New Tools and Approaches in Reservoir-Quality Prediction*

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Background

Reservoir-quality prediction has historically been the "holy grail" of reservoir geologists; yet few have been completely successful at achieving this in a truly quantitative fashion. Saudi Aramco, like many oil companies, has long had an active reservoir-quality study program that traditionally was based on qualitative studies of outcrop, well and seismic data, and to a lesser extent, observations of modern sedimentary processes. Prediction results from such studies were frequently less than optimal.

The Challenge

The sheer complexity of factors controlling reservoir quality in the subsurface makes prediction challenging, especially in carbonates. These factors include primary depositional texture and composition, as well as a wide variety of post-depositional modifications that occur to the sediment during and after burial. Developing quantitative tools that would allow the prediction of reservoir quality ahead of the bit, and ideally pre-drill, would provide enormous benefits for both exploration and development drilling by reducing the risk associated with exploitation of heterogeneous intervals.

Our Approach

Reservoir-quality prediction means different things to different people; our approach has been to develop new geological tools that allow the quantitative prediction of reservoir quality (porosity and permeability) ahead of the bit. To accomplish this, we have developed a workflow that utilizes a variety of modeling techniques to understand, quantify, and predict the geological processes that control reservoir quality. Since the initial reservoir quality framework is established at the time of deposition by a variety of depositional controls, this workflow uses numerical process models to predict initial reservoir quality. Results from these models are then modified via a series of other modeling technologies (compaction models, kinetic cementation models, reaction transport models, etc.) to quantify and predict various diagenetic modifications that have significantly affected reservoir quality in the interval of interest. Our approach successfully integrates these two different technologies into one workflow that holistically predicts reservoir quality (Figure 1).

Applications

This approach was first applied to successfully predict porosity in a clastic reservoir interval in a large (127 km by 187 km) pilot area in central Arabia (Cantrell et al., 2010). This pilot, focused on porosity prediction, tried to predict reservoir quality in the Permian-Carboniferous Unayzah reservoir away from areas of well control. To do this, stratigraphic forward modeling was used to predict initial reservoir quality, and then calibrated kinetic cementation models were used to predict diagenesis. When these two approaches were integrated, the results were promising, with log-derived average porosity values within around 10% of model derived average porosities at blind-test well locations (Figure 2).

Recent efforts have been directed toward developing similar predictive tools for carbonate reservoirs, although the greater influence of diagenesis (especially early diagenesis) on carbonate rocks requires a different, and more complicated, approach. A workflow for the development of these quantitative prediction tools has been mapped out; it involves the integration and enhancement of several existing technologies, including stratigraphic forward modeling (SFM) using Sedsim (Griffiths et al., 2010) and reaction transport modeling (RTM). Results from these models are constrained by subsurface data as well as by stratal geometries observed in outcrop. Because many (most?) carbonate diagenetic reactions occur relatively early in the burial history of the sediment and are caused by fluids associated with the depositional environment, we have tried to parameterize these diagenetic reactions and include them in the SFM process. Development of these tools is still underway, but (1) results from an initial SFM model of the Shu'aiba over a large area of southeastern Saudi Arabia (Figures 3, 4, and 5), as well as (2) results from RTM modeling of diagenesis (focused on dolomitization) in the Arab-D in eastern Saudi Arabia, are discussed.

Summary

The workflow illustrated provides a geological, (almost) first principles approach for predicting reservoir quality in areas where no well control exists. While much still remains to be done to improve the robustness and ease-of-use of this workflow, it shows good potential for helping to reduce risk in exploration and development drilling and decision-making.

References

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Griffiths, C.M., C. Dyt, E. Paraschivoiu, and K. Liu, 2001, Sedsim in hydrocarbon exploration, *in* D. Merriam, J.C. Davis, (eds.), Geologic Modeling and Simulation: Kluwer Academic, New York, 352 p.

