

# Well-Centric Geomechanics

Identify, predict, and prevent costly events and optimally manage your well

Geomechanics is a technical discipline that deals with diagnosis, modeling, and control of rock deformation. Understanding and managing the risks associated with rock deformation helps mitigate associated operational risk such as wellbore instability, sand production, or hydraulic fracturing.

Schlumberger is the leading provider of integrated geomechanics technology and services, with an impressive track record of successful projects worldwide for more than 40 years. Our approach

to geomechanics is based on knowing how to use all oilfield data efficiently and effectively throughout the life of the well.

Schlumberger has enhanced the organizational structure, hardware, and software to bring this process to the market with recent acquisitions and new developments. We have developed two new geomechanical centers of excellence: Schlumberger Reservoir Geomechanics Center of Excellence in Bracknell, UK, and Geomechanics Laboratory Center of Excellence in Salt Lake City,

Utah. We have also enhanced our Pore Pressure Center of Excellence in Houston to advance our leadership in the industry.

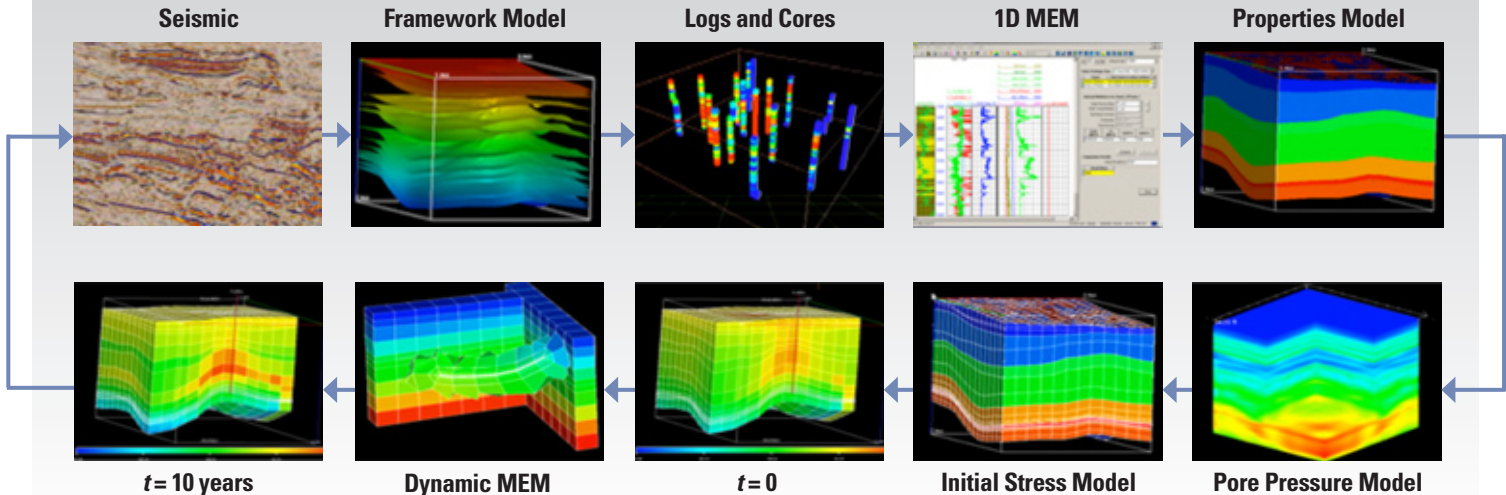
**DRIVEN BY DATA**

The geomechanics process can be tailored to suit individual projects, but it includes five basic elements: the data audit, the dynamic mechanical earth model (MEM), the geomechanics predictions and engineering designs, real-time monitoring and updating via a closed loop feedback system, and technology that supports implementation of the

process over the field life cycle. All of the elements are based on utilizing all data available and incorporating it into the model over the life of the well.

The dynamic Schlumberger MEM is fundamental to the success of the geomechanics program. It is an explicit description of the state of stress, pore pressure, and mechanical properties of the subsurface, including the reservoir and overburden. It includes details of geological structure, such as faults and formation tops as well as details

**GEOMECHANICS MODELING WORKFLOW**

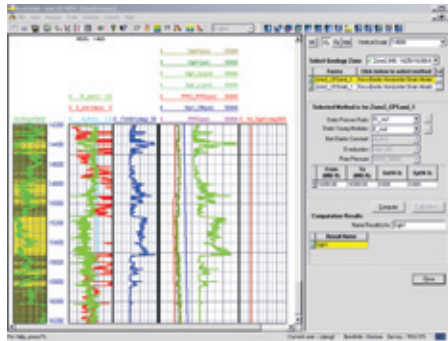


The foundation of every Schlumberger geomechanics plan is a well-defined, fit-for-purpose mechanical earth model built using any type of data available. A successful geomechanics plan is based on knowing how to use all oilfield data efficiently and effectively.

