENINSULAR MALAYSIA

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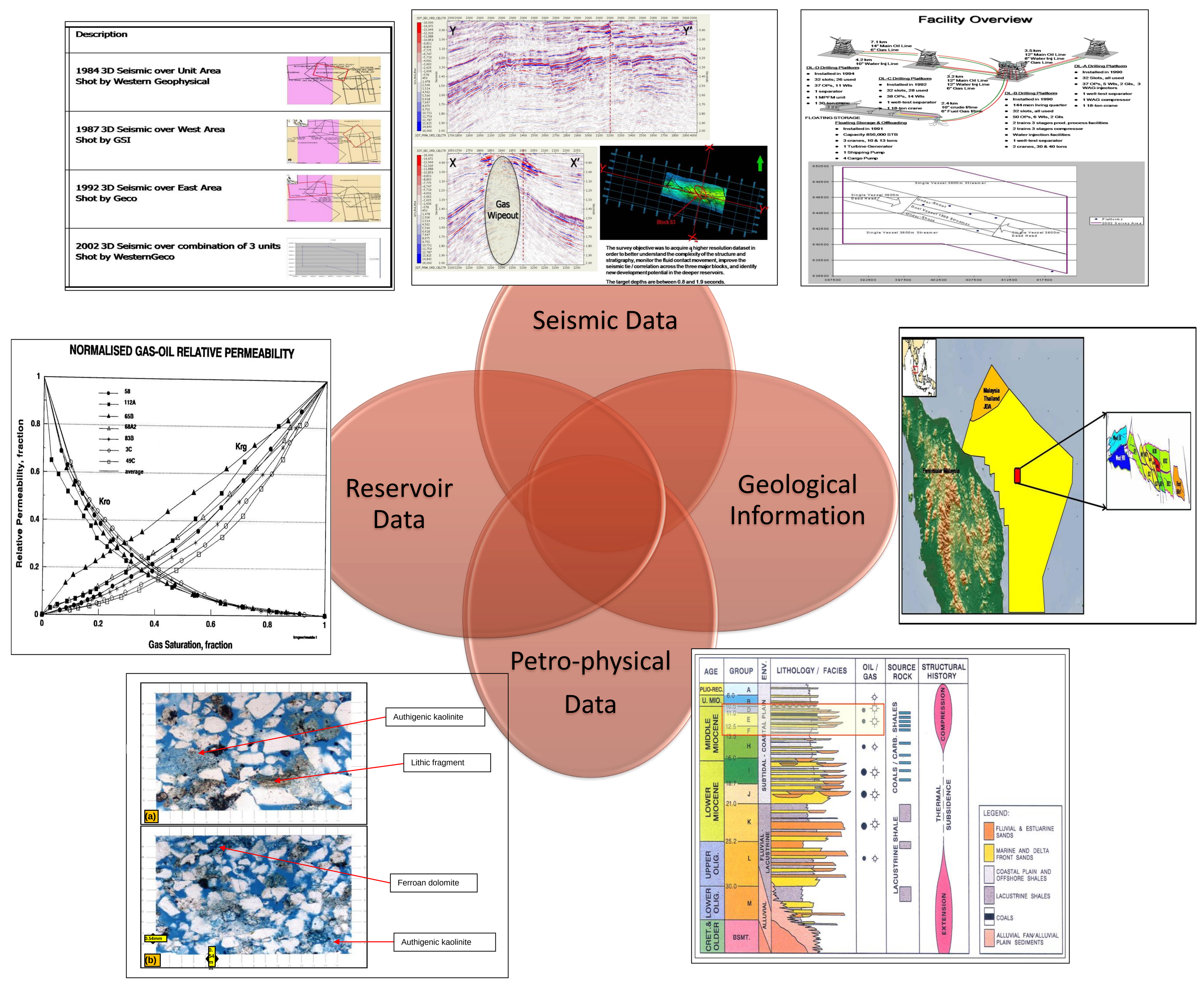
Summary

The integration of geoscientific and reservoir engineering data is critical for reservoir characterization and management in the mature oil field. The flood front movement monitoring through Immiscible Water Alternating Gas (IWAG) injection is a major challenge due to sparse well locations and reservoir heterogeneity. The selected field was discovered in 1981 and is on production since 1991 with cumulative production around 20% of STOIIP. A pilot IWAG injection project was carried out in the sub-block of the main reservoirs for a period of four (4) years successfully as one of iniatitives for enhanced oil recovery (EOR). As a result, full field injection plan has been formulated.

For effective reservoir management, it is very important to detect and monitor IWAG injection effect. In order to understand the potential uncertainty and for effective planning prior to actual project implementation, a time-lapse seismic feasibility study was carried out. Rock physics modeling played a critical role for establishing the relationship between elastic properties and pressure/saturation effects simulated in dynamic reservoir modeling. It has been observed that two years IWAG injection cycles may lead to cumulative acoustic impedance changes of 6%-8%. The present study identifies the factors contributing to the chances of success (COS) of the project. . The time-lapse seismic feasibility outcome ensured both technical and economics success and further prompted for monitoring of full field implementation IWAG injection.