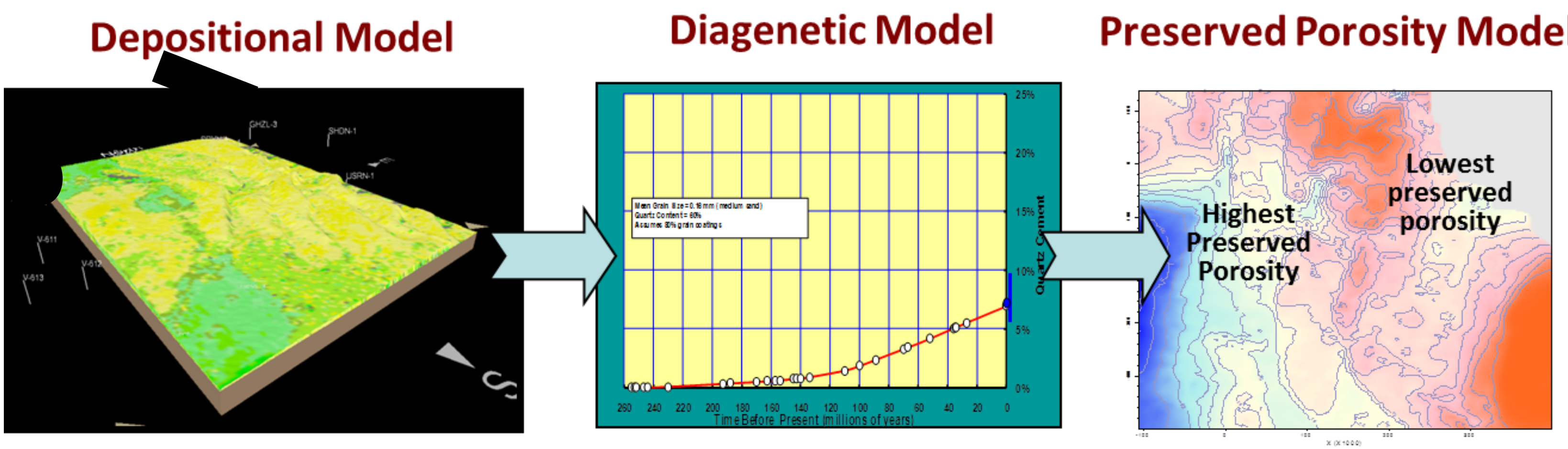

Figure 1. Schematic diagram of the workflow for quantitative prediction of porosity.

	Wireline Logs	Predicted
Well A (Unayzah “A”+”B”)	21.7%	24.8%
Well B (Unayzah “A”)	19.5%	21.0%

Figure 2. Comparison between log-derived and model-derived porosity in the Unayzah pilot study.

