The UT GeoFluids Consortium

http://www-udc.ig.utexas.edu/geofluids/

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Overview:

UT GeoFluids is managed by University of Texas (Institute for Geophysics) and is currently supported by 12 energy companies at a cost of ~ $50,000/year. The 10-year effort ends in 2019. Our results are used to predict pressure and stress, design stable and safe drilling programs, and predict hydrocarbon migration and entrapment. We study the state and evolution of pressure, stress, deformation and fluid flow through experiments, models, and field study:

1. **Experimental:** We analyze fabric, acoustic, electrical, and material properties of mudrocks : 0.1-100 MPa.
2. **Poromechanical Modeling:** We develop and apply coupled models to link realistic rheologies, deformation, stress (shear and normal), and pore pressure.
3. **Field Study:** We analyze pore pressure, stress, and deformation in thrust belts and in the sub-salt.

We produce innovative concepts and analysis work flows that couple geology and fluid flow to predict pore pressure and stress in the subsurface. We have 1) developed on-line software that predicts reservoir pressure, 2) released data bases and material models that describe mudrock material behavior, and 3) developed workflows to predict stress in salt systems and thrust belts.

In the next 3 years, we will demonstrate the effectiveness of our new pore pressure and fracture gradient (PPFG) predictions. We will work with our sponsors to design blind tests based on new datasets(s). We will focus on transferring specific workflows that the sponsors can use in their PPFG efforts. Finally, we will continue the fundamental modeling and experimental work that underpins UT GeoFluids.

Accomplishments:

Experimental:

UT GeoFluids has pioneered the application of resedimentation to the systematic study of mudrock material behavior at high stress levels (up to 100 MPa (14 KSI)). We have shown that the lateral stress ratio, friction coefficient, strength, and compression behavior are stress dependent and that this behavior varies systematically with liquid limit (an easily measured parameter). We have developed models to describe smectite-rich (Gulf of Mexico) and illite-rich mudrocks and we have developed generalized models based on liquid limit. We have embarked on a systematic program to measure velocity (Vp & Vs) at a range of stresses and we are integrating these measurements with observations of mechanical properties. Based on our experimental results, we have developed simple spreadsheets that provide material properties as a function of depth (e.g., permeability, lateral stress ratio, friction angle, velocities – Fig. 1). These spreadsheets are freely available to UT GeoFluids members.

Overburden Stress	Vertical Effective Stress	Porosity, n	RHOB	K_0	Critical State Fricton Angle, Φ	Undrained Strength, S_u/σ'_v	Permeability	Vertical Permeability, k_v	Horizontal Permeability, k_h	P Wave Velocity, V_p	S Wave Velocity, V_s
psi	*psi*	-	*kg/m³*	-	°	*m²*	*m²*	*m²*	*m²*	*m/s*	*m/s*
1686	827	0.365	2136	0.754	18.2	0.188	1.87E-19	1.33E-19	3.14E-19	2029	447
1717	843	0.364	2138	0.755	18.1	0.187	1.82E-19	1.29E-19	3.06E-19	2033	451
1747	858	0.363	2139	0.756	18.1	0.187	1.77E-19	1.26E-19	2.98E-19	2037	454
1778	874	0.362	2141	0.757	18.0	0.186	1.72E-19	1.22E-19	2.91E-19	2040	457
1808	890	0.361	2143	0.759	17.9	0.185	1.68E-19	1.19E-19	2.84E-19	2044	460
1839	906	0.360	2145	0.760	17.9	0.185	1.63E-19	1.15E-19	2.77E-19	2047	463
1869	922	0.359	2147	0.761	17.8	0.184	1.59E-19	1.12E-19	2.71E-19	2051	466
1900	938	0.358	2149	0.762	17.8	0.183	1.55E-19	1.09E-19	2.64E-19	2054	469
1930	954	0.357	2151	0.763	17.7	0.183	1.52E-19	1.06E-19	2.58E-19	2058	472
1961	970	0.356	2152	0.765	17.6	0.182	1.48E-19	1.03E-19	2.53E-19	2061	475
1992	986	0.355	2154	0.766	17.6	0.181	1.44E-19	1.01E-19	2.47E-19	2065	478
2022	1003	0.354	2156	0.767	17.5	0.181	1.41E-19	9.80E-20	2.42E-19	2068	481
2053	1019	0.353	2157	0.768	17.5	0.180	1.38E-19	9.55E-20	2.36E-19	2071	483

Fig. 1: Our experimental results are available to UT GeoFluids Members as simple spreadsheets that summarize the behavior of mudrocks and provide material properties as a function of depth. They can be used to predict fracture gradient and strength.