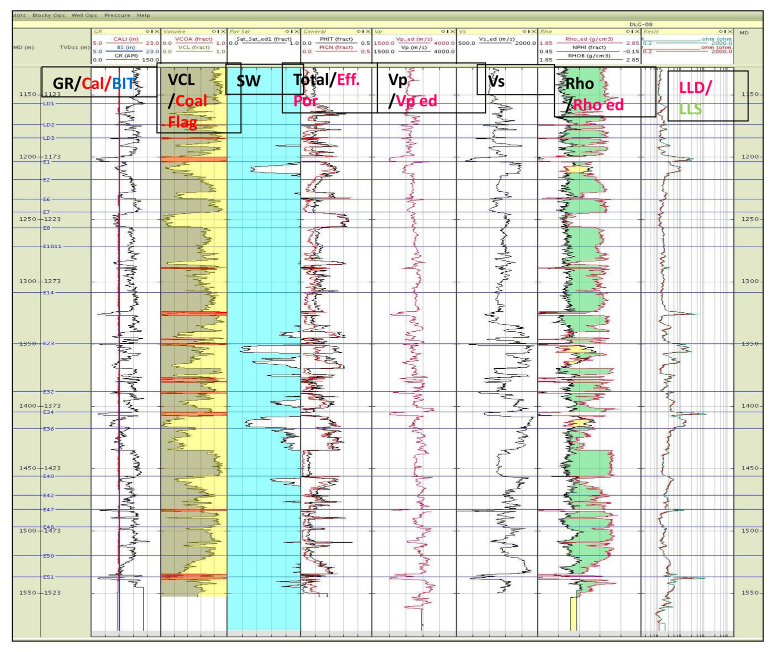
1: Input Data

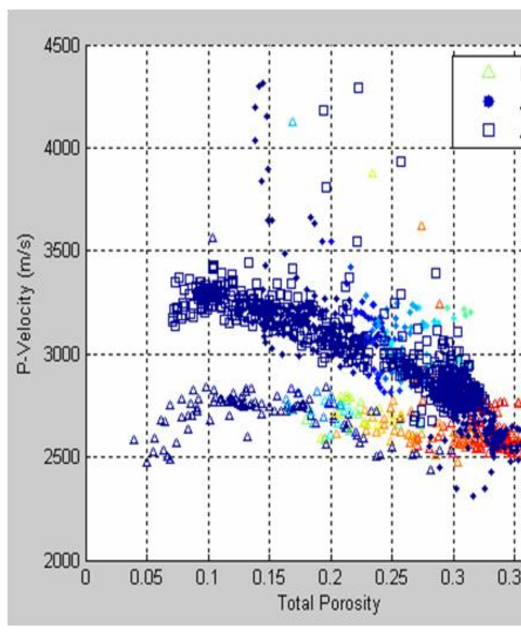


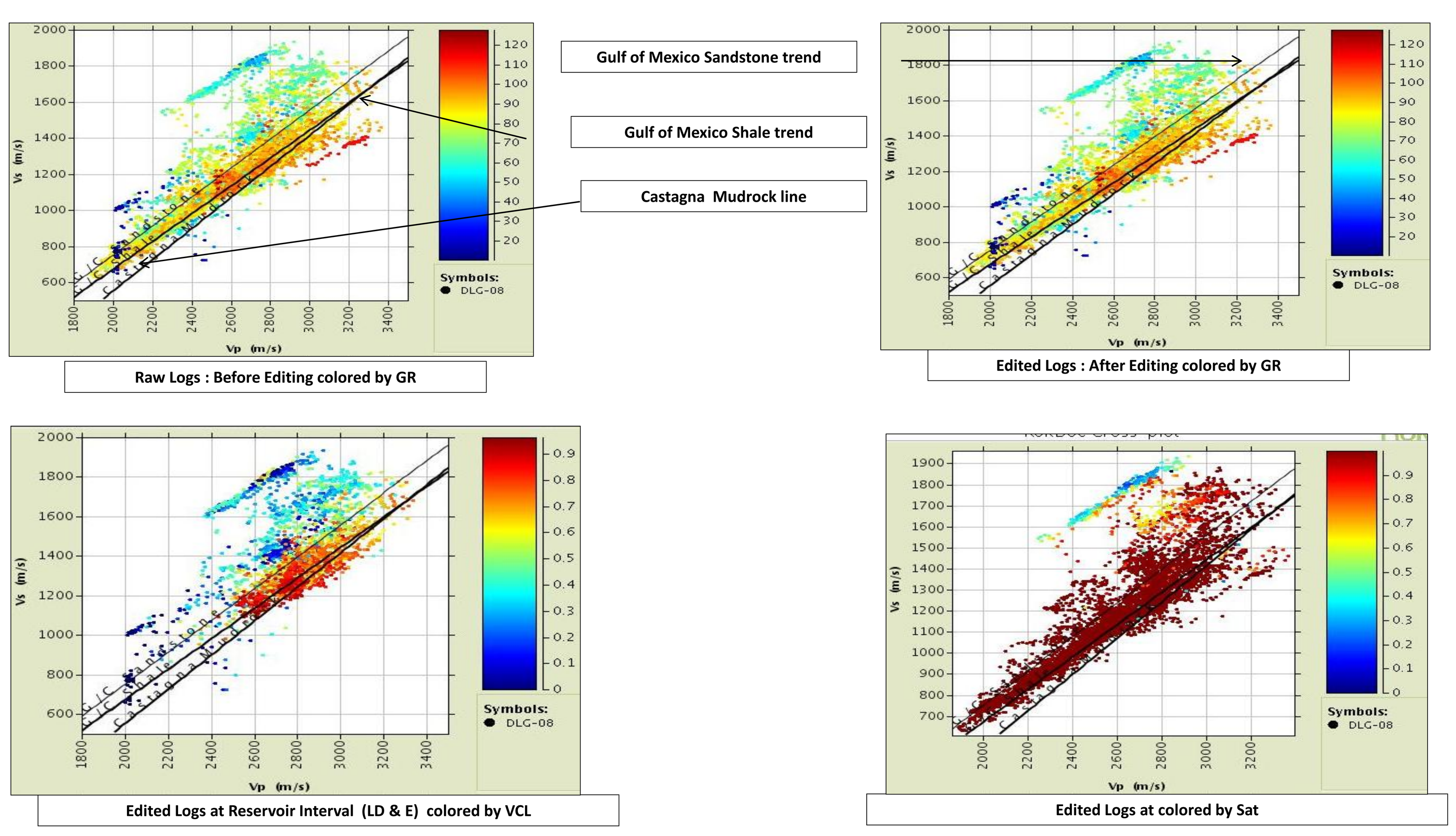
The chosen oil field located in Malay basin , offshore Peninsular Malaysia. There were 20 wells out of 140 wells selected for this study based on certain criterias. Also few seismic vintages acquired but only the latest vintage 2002 was suitable for this study.

