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OPTIMIZING RESOURCES

A Geomodeling workflow used to model a complex carbonate reservoir with limited well control : modeling facies zones like fluid zones.

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Summary

A methodology is presented to build a carbonate reservoir geomodel for a shelf margin which has 3D seismic coverage, but limited well control. The originality of this workflow lies in the approach to modeling the facies distributions. The use of geostatistics alone is inadequate because of the limited well data. Instead, the authors construct a geological model of the prograding carbonate shelf margin based on the interpretation of a series of seismic clinoforms, each of which represents a vertical succession of facies zones. To model these facies zones, we model the geometry of the surfaces between them. Firstly, the surfaces separating individual facies are defined within the limited number of clinoform units for which well control that exists. These surfaces are then extrapolated into clinoform units that lack well control. The facies modeling approach that is used is technically equivalent to modeling fluid contact surfaces from the fluid contacts picked on well data.

Introduction

Plurigaussian simulations are an efficient way to model facies distribution in a prograding carbonate depositional environment because these geostatistical techniques can take into account the spatial relationship between facies (Armstrong et al., 2011). Unfortunately, such approaches may not be applicable in a field where very few wells have been drilled since the geostatistical algorithms cannot be properly constrained. Instead, in the example described in this paper we model the facies using the approach traditionally applied to model fluid zones. The facies zones are not modeled per se but by using well facies logs as constraints the surfaces representing the limits between facies zones are. The resulting facies model is capable of accuratley capturing the geological context that has been defined by the geologist and demonstrates that geomodeling can still be a powerful tool even when the use of geostastitics is limited due to a lack of well data.

Modeling facies zones like fluid zones

In concept the reservoir consists of a succession of clinoforms which each have a vertical succession of facies as shown in Figure 1. Within each clinoform, there is a vertical facies succession from ramp to grainstone to reef. The thickness of each facies unit can differ from one clinoform to the next. Although the true surface between any two facies zones is almost certainly not flat in reality, due to the limited well control that is available, it is prudent at this stage to make the assumption that the limits are flat.

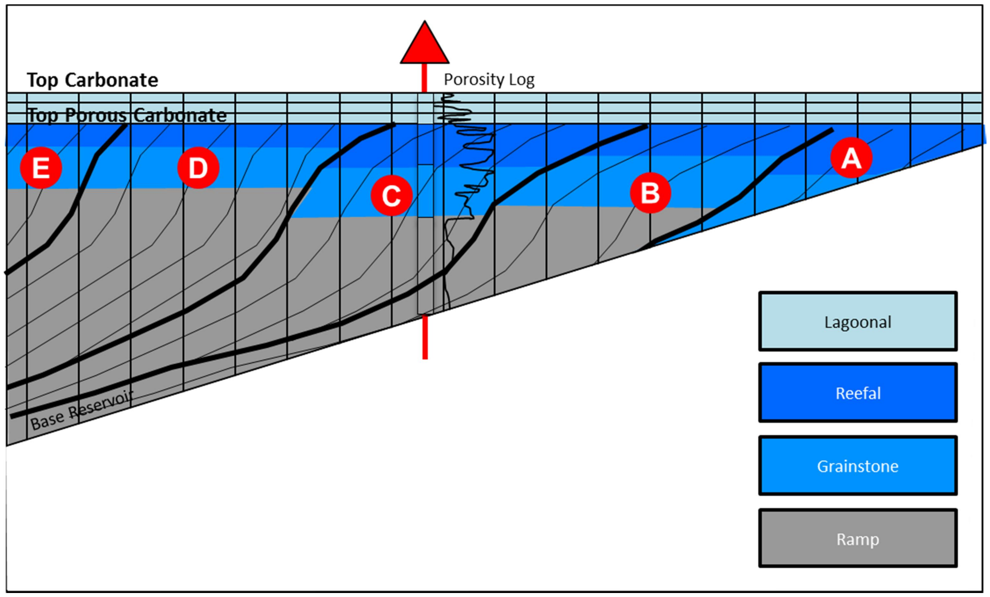

Figure 1. Geomodeling Methodology - Geometry of the 3D Grid Mesh.

Conceptually, one can compare the limits of these facies zones to fluid contacts within a compartmentalized, block-faulted reservoir. In such a reservoir we may find a succession of gas, oil and water contacts from top to bottom, with different fluid thicknesses within each fault block (assuming the faults are sealing). Fluid contacts defined by wells within each fault block can be extrapolated throughout the fault block. This presents us with at least a couple of problems. Firstly, some fluid contacts may not be true fluid contacts. Secondly, not every fault block has a well to provide all the fluid contacts. We must differentiate a true OWC (oil-water contact) from a water-up-to or oil-down-to marker. For every fault block with an existing well, not every well will encounter a contact (i.e. some wells may be gas or oil only to TD (total depth), whilst others may drill through the gas leg into the oil leg; defining only a gas-oil contact and not a gas-water or oil-water contact, or the well may be wet and not define any true contacts at all). The geomodeler can capture this uncertainty by defining a base case depth for each contact within each fault block and then associate a specific range of uncertainty to each.

