Data Requirements and Collection for Wellbore Strengthening

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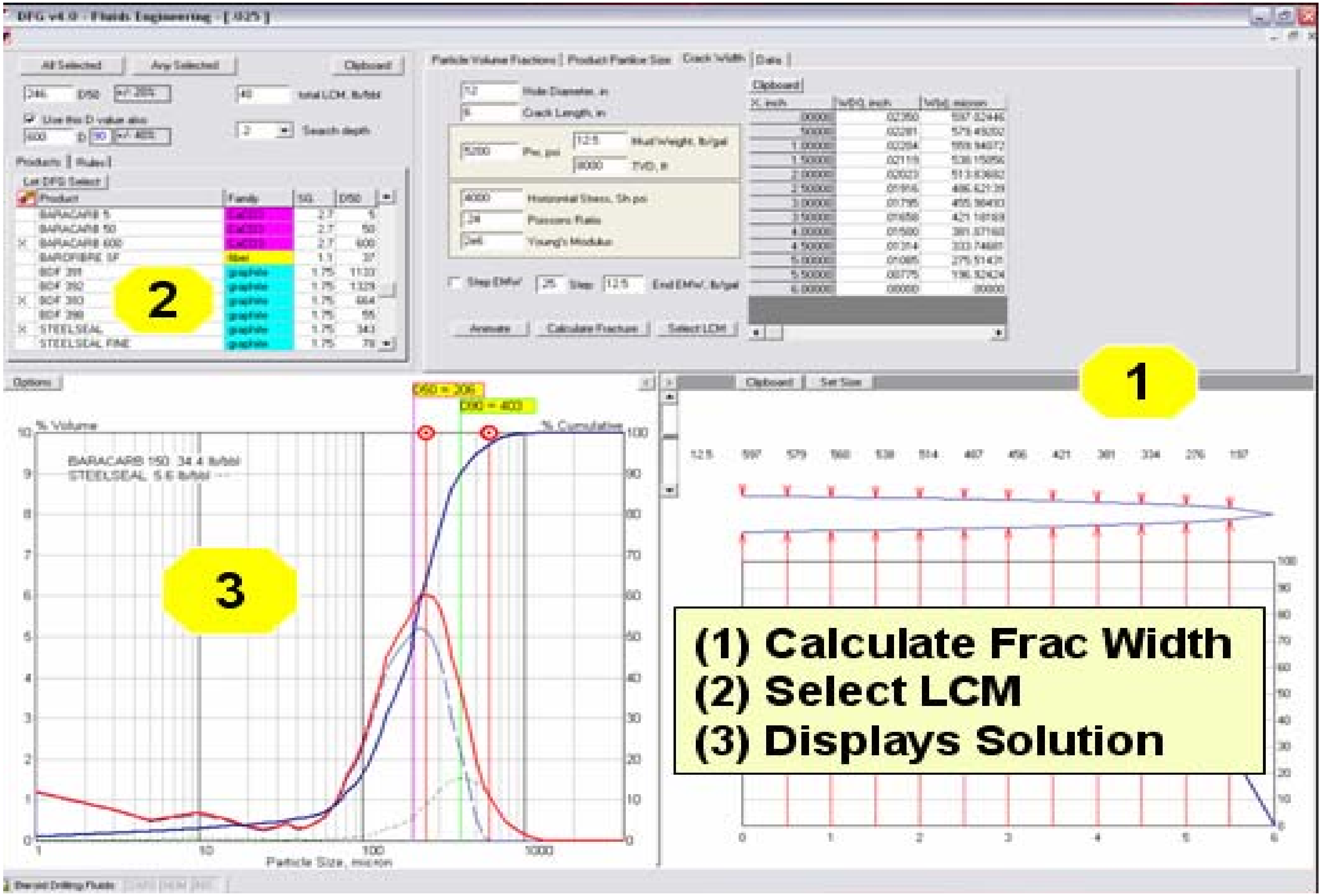
Pictures Removed

- Pictures have been removed that were used to make transitions or specific points during the presentation.
- For Further Information or discussion contact: hong.wang@halliburton.com; phone 281-871-5927