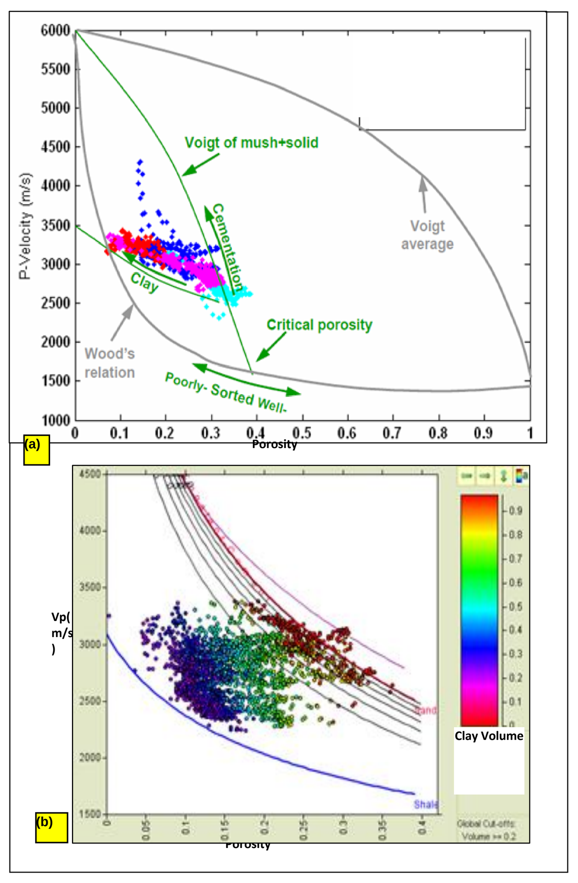
An integrated team compromising acquisition, processing, interprettaions, formation evaluation, rock physics, reservoir modelling and reservoir engineering involved and contributed in this study.