Coming back to our prograding clinoform model the surfaces delimiting the individual clinoforms can be thought of as “faults” in the model, as shown in Figure 2. Instead of fluid contacts along the wells, facies zone boundaries/contacts are picked. The same challenges found in modeling fluid zones also occur here. Some facies contacts may not be true facies contacts and not every clinoform has a well to provide all the facies contacts.

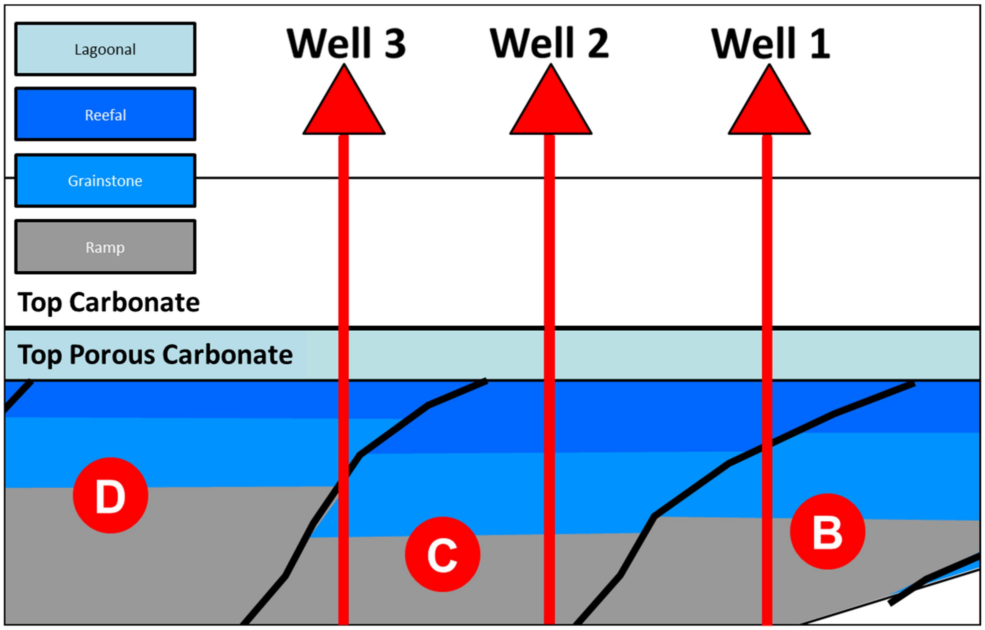

Figure 2. Geomodeling Methodology - Identifying Depths for the Limits between Facies.

The example shown in Figure 2, demonstrates some of these challenges:

- Well 1 shows two facies contacts. The lower contact between Grainstone and Ramp facies, is a true facies zone contact within clinoform B. The upper contact is an apparent contact which only exists because the well crossed from clinoform C to clinoform B.
- Well 2 shows two facies contacts. Both of these facies contacts are true contacts and show the limits between Reefal, Grainstone and Ramp facies within clinoform C.
- Well 3 shows two facies contacts. The upper contact from Reefal to Grainstone is a true facies contact within clinoform D. The lower facies contact from Grainstone to Ramp is also a true contact, but on clinoform C. As the Grainstone facies encountered by the well is in both clinoforms C and D, the entire thickness of the Grainstone facies within either clinoform is unknown from this well alone.

With these three wells, missing pieces of information on facies thicknesses in clinoforms B and D can be extrapolated from clinoform C. Ranges of uncertainty can be statistically added to each base case facies limit and multiple scenarios of facies thicknesses can be analyzed.

This technique of facies modeling was applied to the workflow used to model the prograding shelf margin in our geological model.

Geomodel Case Study

The subject oil and gas field for the study is located in the hanging-wall of a large thrust fault. 3D seismic data was acquired over the entire field in 2013 and is calibrated using six wells. Data-quality in the hanging-wall is excellent and three seismic horizons representing Top Carbonate, Top Porous Carbonate and Base Reservoir were used to constrain the geomodel.

A full suite of wireline logs and VSP data is available for each well. Facies descriptions and petrophysical studies (Figure 3A) conducted on each well shows that the reservoir is a highly heterogeneous system (Figure 3B) which is characterized by clinoforming units on seismic data (Figures 3C and 3D). Each clinoform shows the facies succession of Reef, Grainstone and Ramp from the north-east to the south-west.

