[PS]Model-Centric 3D Petrophysical Application Technology*

Roger R. Sung[1] and Khalid Al-Wahabi[2]

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[1]Saudi Aramco, Dhahran, Saudi Arabia (roger.sung@aramco.com)
[2]Saudi Aramco, Dhahran, Saudi Arabia

Abstract

The complexity and heterogeneity of reservoirs makes it extremely difficult to characterize and predict recovery. Oil industry geoscientists and engineers have made strides in developing advanced petrophysical algorithms and formation evaluation techniques to understand the fluid flow mechanisms. These methods have been applied at the individual wellbore level. A new application technology has been developed to incorporate petrophysical methods and extend from well-centric to model-centric, to create 3D geological models. Saturation and permeability attributes in these 3D models — comprised of hundreds of millions of cells — offer a much clearer picture of the fluid flow pathways and connections that are essential to field development and planning.

Uncertainty modeling challenges all aspects of interpretation and examines the uncertainty ranges of each variable. A much clearer reservoir understanding can be derived through hundreds of multiple uncertainty modeling realizations. A new Linux multi-core cluster has been incorporated to meet the large number crunching requirement of the uncertainty modeling.

New methodology has been introduced to capture and conserve the original heterogeneity in the upscaling process between two different data with different resolutions. It overcomes the shortcomings of the traditional averaging tools by including information on the vertical heterogeneity within each cell of the model. It also has been integrated within the Linux cluster computing environment.

The program fits into a 3D geological modeling environment. The environment commonly consists of seven layers: User front-end, Command line interface, Built-in plug-ins, Modeling objects, Algorithms, Geological object properties access layer, and the 3D geological modeling system. This design enables us to timely deliver the added value of the proprietary petrophysical methods in a 3D geological modeling framework.

We have applied these modules successfully in several Saudi Aramco fields, including Ghawar. Not only has pin-point accuracy been enhanced but also the turn-around time has been reduced by orders of magnitude. A major stride in understanding and modeling the heterogeneity of complex carbonate reservoirs was made. A paradigm shift of 3D petrophysics from well-centric to model-centric has been fostered.