Wellbore Strengthening Design Process



246 D50 +/- 20%

40 total LCM, lb/bbl

☑ Use this D value also

600 D 90 +/- 40%

2 Search depth

Product	Family	SG	D50
BARACARB 5	CaCO3	2.7	5
BARACARB 50	CaCO3	2.7	50
X BARACARB 600	CaCO3	2.7	600
BAROFIBRE SF	fiber	1.1	37
BDF 391	graphite	1.75	1133
BDF 392	graphite	1.75	1329
X BDF 393	graphite	1.75	664
BDF 398	graphite	1.75	55
X STEELSEAL	graphite	1.75	343
STEELSEAL FINE	graphite	1.75	79

12 Hole Diameter, in

6 Crack Length, in

5200 Pw, psi

12.5 Mud Weight, lb/gal

8000 TVD, ft

4000 Horizontal Stress, Sh psi

.24 Poissons Ratio

[illegible] Young's Modulus

☐ Step EMW 25 Step 12.5 End EMW, lb/gal

X, inch	w(X), inch	w(x), micron
.00000	.02350	597.02446
.50000	.02281	579.49202
1.00000	.02204	559.84072
1.50000	.02115	536.15056
2.00000	.02023	513.83682
2.50000	.01916	486.62139
3.00000	.01795	455.98400
3.50000	.01658	421.16169
4.00000	.01500	381.07160
4.50000	.01314	333.74681
5.00000	.01085	275.51431
5.50000	.00775	196.92424
6.00000	.00000	.00000

(1) Calculate Frac Width
(2) Select LCM
(3) Displays Solution

Required Data for Wellbore Strengthening

- Wellbore geometry
- Rock mechanical properties
- Stress field
- Needed wellbore pressure containment

Summary of the Data Documents for Geomechanical Modeling

- Well diagrams
- Formation Pressure, Mud weight, Frac Gradient Profile Plots
- Drilling, Mud and Mud Logging reports
- Logs
  - Full Wave Sonic (Compressional & Shear)/other sonic logs
  - Density/Neutron/GR/Caliper/Borehole image logs
  - Formation pressure tests
  - Other logs
- Region information
  - Basin study report/Seismic map/Fault map
- Other information
  - Core test report
  - Well testing, hydraulic fracturing report or water injection report
  - LOT/Extended LOT

Minimum Data Requirements for Wellbore Strengthening

- Young’s Modulus (E)
- Poisson’s Ratio (ν)
- Hole size
- Minimum Horizontal Stress (S_h)
- Needed Wellbore Pressure Containment

Measuring E and ν in the Lab

Determine E and ν from Electrical Logs

$$\nu = \frac{\left(\frac{v_p}{v_s}\right)^2 - 2}{2\left(\left(\frac{v_p}{v_s}\right)^2 - 1\right)}$$

$$E = \frac{\frac{\rho}{v_s^2} * \left(3\left(\frac{v_p}{v_s}\right)^2 - 4\right)}{\left(\frac{v_p}{v_s}\right)^2 - 1}$$