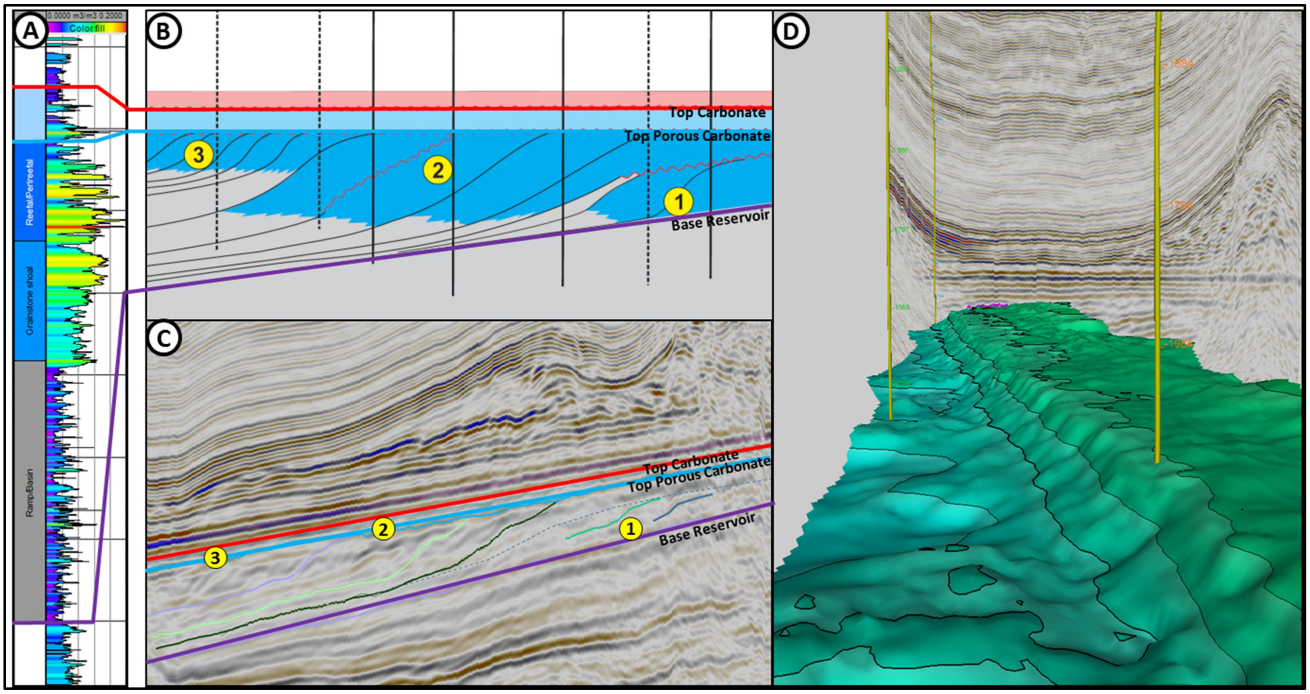

Figure 3. Model Inputs - (A) Facies Descriptions; Petrophysical Analysis; (B) Conceptual Geological Model; (C) Interpretation of Clinoforms on a Flattened Seismic Section; (D) 3D view of a Clinoform in the Flattened Domain

The goal of the project was to use the well data and seismic interpretation (fault, horizons and clinoform surfaces) to populate the petrophysical properties in 3-D. Since each facies type has a distinct range of porosity values, in order to properly model porosity distribution the facies distribution was modelled first. The modelled area extends to 450 km2 and with only six wells drilled to date; geostatistics alone cannot adequately model the facies distribution. To overcome this limitation the method described in the previous section was applied.The steps in this workflow were as follows:

1. Key seismic horizons (Top Carbonate, Top Porous Carbonate and Base Reservoir) and the thrust fault surfaces were picked on the 3D seismic data and surfaces were created to constrain the model.
2. The seismic data, interpretation and wells were flattened on the Top Carbonate horizon to aid picking of the clinoform surfaces in what approximates to the flat depositional space. The analysis of the change of facies along the well is also performed this space since surfaces delimiting facies zones approximate to being flat in the depositional space.
3. The key surfaces, clinoform surfaces and facies limit surfaces are converted back to the present-day structurally deformed domain.
4. Each clinoform is modeled as a geological unit in the 3-D grid (Figure 4). The mesh of the 3-D grid is parallel within each clinoform to its associated upper clinoform surface and the facies limit surfaces are used to assign a facies code to each cell of the 3-D model.
5. Sequential Gaussian Simulation (SGS) is used to distribute the porosity in each facies zone within each clinoform.