# Well-Centric Geomechanics

## INTEGRATED SOFTWARE: MODELING TO APPLICATION

Seismic  
Geology  
Drilling  
Logs  
Core  
Production

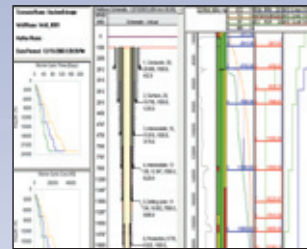


1D Mechanical Earth Model

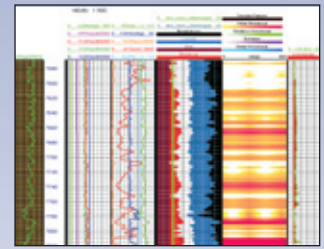
### Input Parameters for a Mechanical Earth Model

GEOLOGIC DATA
<ul style="list-style-type: none"> <li>Regional tectonic framework</li> <li>Structure depth maps</li> <li>Lithostratigraphic column</li> <li>Regional compaction trends</li> <li>Basin analysis</li> <li>Earthquake fault-plane solutions</li> <li>Tiltmeter surveys</li> <li>Core tests and descriptions                             <ul style="list-style-type: none"> <li>Rock composition and texture</li> <li>Core-log integration</li> <li>Heterogeneity and anisotropy</li> <li>Petrophysical and mechanical characterization</li> </ul> </li> </ul>
SEISMIC DATA
<ul style="list-style-type: none"> <li>3D seismic cube</li> <li>2D seismic profiles</li> <li>Tomographic velocity</li> <li>Vertical seismic profiles and checkshot data</li> <li>P-wave velocity profiles</li> </ul>
FORMATION EVALUATION DATA
<ul style="list-style-type: none"> <li>Wireline and LWD logs                             <ul style="list-style-type: none"> <li>Gamma ray, resistivity, density, sonic, caliper</li> <li>Nuclear magnetic resonance</li> <li>Borehole imaging</li> </ul> </li> <li>Well test and production pressure measurements                             <ul style="list-style-type: none"> <li>Formation tests and drillstem tests</li> </ul> </li> </ul>
DRILLING DATA
<ul style="list-style-type: none"> <li>Daily drilling reports</li> <li>End of well reports</li> <li>Mud weight profile</li> <li>Leakoff tests, extended leakoff tests, formation integrity tests, minifrac tests</li> <li>Directional surveys</li> <li>Mud logs</li> </ul>
CALIBRATION DATA
<ul style="list-style-type: none"> <li>Laboratory measurements on cores</li> <li>In-situ stress measurements from hydro-fracturing tests</li> <li>Observed breakouts and stress-induced features</li> <li>Field and production observations</li> </ul>

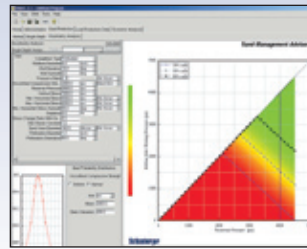
## APPLICATIONS



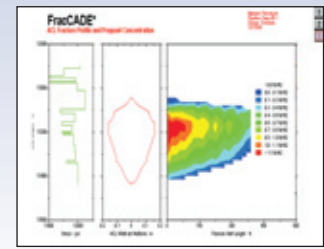
Drilling Simulation



Wellbore Stability



Sand Management



Fracture Simulation

of rock fabric, fractured zones, and anisotropic behavior. Details of any known chemical instability are also included with both a predictive function and an interpretive function. The former will depend on the quality and quantity of input data. The latter allows the interpretation of observations during drilling and therefore the application of correct remedial treatment.

The MEM is an integral part of new software that involves calculations of earth stress, rock mechanical properties, and rock deformation. The model provides data for

- drilling planning and risk analysis in Osprey\* drilling software
- well planning in RockSolid\* wellbore stability software
- sand control in Sand Management Advisor software
- FracCADE\* fracturing design and evaluation software
- ECLIPSE\* reservoir simulation software
- VISAGE\* stress analysis simulator.

For single-well applications, the MEM is generally constructed in 1D, that is to say, properties and stresses are considered to vary with depth but are assumed to be laterally constant. The 1D MEM will however include the location and behavior of faults and lateral changes in formation tops. In cases where the geological structure is complex, e.g., in highly faulted or dipping structures or where there are complex pore pressures owing to heterogeneous depletion or injection, a 3D MEM is required to adequately model stress and material properties changes.