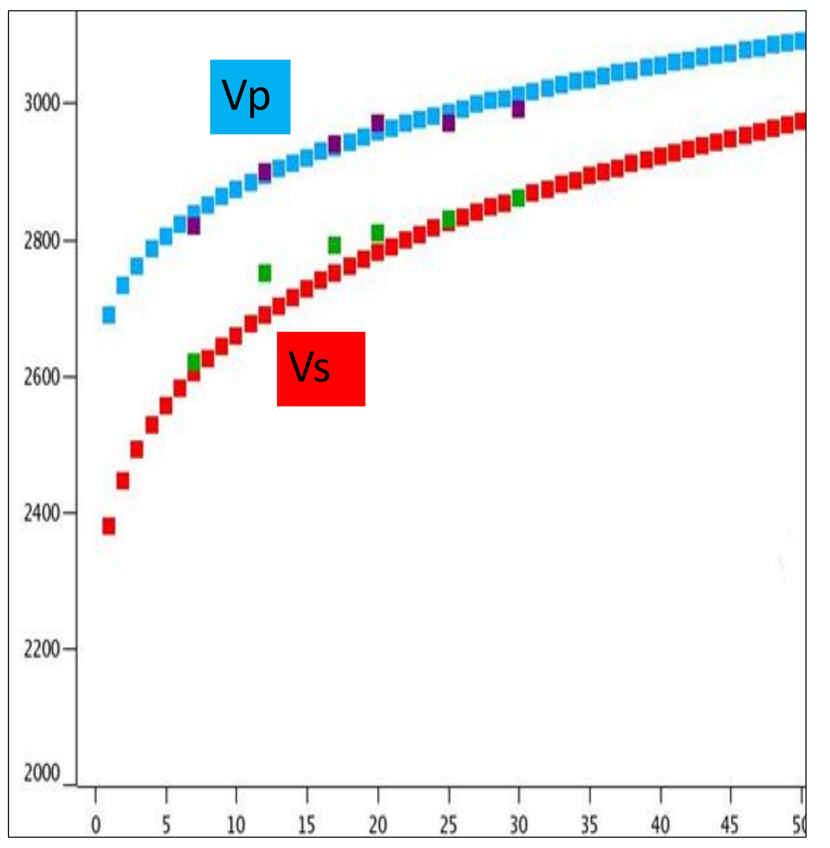
2 : Data QC & Rock Physics









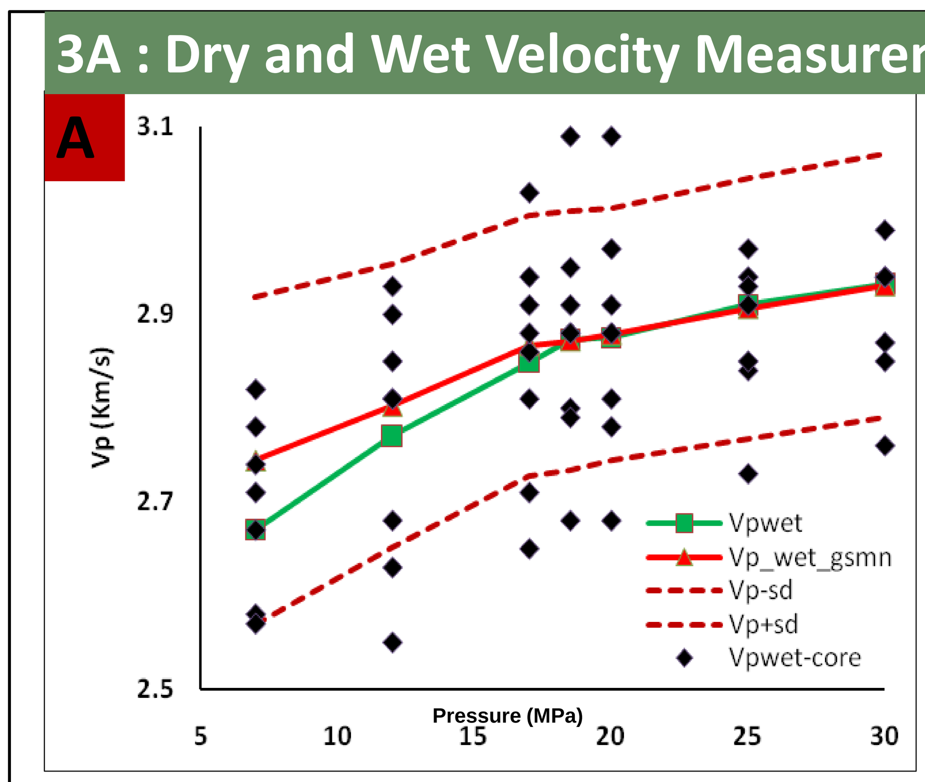


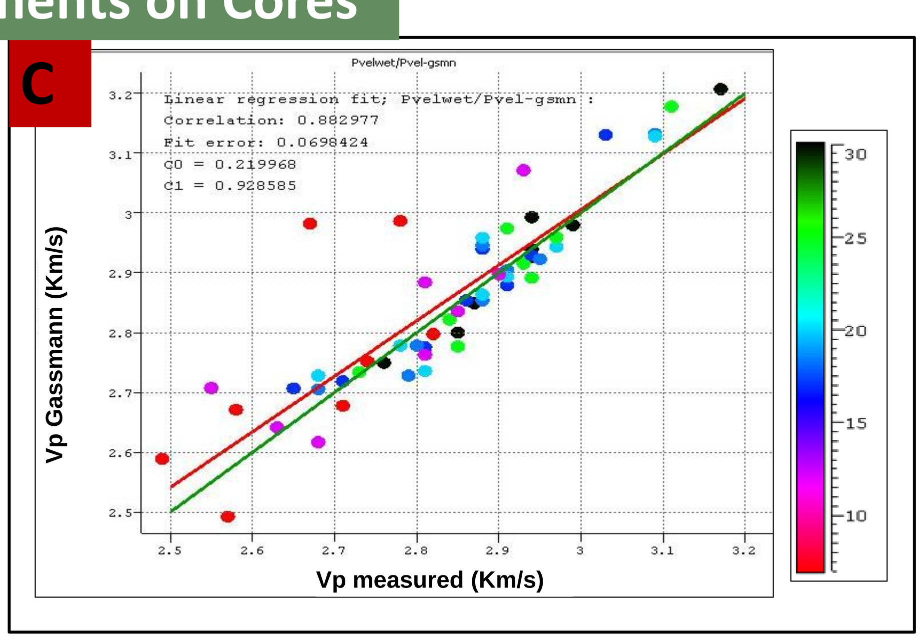
The rock physics analysis is the platform to relate rock properties, geological depositional environment, core information and production related pressure-saturation changes with seismic amplitudes. There were three following basic objectives for rock physics modeling:

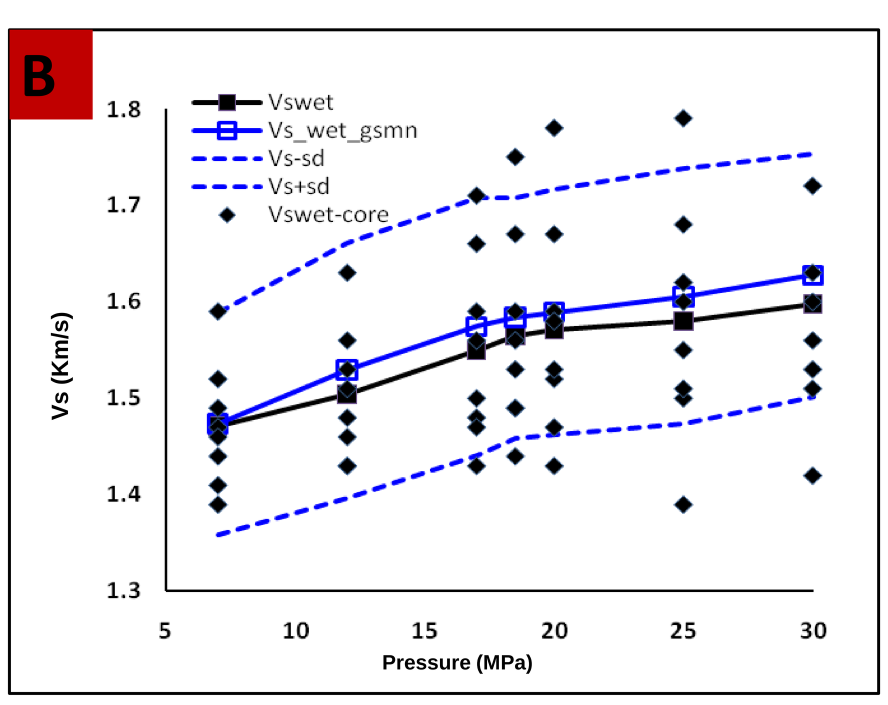
- Well log editing
- Shear log prediction
- To establish rock physics transforms between elastic properties: P-velocity, S-velocity and density with Pressure/saturation varation.

Several rock physics models analysis indicated that "Unconsolidated Sand Model" (by Dvorkin and Nur, 1996) explains rock properties varation in the study area. The rock physics models results were also validated with core analysis

