Cascade and Chinook are milestones in the development of ultradeepwater assets in the Gulf of Mexico, where the industry’s experience in Lower Tertiary, Wilcox trend reservoirs is still very limited. The initial development of Cascade, Chinook, and other ultradeepwater fields requires large capital investments, advanced technology, and the creative use of existing tools.

The financial risk is great. Beyond that, factors such as reservoir compaction, the production of sand, the reactivation of fractures, and other geomechanical processes affect the quality of the reservoir and integrity of the wells.

The 4D geomechanical model

"Understanding all of the drilling, completion, and production risks is a critical step in the engineering process," says Jose Adachi, principal geomechanics specialist for Schlumberger. "To help evaluate these risks, Petrobras and Schlumberger Data & Consulting Services (DCS) built a comprehensive 4D geomechanical model for the Cascade field."

The model includes the reservoir and the overburden up to the seabed, as well as the side burdens, underburden, and all major faults.

"We characterized the geomechanical properties of the rocks using a combination of log data, seismic velocities (acquired and processed by WesternGeco), TerraTek* geomechanics laboratory testing, and in-situ measurements such as minifracs and leak-off tests," says Adachi.

The model was constructed in Petrel* and ECLIPSE* software. Rock properties and pore pressures were transferred to VISAGE* modeling software, a finite-element code that runs fully coupled simulations with the ECLIPSE reservoir model. The VISAGE software uses state-of-the-art numerical methods to calculate the stress and strain induced by production and injection. The computations can be performed at any time during the life of the field, which is why the model is called 4D.

"Our 4D geomechanical model of Cascade allows Petrobras and DCS to evaluate the risks of compaction, fault reactivation, and wellbore failure for the life of the reservoir," Adachi says. "Preliminary results indicate a relatively low level of compaction, which is consistent with the high strength of the rock."

The final integrity evaluation of the wells was performed using "sector models," which are local grid refinements around selected wells. They include details of the casing, cement, and completion, which can also be modeled with the VISAGE software.

The 4D geomechanical model also predicted the porosity and permeability losses caused by compaction.

"That data helped further refine the ECLIPSE reservoir model," Adachi says. "And we used the stress orientation and magnitude predictions to assess potential problems with the hydraulic-fracture completions."

Record well completions

The first production wells for Cascade and Chinook include the two largest ultradeepwater, high-pressure perforating

The Cascade 4D geomechanical model is shown depicting predicted compaction after 33 years.
jobs ever done in the Gulf of Mexico. With gross perforation intervals of more than 800 feet and downhole pressures higher than 19,000 psi, completing and perforating the wells was a world-class challenge.

“We needed to perforate several intervals in one run to complement the single-trip multizone (STMZ) frac-pack system,” says William Sanders, Deep Water and Special Projects supervisor. “In a typical STMZ job, all zones are stimulated in a single trip.”

At Cascade and Chinook, perforating all the intervals with long gun strings and then frac-packing multiple zones in a single trip saved more than 67 percent of the rig time that would have been needed to perform conventional stacked frac-packs, which require several trips for each zone.

“One of the biggest challenges was managing the intense pressure inside the wellbore when the guns went off,” Sanders explains. “Perforating gun-shock loads are generated by sudden pressure waves in the completion fluid and stress waves in the structural components. The magnitude, duration, and timing of these waves depends on the design of the job, including the gun system, loading of the guns, number of shock absorbers, and the distance from the packers to the guns.”

**The solution**

For Cascade and Chinook, Sanders and the Schlumberger team selected a unique combination of tools that functioned as a true 25,000-psi perforating gun system. It included the 7-inch, 18 spf HSD* gun with PowerFlow* charges, 7-inch perforating shock absorbers (SXVA), and 7-inch eFire* redundant electronic firing head systems.

“The two wells at Cascade and Chinook represent the longest intervals ever perforated under extreme conditions of total depth, water depth, and hydrostatic pressure,” Sanders notes. “Our success extends the range of what is possible in the development of ultra-deepwater fields.”

*Mark of Schlumberger*