ارامكو السعودية
Saudi Aramco

Model-Centric 3D Petrophysical Application Technology

Roger R. Sung and Khalid S. Al-Wahabi, Saudi Aramco

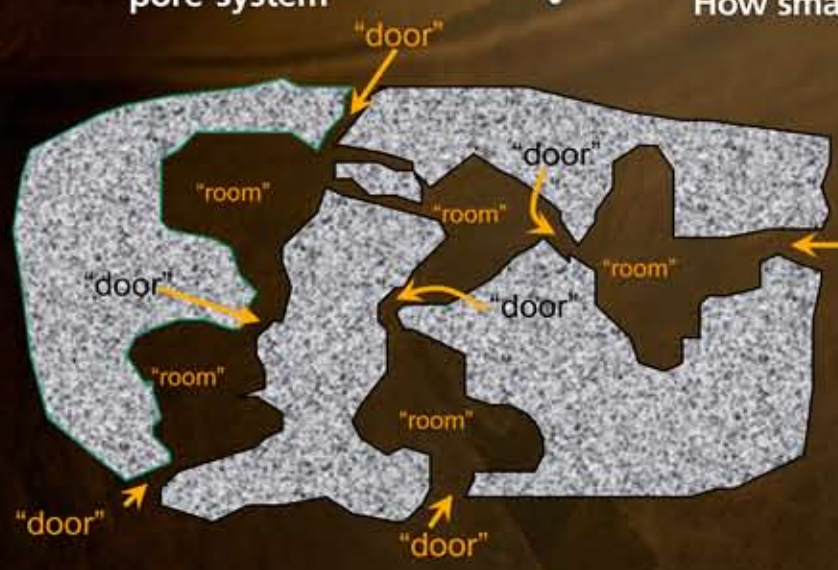
Pore System Architecture of Carbonates

Porosity Φ

Architecture of the pore-system

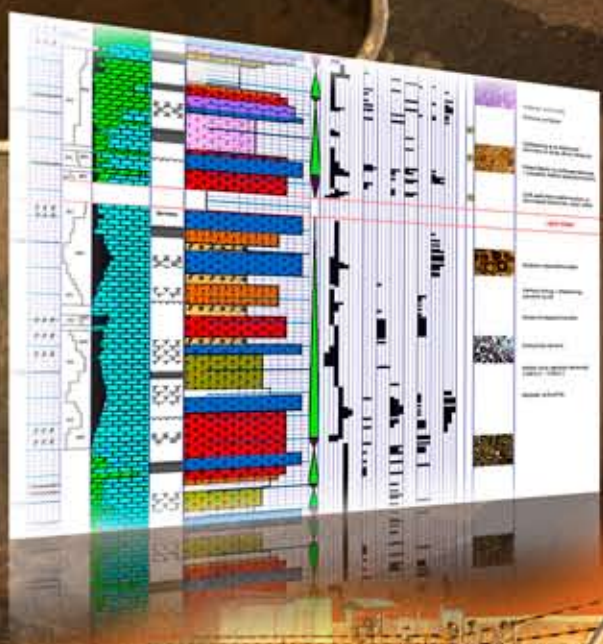
How big are all the "rooms"?

How small are all the "doors"?



pores ↔ "rooms"

pore-throats ↔ "doors"



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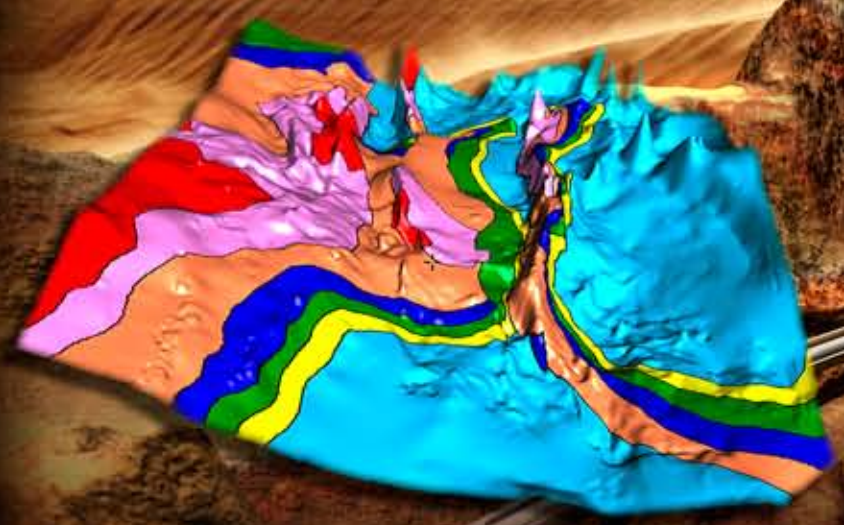