3A : Dry and Wet Velocity Measurements on Cores

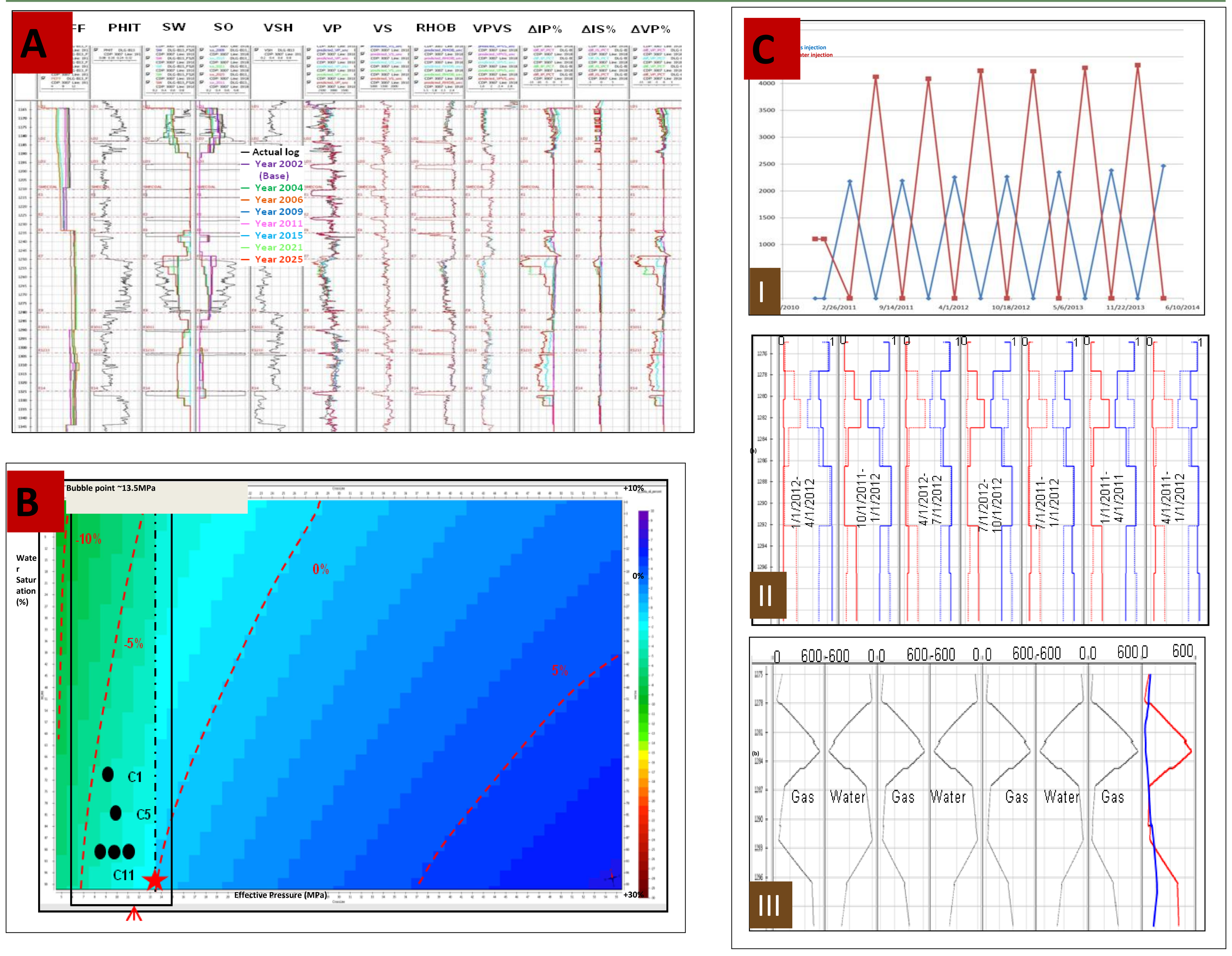






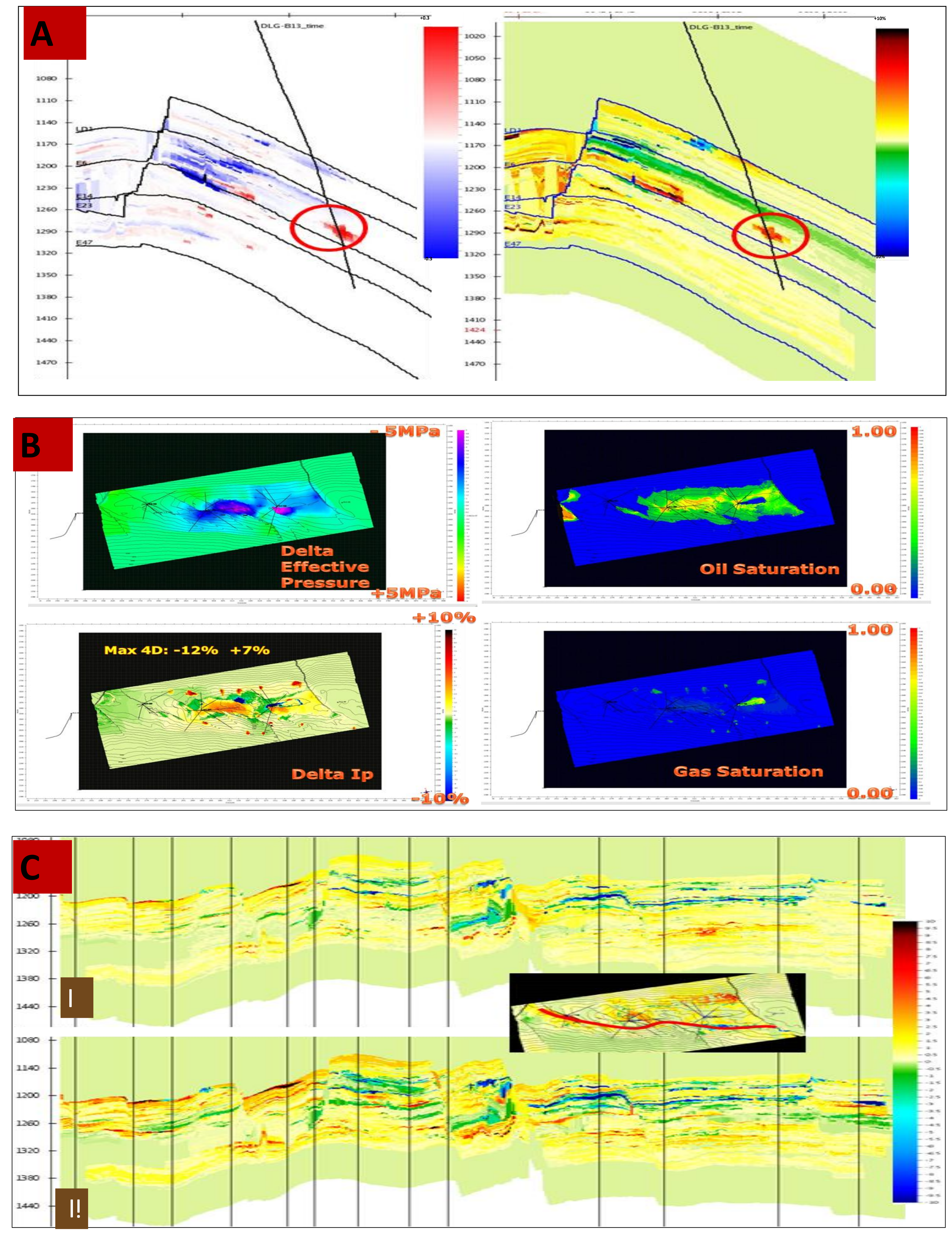
(A) and **(B)** Velocity versus effective stress response of core data of core plugs from two wells. Dots indicate core measurements for brine saturated plugs. Solid curves judge against core and predicted response using Gassmann equation. **(C)** Vp predicted versus Vp measured cross plot as validation QC for Gassmann fluid substitution. Green curve is the line for perfect prediction. A red curve is the linear regression indicating 88% correlation between measured and predicted velocities.

