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Development of complex layered and fractured reservoir models

Manuel Gomes Correia

"The main purpose of this work is to develop a methodology to build robust simulation models for naturally fractured carbonate reservoirs with multi-scale geological characterizations."

Introduction

Linking geostatistical modeling of multiscale carbonate heterogeneities with representative simulation flow models is challenging as conventional upscaling procedures often disregard the complex dynamic behavior in reservoir simulation. This work presents a methodology to build robust flow simulation models considering: (1) multiscale geological scenarios based on carbonate reservoirs; (2) accurate representation of static and dynamic data in reservoir simulation; (3) an enhanced production prediction based on enhanced well completion. The methodology we present here is useful for multidisciplinary areas of expertise as it ensures the appropriate link between the fine scale geomodelling and the coarser scale reservoir simulation, considering the development of complex carbonate reservoirs. A detailed description for this work is presented by Correia *et al*, 2016.

Methodology

This work follows three elementary steps: (1) hierarchical upscaling procedure by flow units, (2) integration of flow units into a full reservoir simulation model, (3) validation of simulation model. The first step of this methodology defines the dynamic and static data in an inter-well region based on an hierarchical upscaling procedure. Correia *et al.* (2015) detailed the first step and its application (Figure 1).

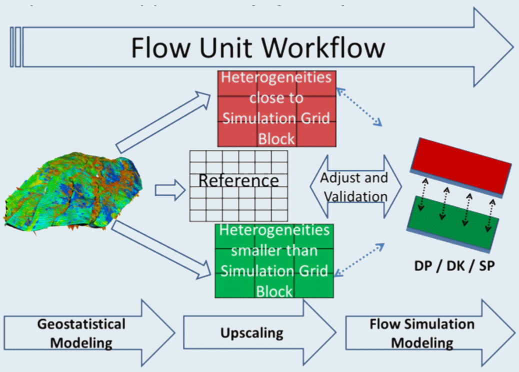

Figure 1: *Main drives for the hierarchical upscaling procedure (Correia* et al*, 2015).*

The second step consists in populate static and dynamic properties for the full simulation model. Commercial software based on geomodelling tools can be used for this procedure. First we must extrapolate the dynamic data and static properties defined in the inter-well region to each flow unit. This step uses the output information from the hierarchical upscaling procedure (Figure 2). The pseudo-dynamic data (capillary pressure or relative permeability) applied for upscaling matches and the upscaling method for discrete fracture networks (DFN) and matrix are valuable information to extrapolate the inter-well characterized region to the flow unit. As a flow unit is characterized by a close spatial petrophysical distribution and similar flow features, we can reasonably assume, for reservoir simulation purposes, that the upscaling procedure and/or dynamic data can also be very similar. We then integrate the defined dynamic and static properties, for each flow unit, into a full reservoir simulation model. Flow units, facies, or regions can be associated in simulation model by the *rock type* keyword. For each rock type we can link different types of rock/fluid data. The association of these data for each rock type is called extrapolation of dynamic data.

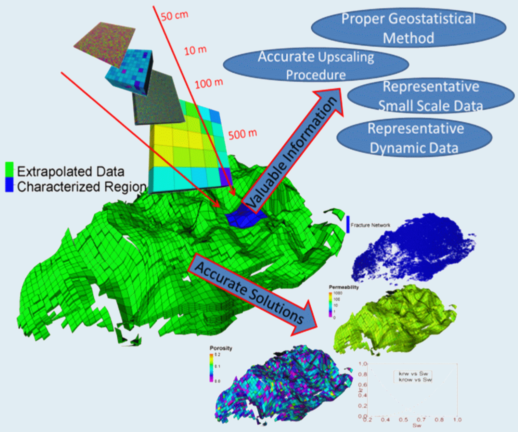

Figure 2: *Integration of static and dynamics properties into a full reservoir simulation model.*

Finally, we validate the numerical simulation model based on the numerical consistency evaluation and by applying an enhanced well position and completion based on the previous characterization.

Application and Results

Figure 3 shows a schematic representation of hierarchical upscaling procedure for flow unit C, as example. The upscaling procedure is separated by the dimensions of heterogeneities comparatively to simulation grid block size. For small heterogeneities, the upscaling procedure is applied to small models in order to use a refined grid block. The upscaling match is validated by histograms and virtual wells for dynamic matching. The procedure is the same for larger heterogeneities. In this case, the upscaling match is validated in an inter-well region, using the simulation grid block size. The numerical flow model is selected for each flow unit based on the qualitative

