From Thin Section to Seismic Constraint: example from 2 Carbonate Reservoirs in the Middle East

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1. Introduction

This presentation aims at demonstrating the methodology and know-how developed by Beicip-Franlab to integrate all pertinent data into 3D reservoir models. All disciplines such as sedimentology, petrophysics, log analysis, reservoir engineering or geophysics can actually contribute to a better definition and 3D distribution of the rock properties that control the flow behavior within carbonate reservoirs.

The first challenge consists in integrating data from cores and thin sections (sedimentology), plug (CCAL, SCAL), logs, reservoir engineering data (production logs, well tests...) to derive the Reservoir Rock Types that are the building blocks of the reservoir models. The second challenge consists in linking the Reservoir Rock Types with 3D seismic data, so that the seismic derived information can be used to constrain the distribution of reservoir properties in between the wells.

Two examples from two giant carbonate reservoirs in the Middle East are presented to describe how these challenges were successfully achieved.

2. Integrated Reservoir Rock Types Definition – Case study 1

This example illustrates an integrated rock typing workflow leading to enhanced 3D models. The work is based on the integration of several tools which optimize the contribution of all available data:

- A specific thin section methodology
- A sophisticated log derived electrofacies calibration approach, incorporating sequence stratigraphy rules;
- An enhanced calibration approach based on dynamic data.
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It is illustrated by an application to the lower cretaceous carbonate reservoir which contains high permeability thin streaks.

In this case, the first step consisted in describing more than 8000 thin sections in order to define the so called “Candidate Rock types”. At this step, the “candidate rock types” integrate sequence stratigraphy rules, depositional and diagenetic environments, and CCAL data, so that they have a strong geological and petrophysical consistency. In a second step, the “candidate rock types” defined along cored wells only (from thin sections) were used as “training samples” to calibrate the log response. It was then possible to define electrofacies along all (non-cored) wells using a supervised discriminant analysis implemented in Easytrace® IFP software. The use of micro-resistivity log together with sequence stratigraphy rules was determinant to locate the thin high permeability streaks. In a third step, electrofacies were merged into a reasonable number of final Reservoir Rock Types, based on CCAL and SCAL data. Finally, dynamic data such as TDT/PDK and AFL/WFL logs and well test analysis are used to improve the determination of high permeability streaks. These final Reservoir Rock Types were then distributed into realistic 3D models, reliable enough for initializing the fluid flow modeling.

3. Incorporating seismic characterization into 3D models – Case study 2

This example shows the use of 3D seismic data to constrain the 3D Reservoir Rock Types distribution within a carbonate (limestone / dolomite) reservoir.

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In this case, the first step consisted in defining integrated Reservoir Rock Types, as previously described for the first case study. Eleven rock types were then defined from core and thin section description, CCAL, SCAL, log… and propagated along all non-cored wells using Easytrace® software. In a second step, an attempt was made to extract reservoir property information from the seismic data, in order to address the lack of inter-well control points. Using optimally reprocessed existing 3D seismic data (to eliminate noise and preserve relative amplitudes) and pre-stack elastic inversion, advanced reservoir characterization techniques yielded volume data including lithology, lithology probability, and porosity that could be used as geo-statistical constraints.

Initially, a detailed petro-elastic analysis was performed on select wells to calibrate well-derived elastic properties with seismic data in order to design the most appropriated seismic characterization workflow. The results demonstrated that acoustic and elastic impedances could be used to discriminate Calcites, Dolomites, and Anhydrites. Well analysis also indicated a robust relationship between impedance and porosity and each dominant lithology. Subsequently, a pre-stack inversion was conducted prior to 3D discriminate analysis to produce dominant lithology and associated probability volumes. Following this, seismic reservoir characterization resulted in generation of a lithology based porosity volume.

During geo-statistical modeling, dominant lithology probability volumes were used as a co-simulation parameter for generating a facies model, and the seismic porosity volume was used as co-simulation parameter for porosity distribution, resulting in a high-resolution static model of the reservoir.

This work demonstrates the added value of pre-stack seismic reservoir characterization for modeling of carbonate reservoir. In addition to porosity, this technique gives light to lithology changes throughout the reservoir, providing otherwise unobtainable information of rock-type distribution.

4. Conclusions

Beicip-Franlab has developed an integrated methodology to define Reservoir Rock Types, which integrate data from all available sources. In some cases, Reservoir Rock Types properties can be integrated with seismic reservoir characterization. 3D seismic derived information can then be use to constrain reservoir modeling.

This method has been developed and successfully applied in carbonate environments in the Middle East where Beicip-Franlab has now a large experience in Rock Typing.