3B : Time Step Analysis, Periodicity and IWAG Injection Response To Ip Variation



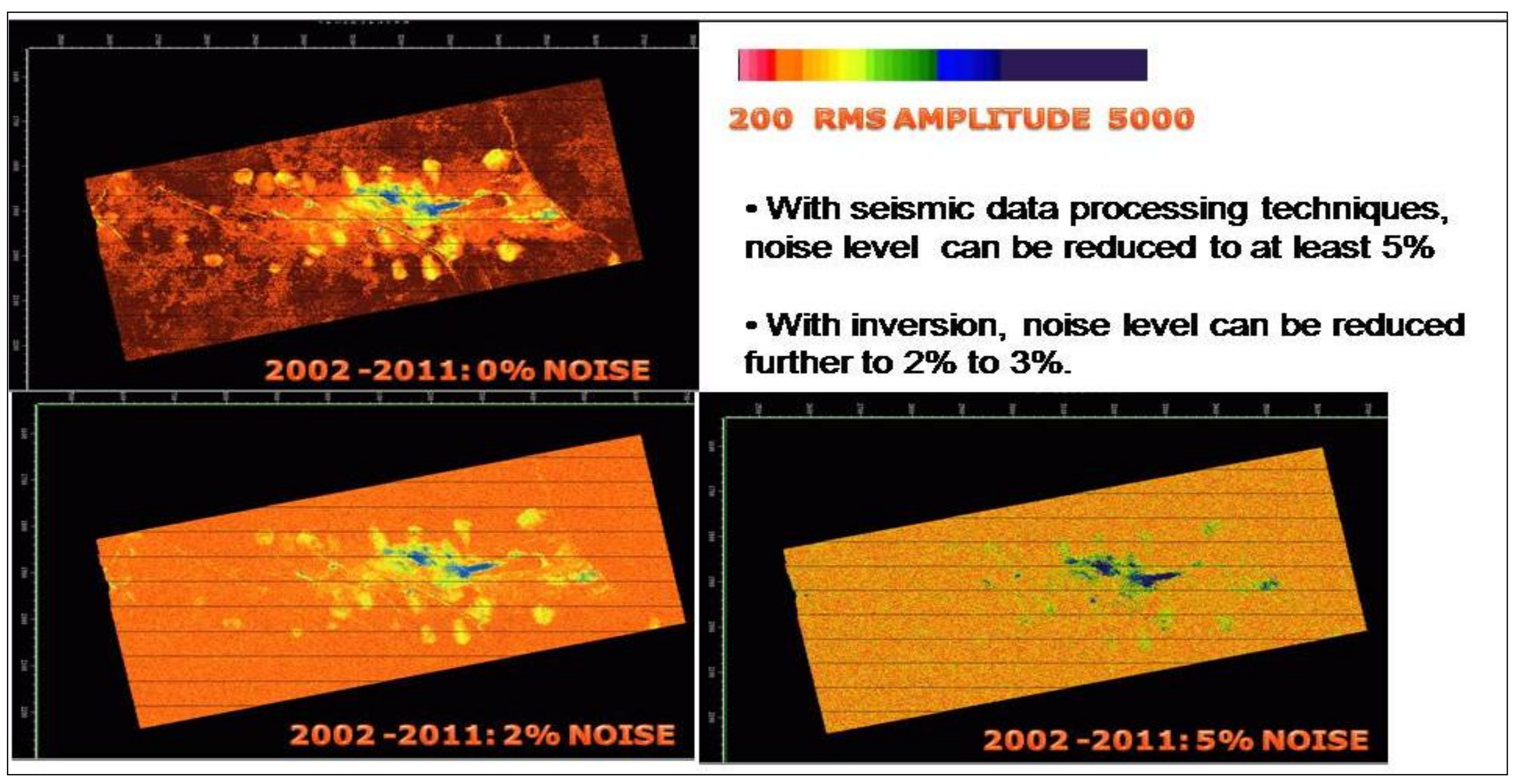
A : Varitaion of Ip, Is and Vp for injector and producer well calculated from the difference between specific vintage and the reference base case (Year 2002)
B : Acoustic Impedance change with bubble point modelling
C : (I) Volume of fluid injection increases with time. (II) Saturation curves at various stages of WAG injection. (III) Acoustic impedance changes observed due to each WAG cycle. Red curve in right most panels indicates cumulative effect due to seven cycles and blue curve indicate 6 cycles cumulative responses.

