Volumetric Characterization of Reservoir Using the Multilayer Approach

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Introduction and Objectives

- Nowadays in the reservoir characterization process the access to uncertainties due to estimation of the oil in place volume is one of the main questions that need to be solved.

- Classically modeling of each horizon is accomplished through a sequential estimation process, where the solution consists in the individual processing of each surface beginning the process from the reference surface.

- This approach is correct for the shallow layers and when we have vertical wells but in the case where we have deviated wells, the information is fuzzy leading to increase the uncertainty (Figure 1). Then for the deeper layers the more imprecise information will be used increasing significantly the variance of the estimation which may induce a bias in the estimate of volumes above contacts.

- This approach results in additional errors, because the fundamental relationships between the different zones of the reservoir are ignored.

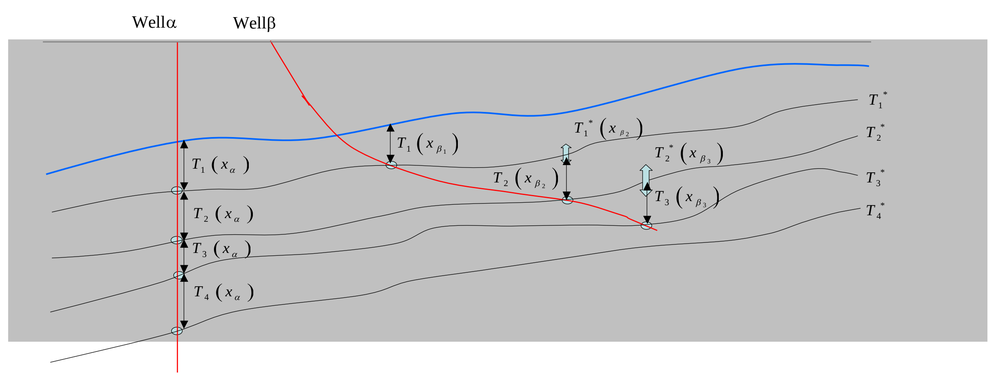

Figure 1: *Sequential processing of the horizons considering the estimated top of each layer as known when estimating its bottom.*

- The main objective of this work is to present an alternative approach to the sequential modeling of the layers of the reservoir, using a global, integrated and multivariate approach where the layers of the reservoir are modeled simultaneously and the relationships between the zones are considered.

Data and Methods

- For this work the Namorado Field is used to demonstrate how global methodology compares with the sequential approach.

- This dataset is made of 54 wells with the complete set of logs, among them 14 wells are vertical and the others are deviated.

- An alternative approach to the sequential approach consists in considering the model of the layers in a simultaneous way with the objective to respect the spatial correlations between the layers and to reflect in a more effective way the geological structure of the field.

- In this global approach the first step consists in a generation of a base case using for this cokriging based techniques.

- The key idea is the following:

Each thickness or interval velocity is cokriged from the cumulated thickness (or apparent velocity) from a reference surface by means of a **factorial kriging** where the cumulated variable is a weighted sum of the elementary variables lying between the top and the layer of interest.

When the top and bottom of the whole formation is given (resulting for instance from a time to depth conversion procedure) the sum of all layers is introduced as an additional variable used in **collocated cokriging**.

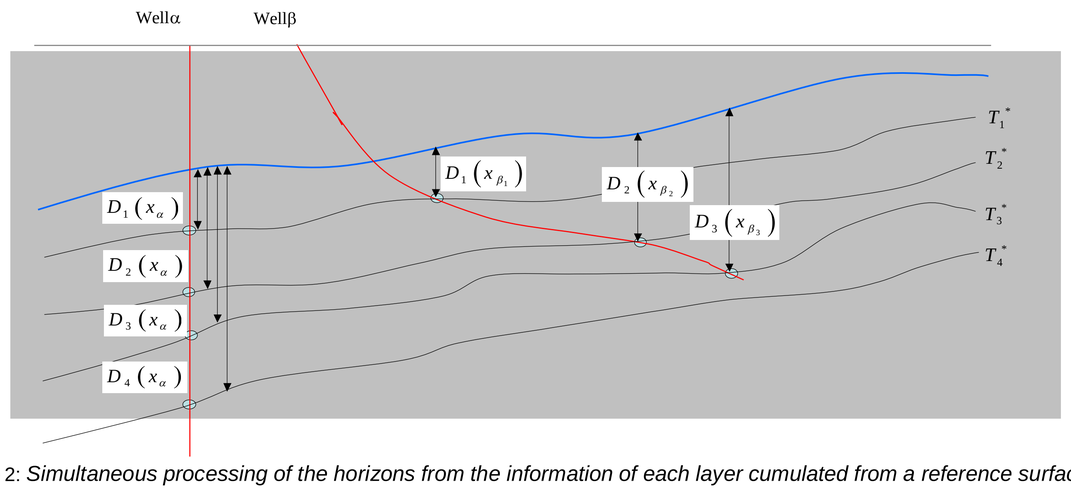

Figure 2: *Simultaneous processing of the horizons from the information of each layer cumulated from a reference surface.*

- After validation of the base case it is possible to apply simulation techniques to obtain the curves that show the volume distribution from many realizations of the same model.

- An important requirement of the method is the necessity to build a multivariate model from the information available and fit this model by a linear co-regionalization model.

Results and Discussion

At the end of the sequential process the zones are stacked to represent the general shape of the reservoir structure, as shown in the Figure 3.

We can observe that in some regions the modeled surfaces cross each other. These crossings are present because the surfaces are modeled in an independent way, hence the relationships between the surfaces are not considered. It implies that a **post-processing** is required to eliminate these inconsistencies. Furthermore when we want to constrain the sum of all layers to match the total thickness of the formation, all horizons a **global rescaling** has to be applied.

