Improve predrill pore pressure prediction in GOM and other salt basins

During the well planning stage, reservoir pore pressure influences everything from the casing design to the mud weight and type selection. If the pore pressure is predicted inaccurately, costly damage to the well or reservoir can occur—resulting in NPT and safety hazards.

For offshore operators, particularly in deepwater areas of the GOM where salt bodies are present, pore pressure prediction is a common challenge.

Today, the industry standard involves using seismic velocities to gain a better understanding of pore pressures. However, seismic velocity is not directly sensitive to pore pressure distribution.

To address limitations of using seismic velocities and improve pore pressure prediction, a team of petroleum systems geologists from Schlumberger in collaboration with various industry partners of SEG Advanced Modeling (SEAM) Corporation began work on a pore pressure prediction project in 2014.

The SEAM Corporation, which is an industrial consortium dedicated to geophysical numerical modeling, wanted to modify the SEAM Phase I earth model created in 2007 to include realistic pore pressure scenarios. This 3D model addressed the challenges of subsalt imaging in Tertiary basins in the GOM and was used as the basis for the pore pressure prediction project.

To achieve the goal of improving pore pressure prediction, Schlumberger and SEAM industry partners chose to explore basin- to pore-scale properties by combining methodologies from a range of technical disciplines.

The following objectives were set by SEAM:

- understand how various geological phenomena modify the predicted pore pressures
- use the basin simulation output to generate seismic velocities via rock physics models and improve seismic imaging
- improve predrill pore pressure prediction methodologies to reduce drilling risk
- deliver a benchmark simulated seismic dataset to be used by SEAM industry partners and academic research institutes.

The main objective for the Schlumberger team was to test the causes and effects of geopressure in the subsurface through basin modeling and simulation.

“Schlumberger helped to define, implement, and improve the workflow as we worked from performing 2D simulations to 3D simulations. Using the knowledge we gained from the 2D simulations, we were able to narrow the range of issues we wished to investigate in 3D where simulation challenges were considerably greater.”

Michael Fehler
Technical Project Manager, SEG Advanced Modeling project (Phase I and Pore Pressure Prediction projects)
SEAM Corporation
Provide basin simulation output for multidisciplinary pore pressure prediction solution
Schlumberger proposed using Petrel Exploration Geology integrated with PetroMod petroleum systems modeling software to conduct the following:

- develop the model framework and paleohistory
- set lithological constraints, including porosity, permeability, and elastic properties
- simulate the evolution of pressure and stress through geological time
- analyze the different pressure generating mechanisms through geological time.

The PetroMod software simulator is a core part of PetroMod software workflows facilitating the incorporation of geological phenomena that affect pressure and stress through geological time.

Pressure generating mechanisms in the earth are relatively well understood, however, the relative influence of the various mechanisms is poorly understood in geologically complex environments. An initial 2D modeling study was conducted using the SEAM Phase I earth model to test the influence of several pressure generating processes. Aside from disequilibrium compaction, pressures resulting from clay diagenesis, quartz cementation, basal heat flow variations, hydrocarbon generation, the influence of the salt on the subsurface rock stresses and the presence of faults were examined.

A 3D model was then built to incorporate these mechanisms and analyze their influence on spatial distribution of present day pressures and stress. The 3D basin simulation output which included pore pressure, stress, porosity, and ratio of smectite to illite was then used in a specifically designed theoretical rock physics model to develop a 3D anisotropic elastic model that could be used for seismic simulation.

Facilitated new predrill pore pressure prediction approach to mitigate catastrophic risks to the well and reservoir
Seismic simulation was conducted on the model to develop a set of synthetic seismic datasets for testing and improving methodologies for predrill pore pressure prediction.

The contribution of basin simulation output using PetroMod software, combined with the rock physics model, was critical to the success of the pore pressure prediction solution. Models that do not consider basin evolution ignore the crucial effects of specific rock properties on the modeled pressures. This new multidisciplinary approach, which ties basin simulation outputs to a geophysical simulation, combined the best of both disciplines to create a new methodology for pore pressure prediction that also improves seismic imaging.

Both the dataset and the workflow created during the project have been distributed to the SEAM Corporation industry partners for use as a benchmark to improve pore pressure prediction in the GOM and salt basins spanning the globe. This is helping industry mitigate potentially catastrophic risks to their operations during the predrill stage.

High-resolution 2D east-west cross section of the basin model (left) showing detailed facies distribution with fine grid increments applied laterally (20 m) and vertically (10 m) and 3D perspective view of the modeled facies (right) illustrating the salt stem connecting the salt bodies to the source.