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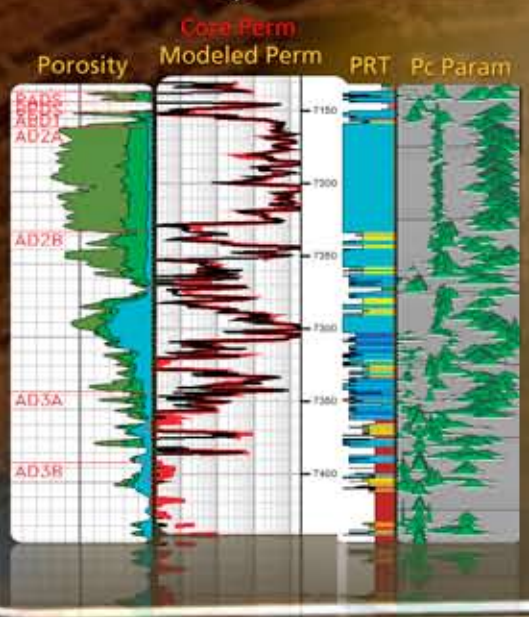
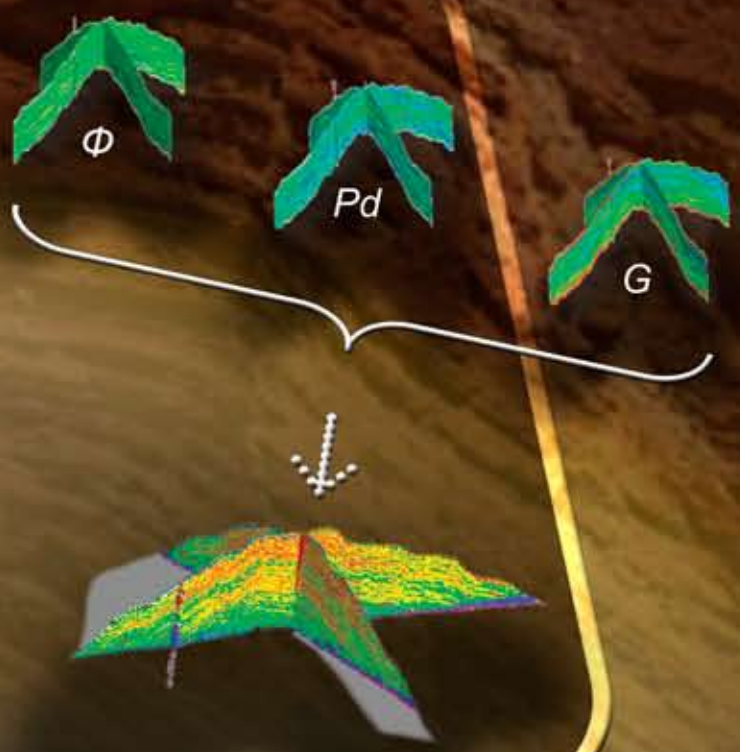
Well-Centric to Model-Centric

Well Data - from log reprocessing

Porosity

Modeled Permeability, PRT's and Cap. Pressure parameters





3D Modeling Application Architecture

User front-end

Command Line Interface CLI

Plug-in UI | Built-in Plug-ins UI

Modeling Objects LIBs

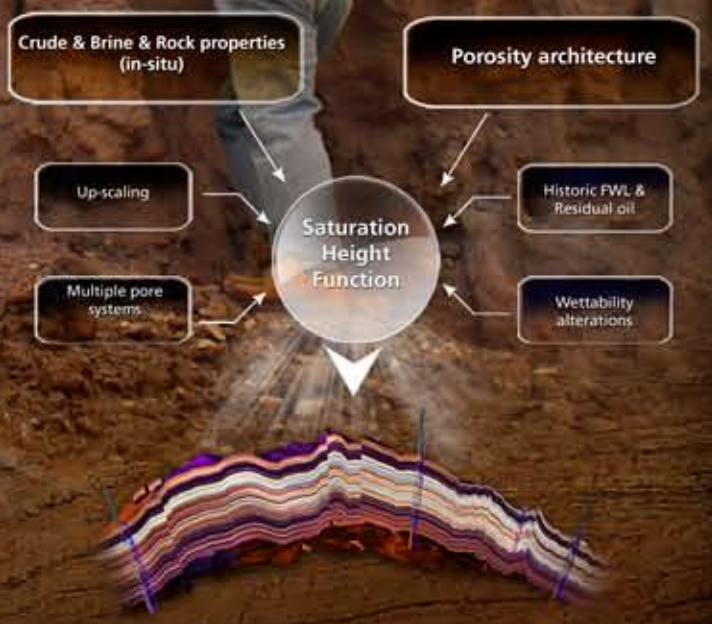
User Algorithm | Built-in Algorithms

Geological Object Properties Access Layer

3D Geological Modeling System

This application technology has been implemented in a 3D geological modeling environment. The environment commonly consists of seven layers: user front-end, command line interface, built-in plug-ins, modeling objects, algorithms, geological object properties access layer, and the 3D geological modeling system. The proprietary plug-in interfaces with two layers: built-in plug-ins and algorithms. It utilizes existing components in the other five layers to significantly minimize the program development cycle time.