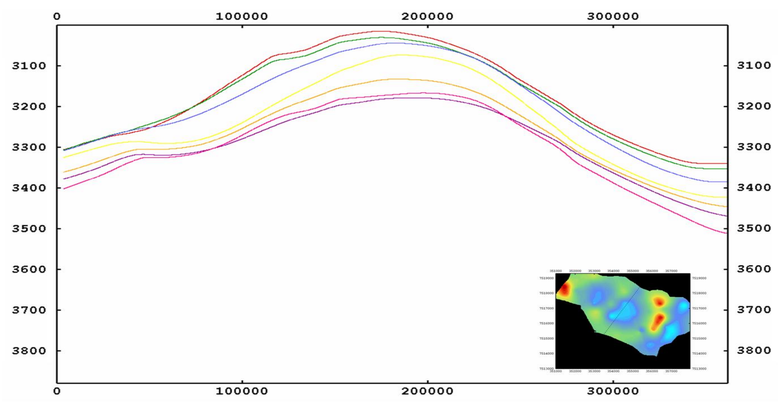

Figure 3: *Cross section showing the horizons interpolated using the sequential approach before any post-processing corrections*

In the global approach the surfaces are modeled in a simultaneous way as shown in the Figure 4.

It has to be noted that **no particular post-processing** is required to get a consistent model of the surfaces, particularly the sum of each layer matches, by construction, the total thickness of the formation considered as known, while it still honors the data (which was not guaranteed by the rough rescaling applied after the sequential approach).

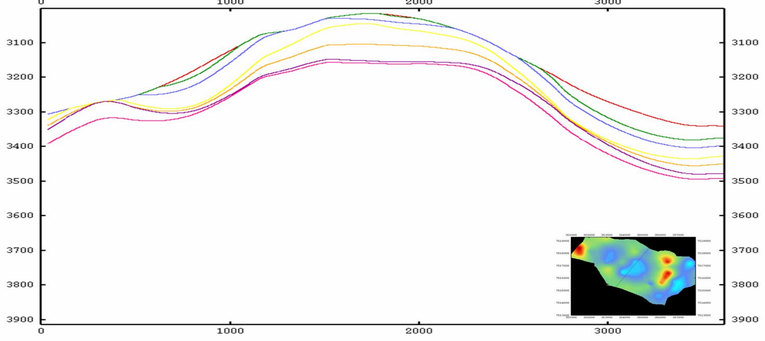

Figure 4: *Cross section showing the horizons interpolated using the global approach.*

After the base case has been obtained and the reservoir structure validated, the next step is to run geostatistical simulations (by turning bands method) to obtain the histograms of possible volumes of the different reservoir layers. We have here considered the oil-water contact as constant all over the field and the same for all layers. The same models have been used to run 50 simulations using the sequential approach then the global approach.

In the Figure 5, we represent a vertical section for one of the realizations, where it is possible to see the higher variability in the simulated surfaces for the sequential approach than the global approach. This may be explained because in the global approach the spatial relationship between the surfaces are used and more data are used to constrain the simulations.

We can also see an example for one layer of the distribution of the possible volumes from the 50 realizations of both approaches: it shows a significant difference in the average volumes that are here about 50% higher for the sequential simulations: it is the consequence of the arbitrary rescaling that may introduce a bias after shifting the surfaces away from the contact.

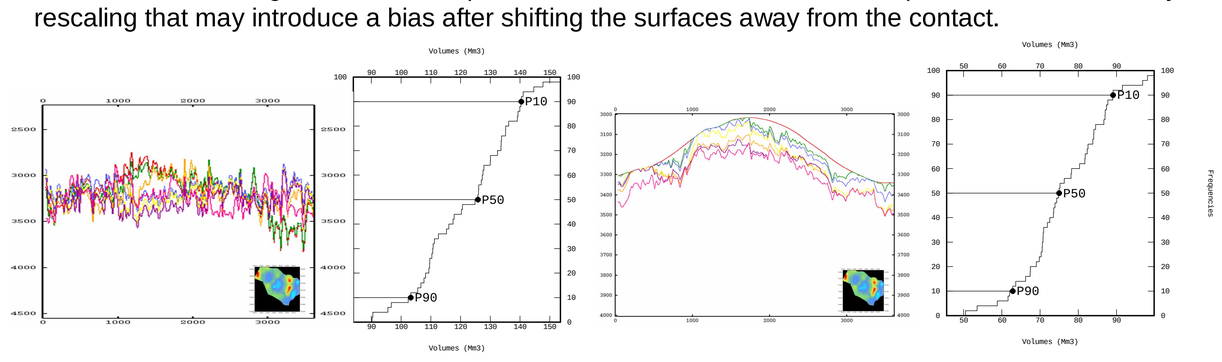

Figure 5: *Cross section showing the simulated horizons using the sequential (left)and global (right) approach, and the distributions of possible volumes for one reservoir layer from both approaches.*

Conclusions

- The global approach produces directly a geologically reliable model of the reservoir structure, without problems of consistency between the layers. It also guarantees that the sum of each layer matches the total thickness of the formation.
- Besides, by using all available information from the different layers and a model characterizing their spatial correlations, the uncertainty in the volume estimation is reduced. This global approach provides a powerful tool for the structural modeling and the volumetric characterization of the reservoir.
- The next step would consist in populating the different layers by petrophysical parameters, that could be kriged or simulated. It would then allow to assess the different uncertainties in the in situ oil recovery.

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