4 : Time Lapse Seismic Response From The Simulation Model



To analyse the 4D signal few attributes volumes for selected vintages were generated for reservoir intervals by using 2002 as a base reference.
A : Cross section view of Delta Sw and Delta Ip from 2002 to 2011
B : Pressure, Saturation and Impedance contrast based on dynamic reservoir modelling input
C : Arbitrary line (inset map) Delta Ip cross section view (I) from base to 2009 (II) water replacement with oil

5 : Seismic Noise Analysis



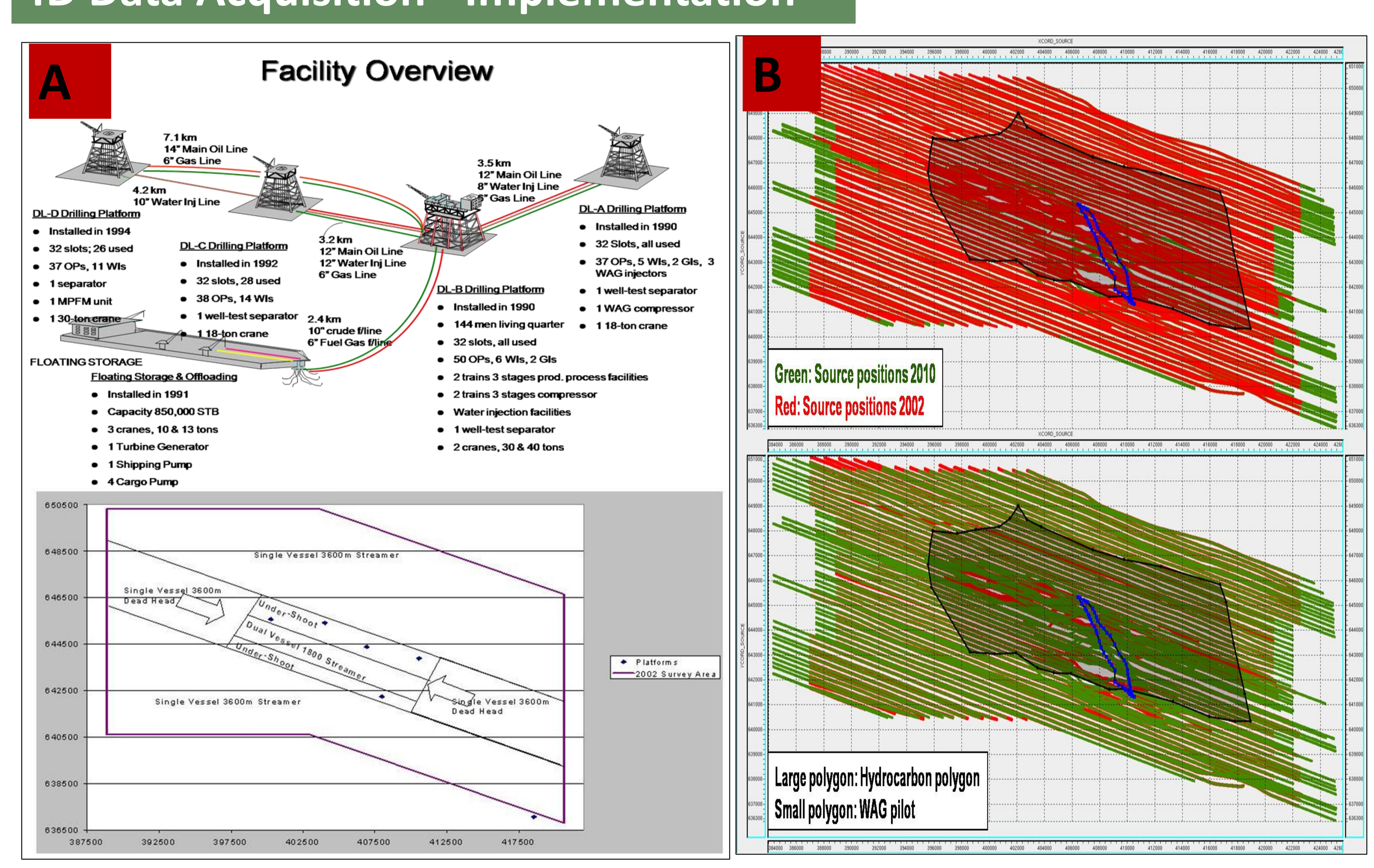
Random noise analysis was analyzed at the reservoir level with dominant frequency of 35hz. 0%, 2% ,5% and 10% random noise were modelled and synthetics produced. With 5% random noise 4D anomalies are detectable.

Positive response from feasibility lead to actual 4D implementation

A: 4D acquisition (100%)

B: 4D PreSTM processing in on going (80%)

4D Data Acquisition - Implementation



A : Seismic survey design challenges due to production facilities
B: Repeatability analysis of base survey (2002) and monitor survey (2010)

Conclusion

Time-lapse feasibility study through integration of G&G and reservoir engineering data indicated that more than 5% change in acoustic impedance is expected. The rock physic model is quite sensitive to uncertainties in input data and field wide heterogeneities but this do not alter the fundamental finding that the 4D seismic response is significant. The calibration of rock physics model prediction with laboratory measured Vp and Vs as a function of pressure and saturation boosted the confidence.

The time-lapse signal is driven by the saturation variation and due to fluid contact movement, however, the pressure impact is limited if it is above bubble point. It has been observed that feasibility analysis results are highly sensitive to lateral variation in reservoir properties across complete study area as well as to uncertainties in measurements. The predictions are sensitive to the presence of fizz gas in the oil column due to pressure drawn down bubble point that will require careful quantitative interpretation of the reasons of any observed time-lapse signal. The drop in acoustic impedance remains higher than 3%. For IWAG monitoring, it is recommended to have 4D monitor survey every two years after the start of injection.

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