Upscaled Water Saturation



Water saturation is one of the most critical parameter for reservoir characterization. Algorithms for water saturation calculation have been developed based on two fundamental reservoir properties: architecture of the pore-system and interfacial tensions. Multiple pore-systems with consideration of pore throat sizes offer much more accuracy over simple formula in carbonate rocks.

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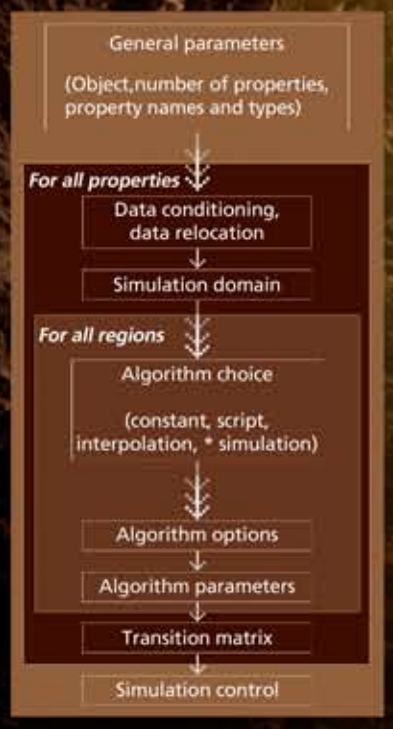

