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RIDING THE WEB-BASED RESERVOIR *Roller Coaster*

A modern E&P asset team encounters a virtual roller-coaster ride when simulating reservoirs. The Web makes it less scary.

AUTHOR

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The low oil prices of 1997 and 1998 drove significant structural changes throughout the E&P industry that have not been wiped out by the price rebound. "Business as usual" is never to return, and nowhere has the change been greater than with the geologist, geophysicist, reservoir and production engineering asset teams that now have direct profit-and-loss responsibility for most of the important oil and gas fields of the world.

The simultaneous invention of new computer capabilities and the growth of the World Wide Web has allowed geoscientists to close in on the integration of all reservoir monitoring information about an oil and gas field. Data from engineering, geology, reservoir simulation and 4D seismic modeling and monitoring can be optimized to produce a best-fit knowledge of a field's drainage history. The growth of real-time monitoring from sensors placed inside and around the reservoir has fueled this requirement to improve knowledge of the physical and chemical state of those fields. Geoscientists have discovered tight integration of reservoir simulator and seismic technologies into a single, most likely view of the reservoir is critical.

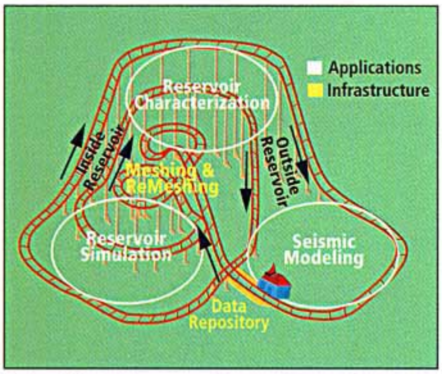

Figure 1. Modern reservoir management is a never-ending roller coaster ride for the asset team: up, down and around the three axes of subsurface fluid flow understanding.

The trick, of course, is to assess the risk vs. reward inherent between the application of advanced technologies to an understanding of the reservoir and the maximization of short- and long-term profitability.

The ride

This integration burden of an asset team can be likened to a perpetual roller coaster ride (Figure 1). Geoscientists must take all the disparate data from a field and labor up that first giant lift by entering data into 10 or more special-built software applications. These include well log analyses, horizon and fault interpretations, geostatistical integration with the 3D seismic interpretation, and porosity and lithology determinations. Once at the top, the team suddenly swirls downward into the first set of loop-de-loops, inversions and high-G turns that make up the laborious construction, running and rerunning of the reservoir simulator software application. That sends the team up another sharp incline that returns it to the reservoir characterization software applications. The pressure decline curve and oil, gas and water production histories predicted by the reservoir simulator never agree on the first pass with the real measurements from the ultimate arbiter of disagreements in the field – the production coming to the surface.

The numbers are jimmied and juggled, interpretations are argued, and a consensus for modifications to the reservoir simulation parameters is determined. The team then swirls downward again into another full-scale run.

Since there is almost always a stack of reservoirs in a field, the team must expand the solution outside the reservoir. The reservoir is reinserted into the computer representation of the field's earth cube, and seismic re-enters the picture. The trick is to rationalize the reservoir simulation's predictions of impedance changes from the withdrawal history of fluids from the field with the observed and modeled seismic changes in the earth cube dictated by the physics of elastic wave propagation.

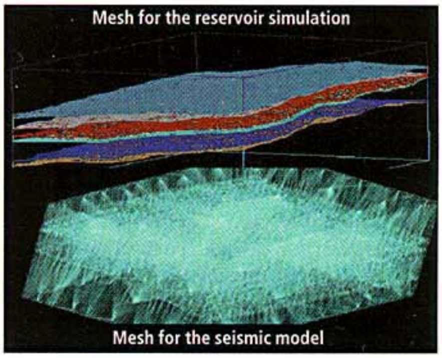

Figure 2. Different meshes or grids are required for each software application. The computational infrastructure manages these meshing tasks.

This seismic reservoir simulator is the newest addition to the roller coaster, a great climb and swoop downward. However, since new information is coming in from the field continuously, the team does not get off the roller coaster at the end of the first circuit. Instead, it is launched immediately into the next ride. On and on the thrills and chills come as the field depletes and the asset team labors to maximize profits right up to abandonment. The very question of when to get off is a critical business decision.

The track and supports

The trick to the success of any good roller coaster is not found in the cars (the software applications), but in the track and support system (the computer infrastructure that allows the movement between and among software applications). Designing and construction of good track is a daunting task. The infrastructure must have a:

- means of integrating all kinds of legacy software codes, each of which may have been built the right way at the time of their implementation but the wrong way for modern optimization;
- rational and speedy approach to data movement and versioning in its multitude of formats;

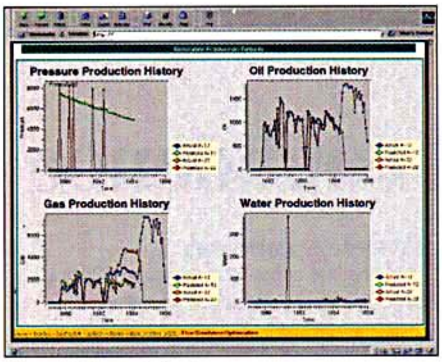

Figure 3. The optimization process for gas production after oil has been selected for a perfect fit requires several iterations, as viewed over the Web.