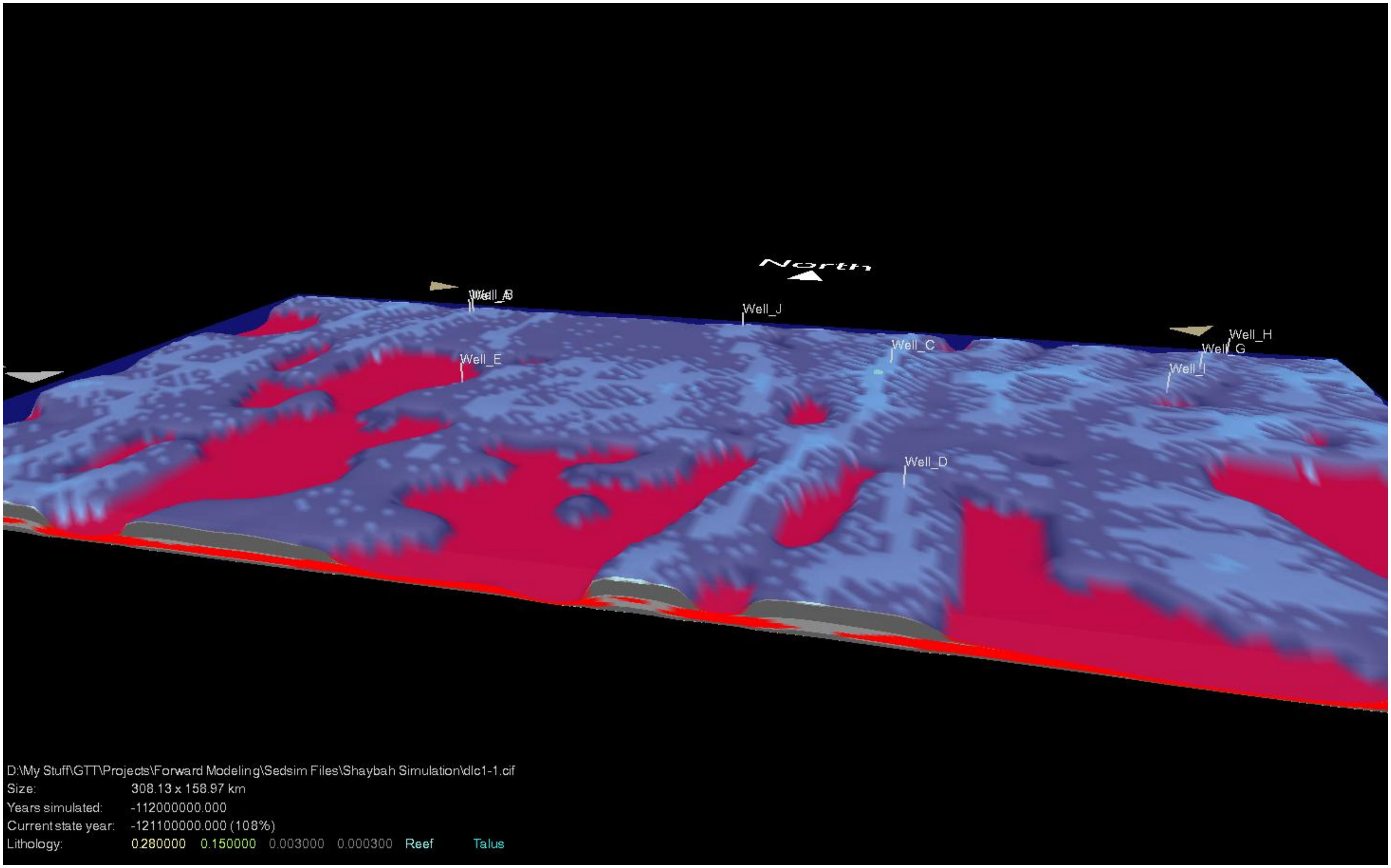

Figure 3. 3D perspective view of Shu'aiba Sedsim modeling results in southeastern Arabia; this model displays/predicts the initiation and growth of rudist shoals localized along pre-existing topographic highs.