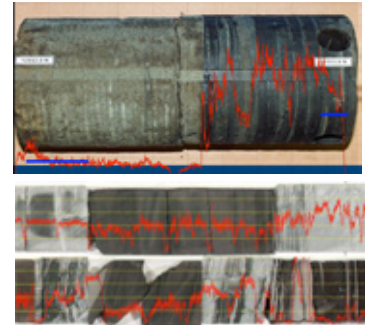


## ROCKS MATTER

Our Geomechanics Laboratory Center of Excellence is a global leader in laboratory measurement and analysis of rock properties, offering state-of-the-art testing equipment, laboratory-testing services, and geotechnical consulting services. Developed after the Schlumberger acquisition of TerraTek in 2006, the

center combines the best in testing, modeling, and analysis of rock properties, together with cross-disciplinary expertise in mechanics, reservoir properties, geochemistry, petrology, geology, and geophysics, to characterize complex behavior of reservoir rocks and seals at in situ conditions (e.g., thermal and poro-mechanical coupled behavior).

The center supports our field labs around the globe with its unique rock property database representing reservoir and nonreservoir rocks from around the world, proprietary expertise in analysis of heterogeneity and core-log integration, and proprietary reservoir simulated tests, including complex, heterogeneous, and HPHT environments.

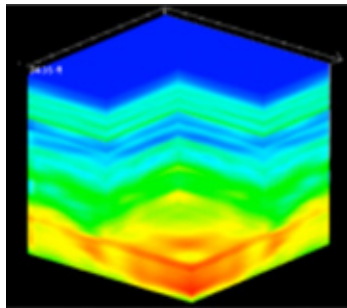


## ALL ABOUT PRESSURE

For 40 years, Schlumberger has been developing MEMs and studying the effects of pressure on reservoir properties. Pore pressure is critical to operations, particularly while drilling and especially in deep water. The Schlumberger Pore Pressure Center of Excellence in Houston has pioneered advances in predicting pore pressure.

The center helps operators predict predrill pore pressure using seismic velocities with a velocity-to-pore-pressure transform calibrated to offset wells. The time required for such projects has been substantially reduced by building a pore pressure cube over the entire northern Gulf of Mexico, using data released by the U.S. Minerals Management Service.

The geomechanics experts in this group have a global reach and support operators around the world. This interdisciplinary team is actively involved in helping clients mitigate risk in drilling, completing, and producing wells in difficult geomechanical applications, such as deepwater exploration, subsalt drilling, unconventional gas, and unconsolidated reservoirs.



*Pore pressure prediction in the Gulf of Mexico using seismic velocities from reflection tomography, with a velocity-to-pore-pressure transform calibrated to offset wells*

## Schlumberger tools for measurements

### SEISMIC

- Q-Marine\* single-sensor marine seismic system
- Q-Borehole\* integrated borehole seismic system

### DRILLING

- EcoScope\*† multifunction logging-while-drilling service
- GVR\* resistivity sub
- seismicVISION\* seismic-while-drilling service
- sonicVISION\* sonic-while-drilling tool
- StethoScope\* formation pressure-while-drilling service

### LOGS

- Sonic Scanner\* acoustic scanning platform
- Platform Express\* integrated wireline logging tool
- PressureXpress\* reservoir pressure-while-logging service
- MDT\* Modular Formation Dynamics Tester
- FMI\* Fullbore Formation MicroImager
- UBI\* Ultrasonic Borehole Imager

### CORES

- TerraTek lab testing and core analysis

# Well-Centric Geomechanics

APPLICATIONS	FEATURES	ADVANTAGES
<b>Drilling</b>	Wellbore stability forecasting Pore pressure prediction Well planning  Drilling risk evaluation	Design a stable trajectory Determine the best mud weight Determine the maximum and minimum allowed equivalent circulating density Provide “solid ground” for casing seat selection Reduce casing strings Optimize drilling parameters Prepare preventive and remedial plans
<b>Completions</b>	Sanding analysis  Tight rock analysis	Optimum design of sand control hardware for screen and blank selection Fit for purpose ESP design and run life management Correctly identifying when oriented perforating can avoid costly sand face completions Understanding heterogeneity and anisotropy for more effective recovery
<b>Stimulation</b>	Mechanical earth modeling	Hydraulic fracture design optimization Fracture containment assessment

\*Japan Oil, Gas and Metals National Corporation (JOGMEC), formerly Japan National Oil Corporation (JNOC), and Schlumberger collaborated on a research project to develop LWD technology that reduces the need for traditional chemical sources. Designed around the pulsed neutron generator (PNG), EcoScope service uses technology that resulted from this collaboration. The PNG and the comprehensive suite of measurements in a single collar are key components of the EcoScope service that deliver game-changing LWD technology.

\*Mark of Schlumberger  
Copyright © 2008 Schlumberger. All rights reserved. 08-DC-004