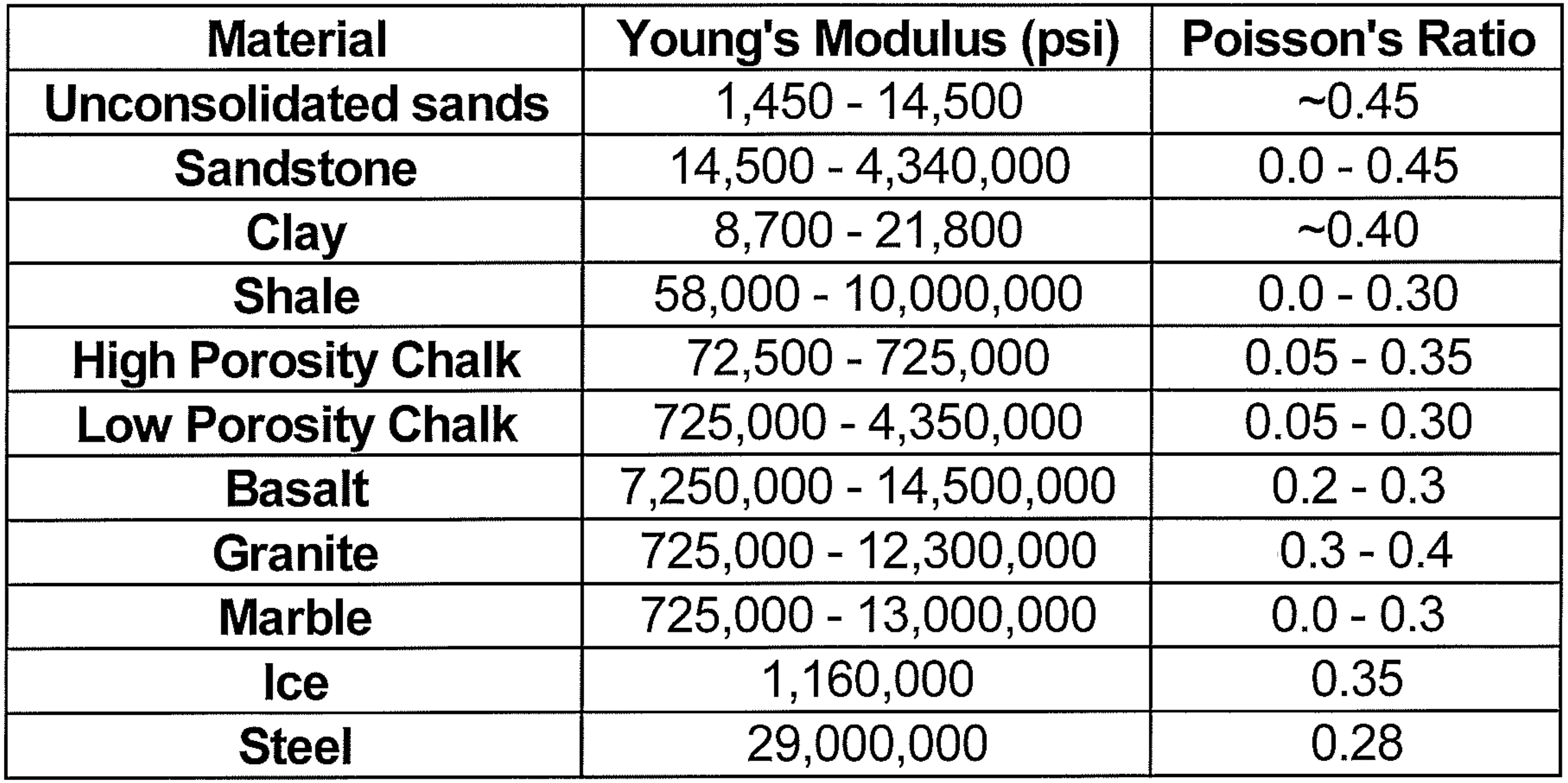
ν_p – compressional velocity

ν_s – shear velocity

ρ - density

The YM determined is a dynamic one. Empirical relationships are needed based on lab tests to convert it into a static one.

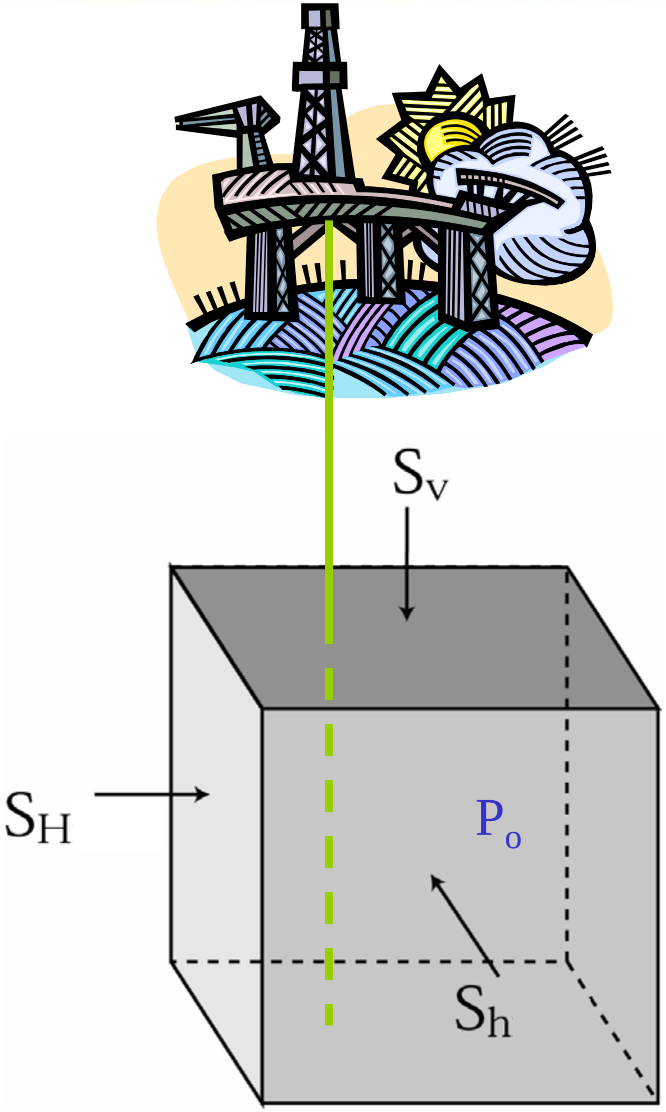
Mechanical Properties of Selected Materials