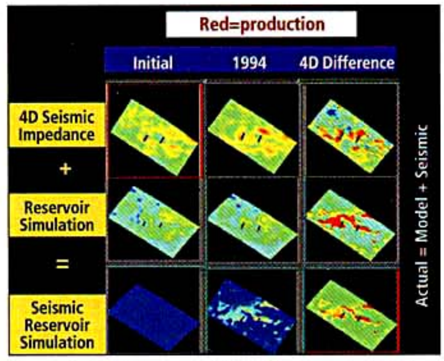

Figure 4. Oil drainage (red) has been computed by iterating the reservoir simulation input parameters until a reasonable fit is made to the fluid flow history and the seismic impedance changes observed by time-lapse seismic surveys or computed from 3D elastic seismic modeling.

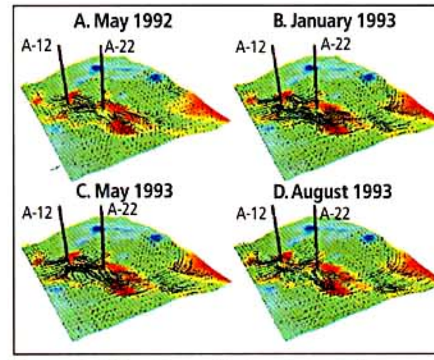

Figure 5. Believable results from the seismic reservoir simulator can be turned into real improvements in cash flow and the field's drainage efficiency.

- way of interacting with distributed computing assets (often involving an enormous amount of parallel processing), coupled in various degrees to the overall architecture;
- means of keeping track of the system's workflow; and
- systems architecture that does not suffocate under its own complexity.

Fortunately, the computer revolution has come to the rescue. The very .com technologies that dominate advertising carry methodologies to build a roller coaster track for reservoir simulation the likes of which the E&P industry has never experienced. Software applications (legacy included) routinely come with applets that take care of the interoperability and automation inherent in Web-based systems. These small software scripts provide the "wrappers and glue" between the overall computational system and individual software applications. In this case, the reservoir simulator is seamlessly connected to other applications.

Data services managed by the infrastructure (persistent data, events, a common registered earth model, workflow publishing using a notebook) are common within large, Web-based optimization systems. In the E&P industry, data is staged by making use of event services requested by the applications, and the results of the computations are reloaded into the system's data repository.

Lastly, the computation infrastructure is actively managed to deal with the complexity of the distributed large-scale systems common in today's thin client/fat server Web world. For example, jobs are launched asynchronously, and the results of the computation reassembled into their synchronous order offline so cycle efficiency can be maximized.

The offshore asset team

To understand this new seismic reservoir simulation world, follow along on one circuit of the roller coaster ride into a deepwater Gulf of Mexico field. The virtual team is comprised of more than a dozen specialists in Houston, Perth, Australia, and London. As one team member goes off duty, another takes his place. Computation continues 24 hours a day, seven days a week over the Web. The software infrastructure keeps track of the progress of reservoir interpretation so each team member can quickly find out what was done in his absence and what is expected of him during his next shift.

First, the 3D seismic data are interpreted, and the reservoir stack description is turned into horizons, faults, log ties and an earth cube representation of the subsurface. The reservoir then is characterized, and a geostatistical function is used to extrapolate the reservoir's log-determined properties, principally porosity and lithology, outward into the rest of the earth cube. This information then must be gridded for insertion into the reservoir and seismic modeling software applications (Figure 2).

At the same time, the engineers prepare the production histories, pressure, PVT and fluids information for the reservoir simulator. The simulator then is run to completion for the first time. Most reservoir simulators allow for an exact match between the computed results and the observed production history for either oil or gas, but not both. The porosity/permeability function then is optimized by repeatedly rerunning the reservoir simulation with varying conversion functions until the production is close to that observed (Figure 3). This optimization loop-de-loop results in the first trip back up the roller coaster to the reservoir characterization, and then the plunge back down into the reservoir simulator.

After several hair-raising twists and turns, the asset team turns to a best-fit to the seismic information represented by impedance (velocity times density of the rock, plus fluids in the pore spaces). The reservoir simulator's fluid flow and pressure decline predictions must account for the seismic observations. That requires that not only the porosity/permeability function be tinkered with, but also the velocity/density/fluid function (the Biot-Gassman equation).

The prediction of how best to drain the remaining reserves can be acted on once the seismic and fluid flow are used to derive a best-fit to how much oil, gas and water was produced from where within the reservoir in the past. As can be seen from Figure 4, the best-fit result doesn't agree exactly with either the seismic observations or the reservoir simulation results but instead represents a minimized-error optimization of the results from both (an inverse problem/solution).

The final drainage prediction (or the understanding of it at that particular time) then is used to test improvements to the performance of wells so remedial action can be taken. In this example, an analysis of the seismic reservoir simulator's description of oil flow into wells **A-12** and **A-22** from 1992 through 1993 (Figure 5) showed that the A-22 well was thieving oil from the A-12 well.

The streaklines of oil flow from the model show the oil produced from the A-22 well could easily be produced by the A-12 well. A decision to shut-in the A-22 well for this reservoir resulted in an immediate increase in production of oil from the A-12 well (Figure 3). The A-22 wellbore was not wasted, however. Perforations opened a completion to a shallower reservoir penetrated by this well, thus increasing the field's overall production.

The infrastructure of the E&P seismic reservoir simulation roller coaster is being constructed for easier and more efficient reservoir management. Fast-approaching Web-based computer technology will greatly improve the business performance of oil and gas fields.

Acknowledgements

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