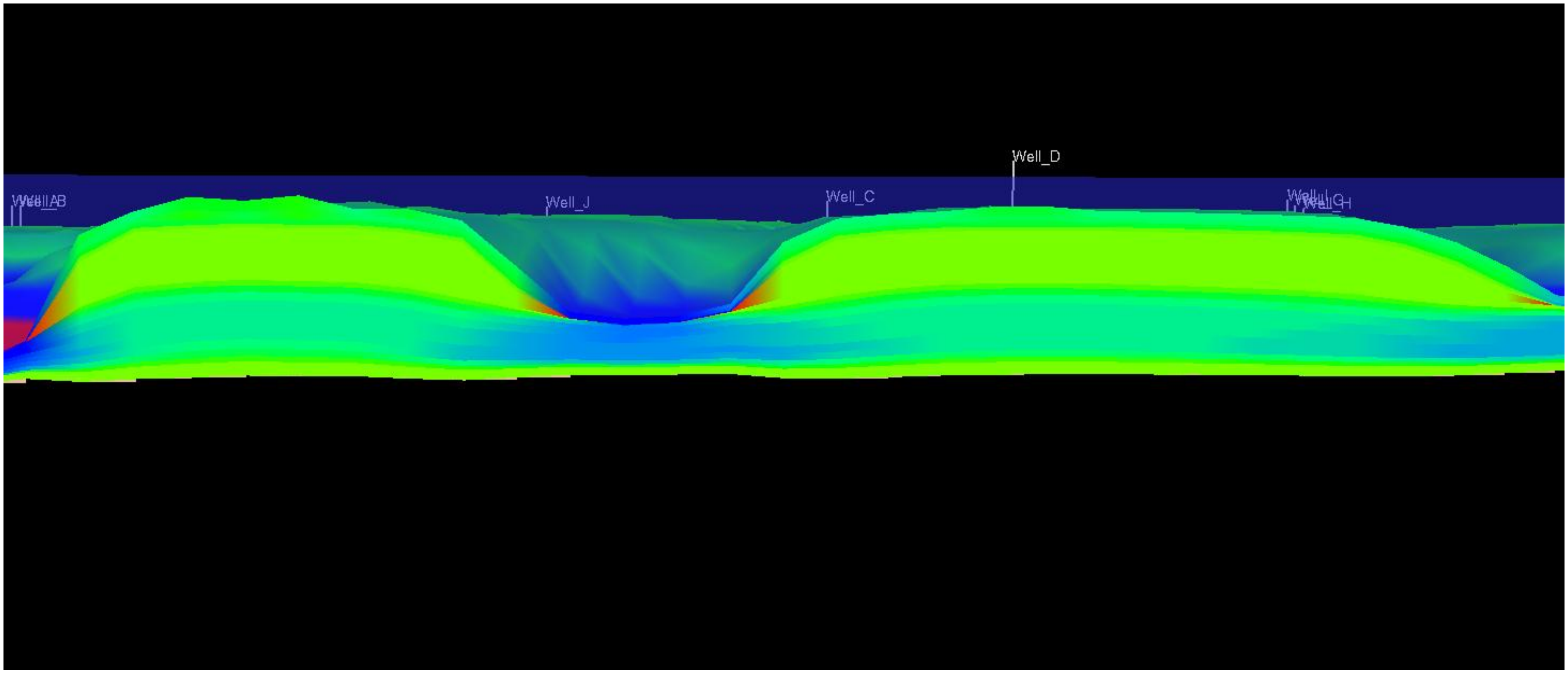

Figure 4. Cross-section through a Shu'aiba Formation buildup showing porosity distribution. The rudist-dominated parts of the section typically have lower porosity – but higher permeability – than does the lower, more mud-dominated interval.

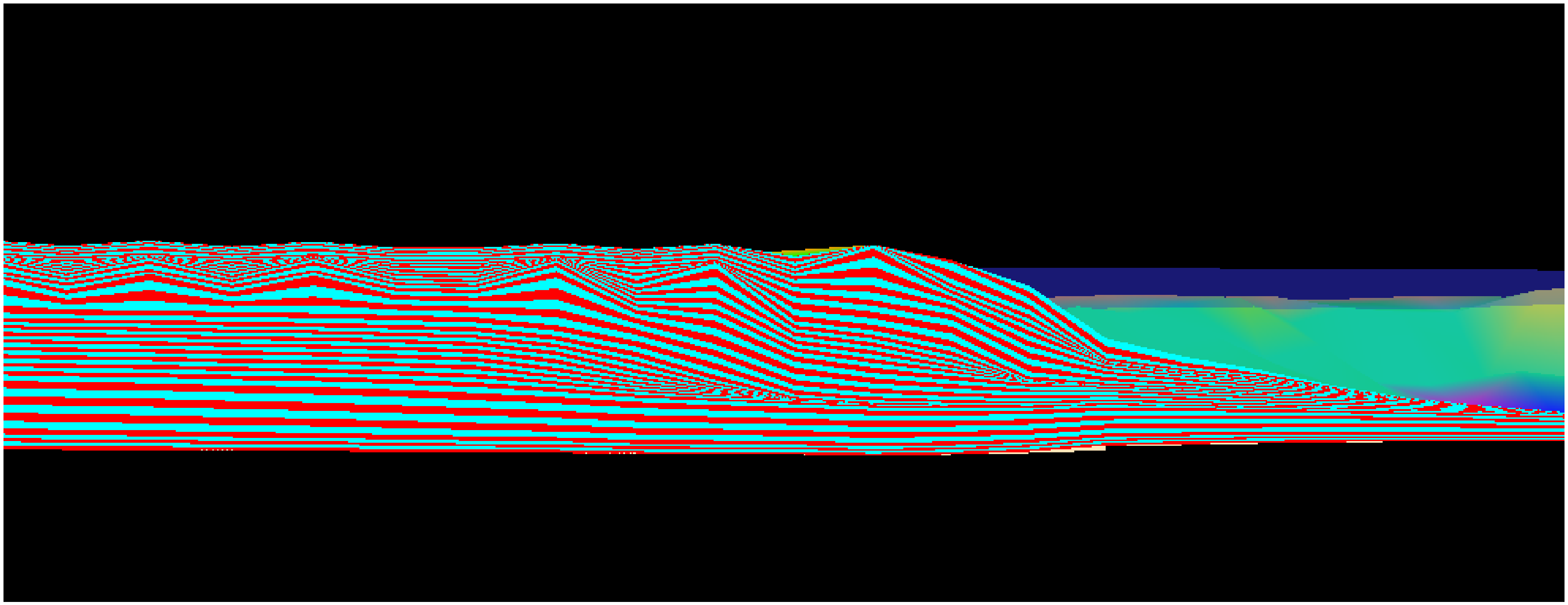

Figure 5. “Pseudo-seismic cross-section” through a Shu’aiba buildup, showing change in stacking style from a dominantly aggradational build-up to a strongly progradational series of lateral build-ups that may induce additional flow heterogeneity.