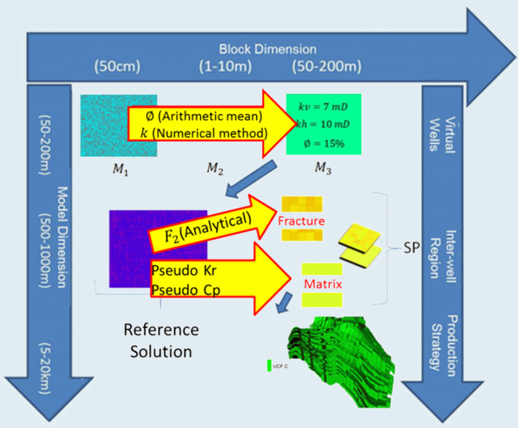

Figure 3: *Main results of hierarchical upscaling procedure for flow unit C (example).*

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analysis of flow behavior in the reference solution and based on matching procedures. At this stage, we apply the guidelines defined by Bourbiaux (2010) for selecting the proper flow model for fractured reservoirs.

After the hierarchical upscaling approach we calibrated three pseudo dynamic relative permeability curves, which characterize the inter-well region. Afterwards, these curves were extrapolated into each flow unit. Although each flow unit is geologically characterized by the same rock/fluid data, each one is characterized by different dynamic data after the hierarchical upscaling approach. The obtained result shows that a detailed characterization and upscaling approach is crucial for a suitable representation of geological heterogeneous scenarios and dynamic behavior in reservoir simulation. The full model is characterized by three different numerical flow models: (1) dual permeability for flow unit A, (2) dual porosity for flow unit B, and (3) single porosity for flow unit C. For validation purposes, producers were allocated in the top of the reservoir and injectors in the base of the reservoir to prevent water coning from an aquifer. The purpose of this step to show the influence of well placement and completion based on flow unit distribution. Figure 4 shows that well completion, exemplified by one well, for flow unit A, has better results than in flow unit C, with little difference for total completion (well perforated through the entire reservoir thickness) in the oil rate parameter, and a lower water rate than total well completion (Figure 5).

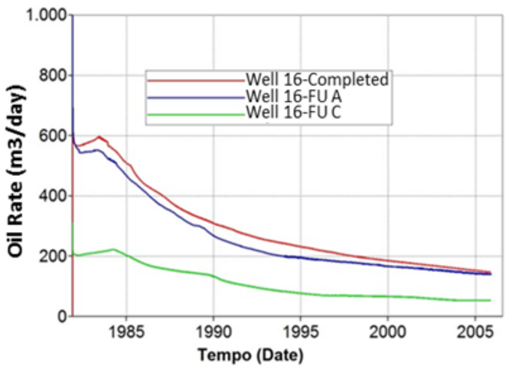

Figure 4: *Comparison between well completion in flow units A and C (oil rate).*

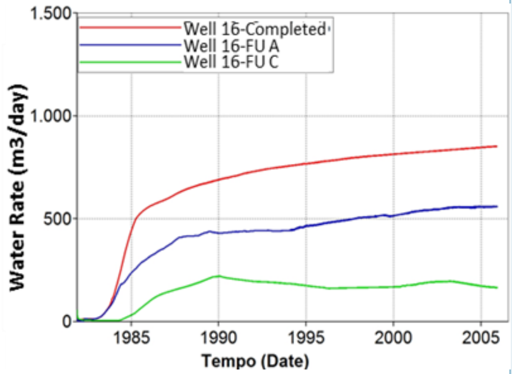

Figure 5: *Comparison between well completion in flow units A and C (water rate).*

Considerations

In addition to the advantages presented by hierarchical upscaling procedures for multiscale carbonate reservoir heterogeneities (Correia *et al*, 2015), this works extends the methodology to construct robust reservoir simulation models. The extension of methodology shows several advantages:

(1) Better representation of static and dynamic behavior from multiscale heterogeneities in reservoir simulation;

(2) Improvement in the selection process for the simulation flow model;

(3) Minimization of risk selecting a production strategy suitable for complex geoengineering scenarios;

(4) Contributions to enhanced well completion through better characterization of representative static and dynamic data for each flow unit.

This work presents a methodology that can be useful for multidisciplinary areas of expertise as it ensures the appropriate link between the fine scale geomodelling and the coarser scale reservoir simulation.

References

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About the author

Manuel Gomes Correia is a researcher from UNISIM, and is currently working with upscaling procedures and reservoir simulation applied to naturally fractured carbonate reservoirs.

Research in Reservoir Simulation and Management Group

Petroleum Engineering Division - Energy Department
School Of Mechanical Engineering
Center for Petroleum Studies
University of Campinas
Campinas - SP

Phone: 55-19-3521-1220
Fax: 55-19-3289-4916

unisim@cepetro.unicamp.br

For further information, please visit
http://www.unisim.cepetro.unicamp.br