It can be seen in Figure 4 that the resulting geomodel captures the initial geological concept very well.

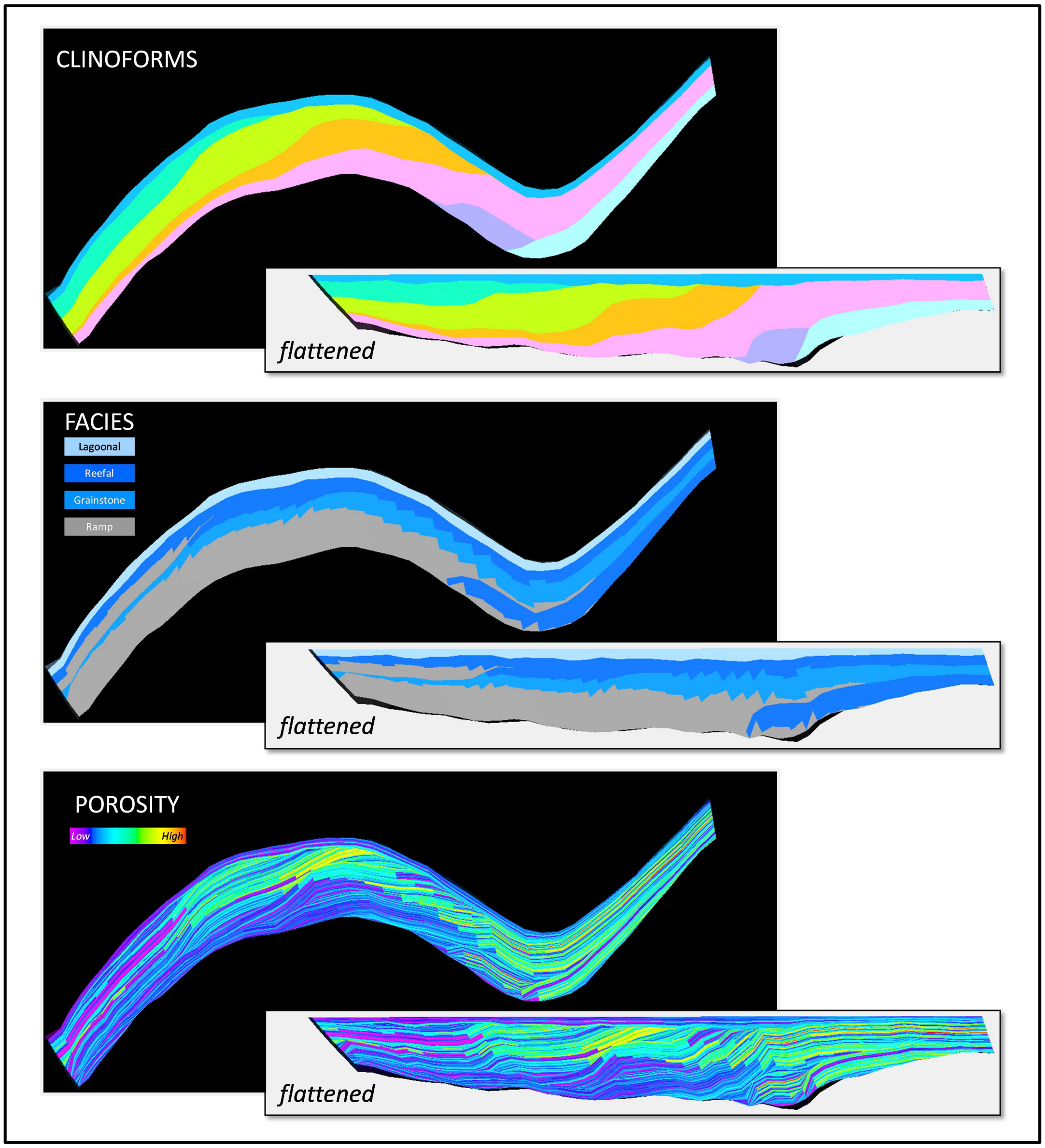

Figure 4. Cross-section through the Geomodel showing (A) Clinoform Geometry (B) Facies Distribution and (C) Porosity Distribution.

Conclusions

Geostatistics are an essential toolbox in the geosciences. However, their use can be restricted in certain geological settings and stages of project maturity. Sometimes, the best approach may be to utilize a more deterministic base case model and capture uncertainties within the model using geostatistical distributions around the base case. This philosophy was applied here to model the facies distribution within a folded and faulted carbonate shelf margin in which few wells are available. Future work on this dataset will include modeling fractures and running models for flow simulation.

Acknowledgements

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References

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