GeoMechanical Modeling:

UT GeoFluids is a leader in the application of coupled evolutionary geomechanical models to understand the state and evolution of pressure and stress in complex environments such as within salt systems and in fold and thrust belts. These models are providing fundamental insights into how stresses are perturbed because of the geologic history, as well as tools and workflows to predict pressure and stress around complex structures (Fig. 2).

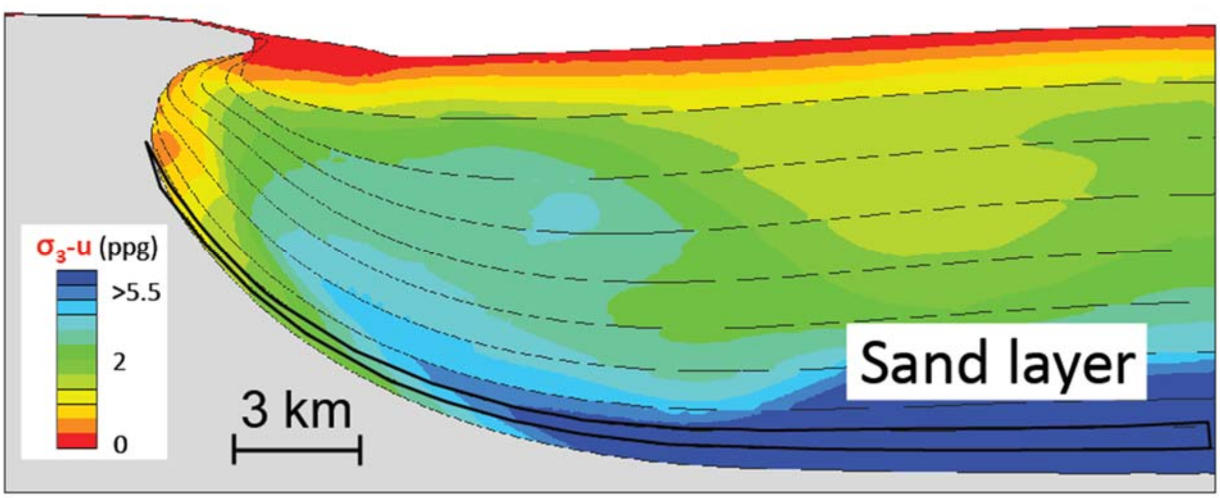

Fig. 2: Coupled evolutionary geomechanical models represent the frontier of basin models. They solve for the full stress tensor, incorporate complex material behavior, and simulate fluid flow and associated overpressure. They are a fundamental advance over uniaxial models (e.g. Temis or Petromod).

Field Studies:

We validate our advances in theory and experiments through field studies. We have performed pressure analysis in the Auger Basin to study the centroid effect. We have analyzed pressure and stress in salt systems in the Mad Dog Field. We have examined sand injection features on land. We have explored pressure, stress, and porosity evolution in fold and thrust belts.

Work Flows:

UT Centroid: We have developed an approach to predict reservoir pressure as a function of reservoir geometry and mudstone permeability (Fig. 3). This workflow is encapsulated in an online software that is freely available to UTGeoFluids members and several member companies are negotiating formal access to the approach.

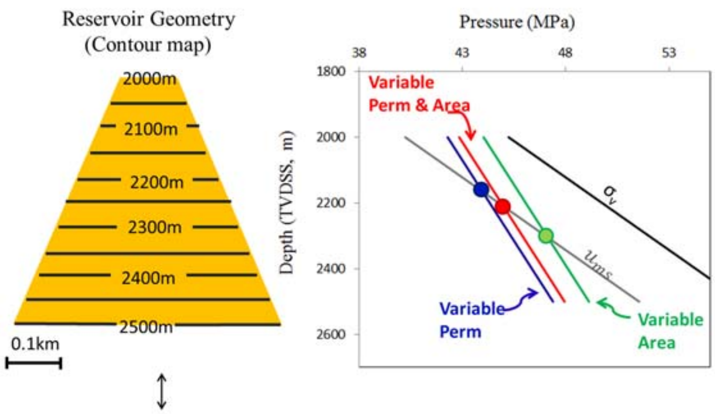

Fig. 3: 'UT Centroid' provides a simple approach to predict reservoir pressure from reservoir geometry and mudstone permeability. http://geofluids.ig.utexas.edu/software/centroid/index.htm

Seismic Pressure Prediction and Geomechanical Modeling: We have developed an approach to predict pressure in complex geologic settings; the workflow incorporates non-uniaxial loading and accounts for shear-induced pore pressures (Fig. 4. The workflow predicts both pore pressure and the full stress tensor. UT GeoFluids members were the first to be exposed to this approach.