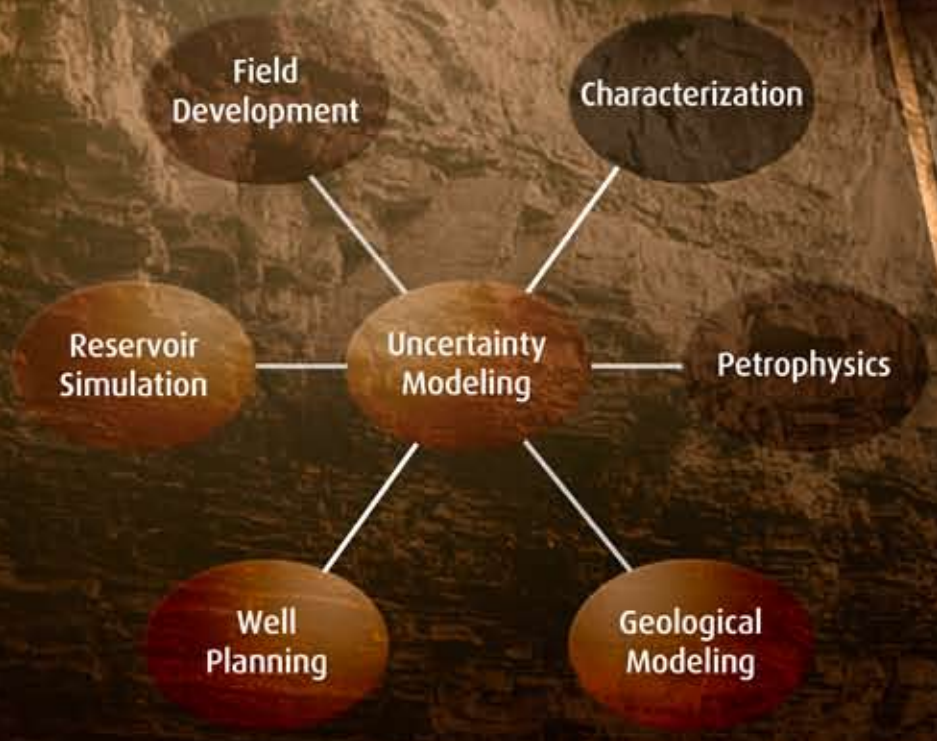

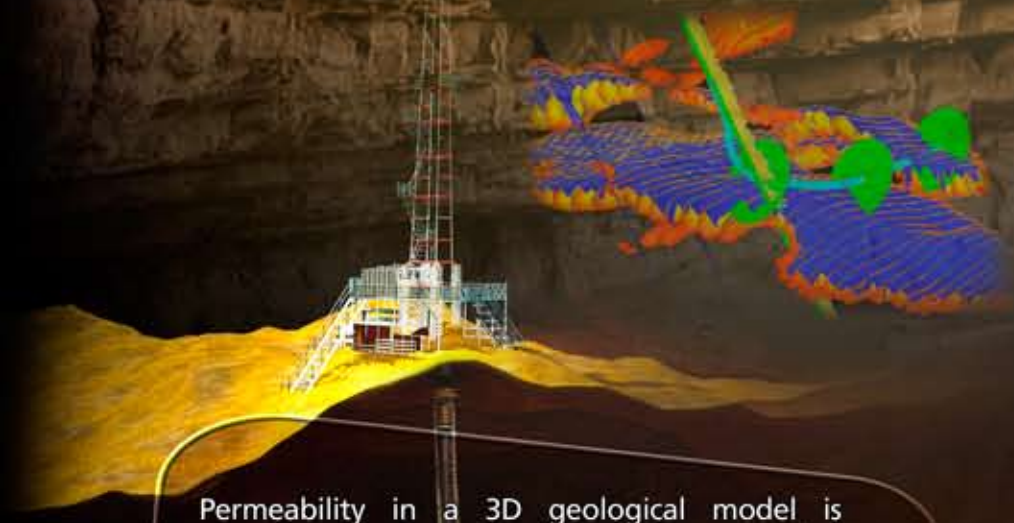

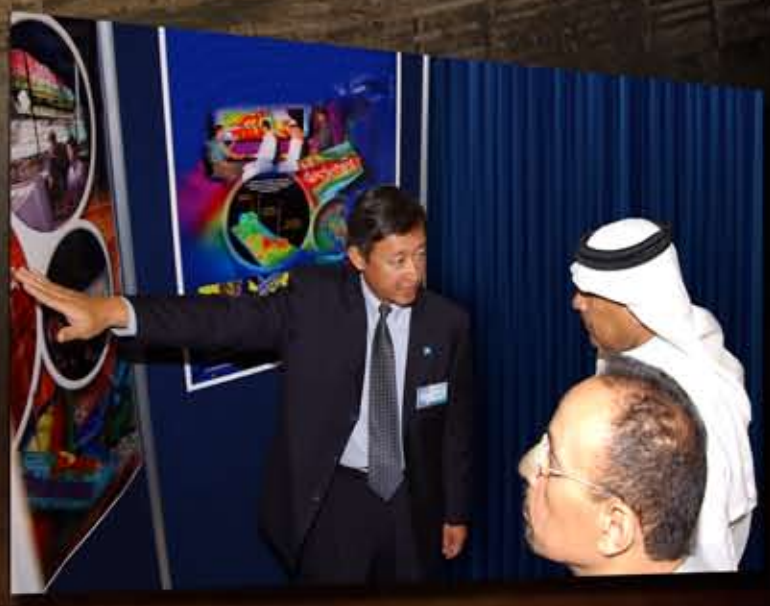

Permeability in a 3D geological model is sometimes estimated using a few empirical equations of the porosity-permeability transform. With limited transform functions, it is very difficult to accurately represent the heterogeneity in a complex reservoir. New module has been developed to calculate permeability at each individual cell with complex petrophysical equations. Furthermore, uncertainty has be modeled and minimized through iterative processes on a Linux cluster supercomputer.

This technology has been successfully applied in Saudi Aramco fields, including Ghawar. Not only has pin-point accuracy been enhanced but also the turn-around time has been reduced by an order of magnitude. A major stride in understanding and modeling the heterogeneity of complex carbonate reservoirs was made. A paradigm shift of 3D petrophysics from Well-Centric to Model-Centric has been fostered.