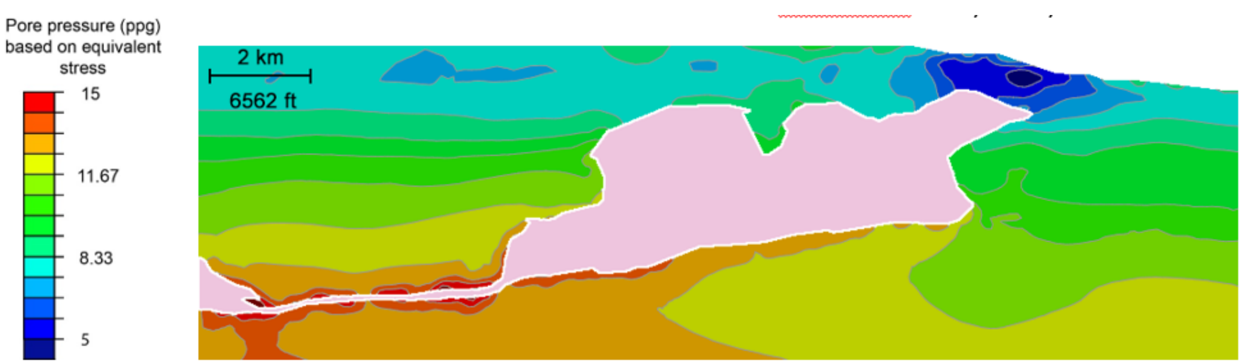

Fig. 4: UT GeoFluids has developed a workflow to couple geomechanical modeling with seismic velocity to predict pore pressure and the complete stress field in complex geologic settings (e.g., around salt bodies).

The Future: GeoFluids: Years 8-10

Testing our New PPFG (Pore Pressure & Fracture Gradient) Workflows

At our GeoFluids 2016 meeting, our sponsors proposed that we work with companies to design a blind test for our new PPFG workflows. We are establishing a technical leadership team with the companies to implement this step. We will work with this team to find new dataset(s) to model and test our latest approaches. We will obtain data for a model, calibrate to a well or two, and then use one or more wells as blind tests within the model to test predictability (both patterns and magnitudes). We will deliver model results and the comparison analysis to our sponsors.

Experimental Work Plan:

Velocity & Elastic Mechanical Properties: We will perform velocity measurements to 100 MPa for GoM mudrocks; we will integrate these measurements with analysis of elastic mechanical properties.

Mudrock deformation under non-uniaxial loading conditions: We will investigate more general loading conditions to elucidate anisotropic mudrock material behavior. We will investigate the geometry of the yield surface through drained shear testing and non-unaxial compression tests to characterize the shear effect on the compression behavior.

Smectite-Illite during compression: We will investigate the overpressure caused due by the smectite to illite transition during burial. We will now perform transformation experiments under uniaxial compression to measure the resultant overpressure.

Mudrock Fabric Evolution: We will investigate the changes in microfabric during compression using high pressure, cryo-freezing technology.

Modeling Work Plan:

Evolutionary Modeling: We will build coupled evolutionary models of salt systems and fold-and-thrust belts that trace realistic geologic histories. We will compile results from these models to establish relationships between present-day geometries and pressure, exit stress, and porosity.

Integrate Stress Dependent Behavior: We will incorporate stress dependent material behavior found in our experimental work into our numerical models. We will show how stress dependency affects geologic evolution, compression and shear failure over time.

Field Studies:

Field Application: We will apply new workflows to predicting pressure and stress in salt systems and thrust belt systems.

Workflow Development and Transfer: We will transfer workflow/technology for full stress tensor pressure prediction. We will develop realistic iso-porosity surfaces that incorporate stress dependency.

Blind Tests (see above): We will apply our PPFG techniques to blind tests developed in cooperation with our sponsors.