Material	Young's Modulus (psi)	Poisson's Ratio
Unconsolidated sands	1,450 - 14,500	~0.45
Sandstone	14,500 - 4,340,000	0.0 - 0.45
Clay	8,700 - 21,800	~0.40
Shale	58,000 - 10,000,000	0.0 - 0.30
High Porosity Chalk	72,500 - 725,000	0.05 - 0.35
Low Porosity Chalk	725,000 - 4,350,000	0.05 - 0.30
Basalt	7,250,000 - 14,500,000	0.2 - 0.3
Granite	725,000 - 12,300,000	0.3 - 0.4
Marble	725,000 - 13,000,000	0.0 - 0.3
Ice	1,160,000	0.35
Steel	29,000,000	0.28

Source: Petroleum Related Rock Mechanics, Elsevier, 1992

Subterranean in-situ Stresses



S_v – Vertical stress (overburden)
S_H – Maximum horizontal principal stress
S_h – Minimum horizontal principal stress
P_o – Pore pressure

S_h from Overburden S_v and Pore Pressure

$$S_h = \sigma_h + P_p$$

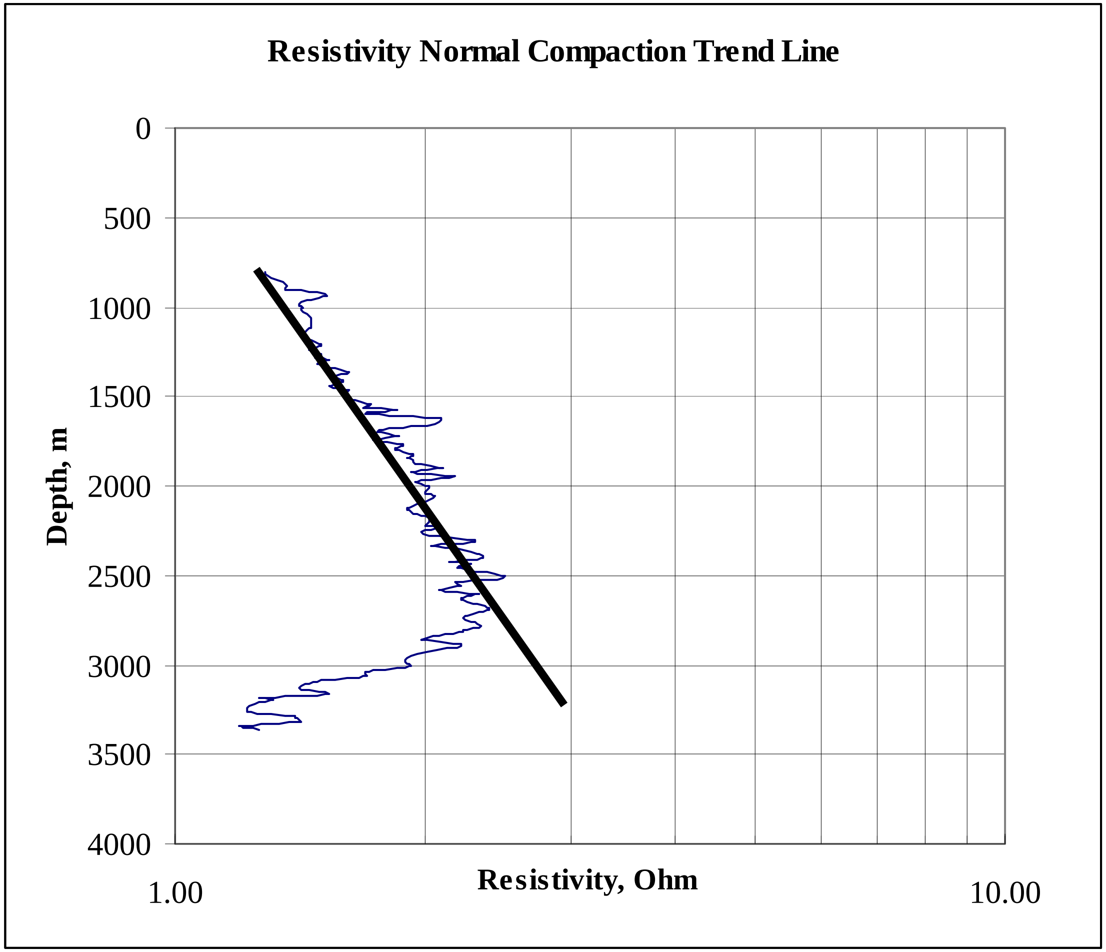
Assuming linear elastic relations

$$S_h = \sigma_h + P_p = \frac{\nu}{1-\nu}\sigma_V + P_p$$

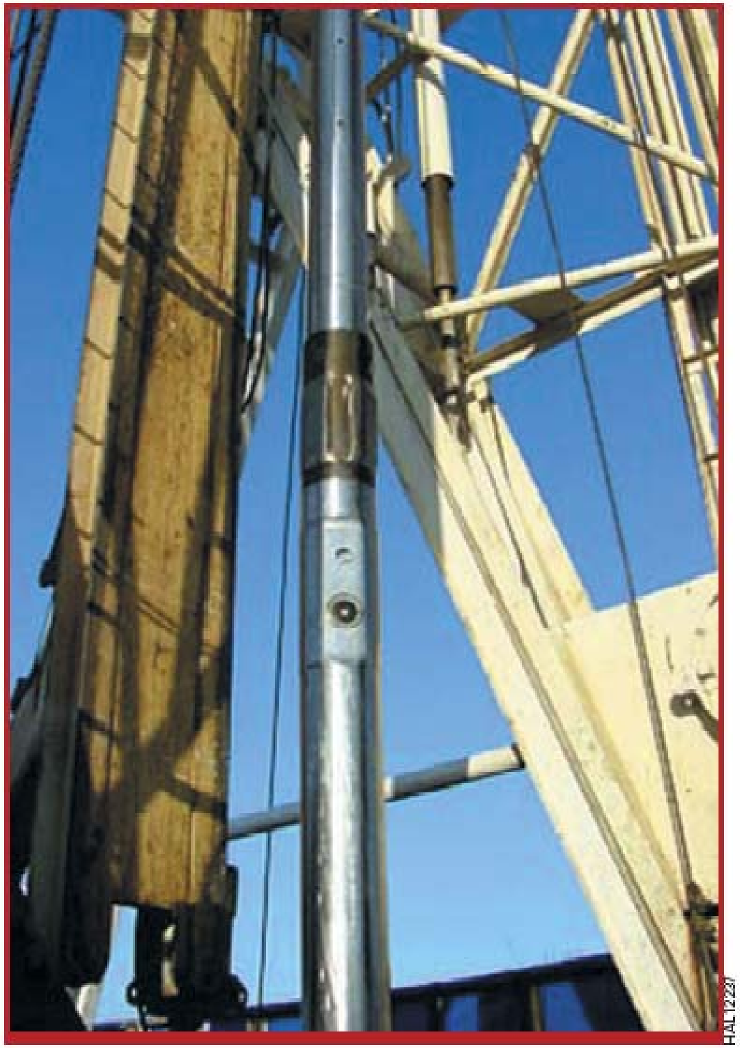
S_v from Integrating Density Logs

$$S_v(z_0) = \int_0^{z_0} \rho \, dz$$

Normal Compaction Trendlines for Pore Pressure Analysis



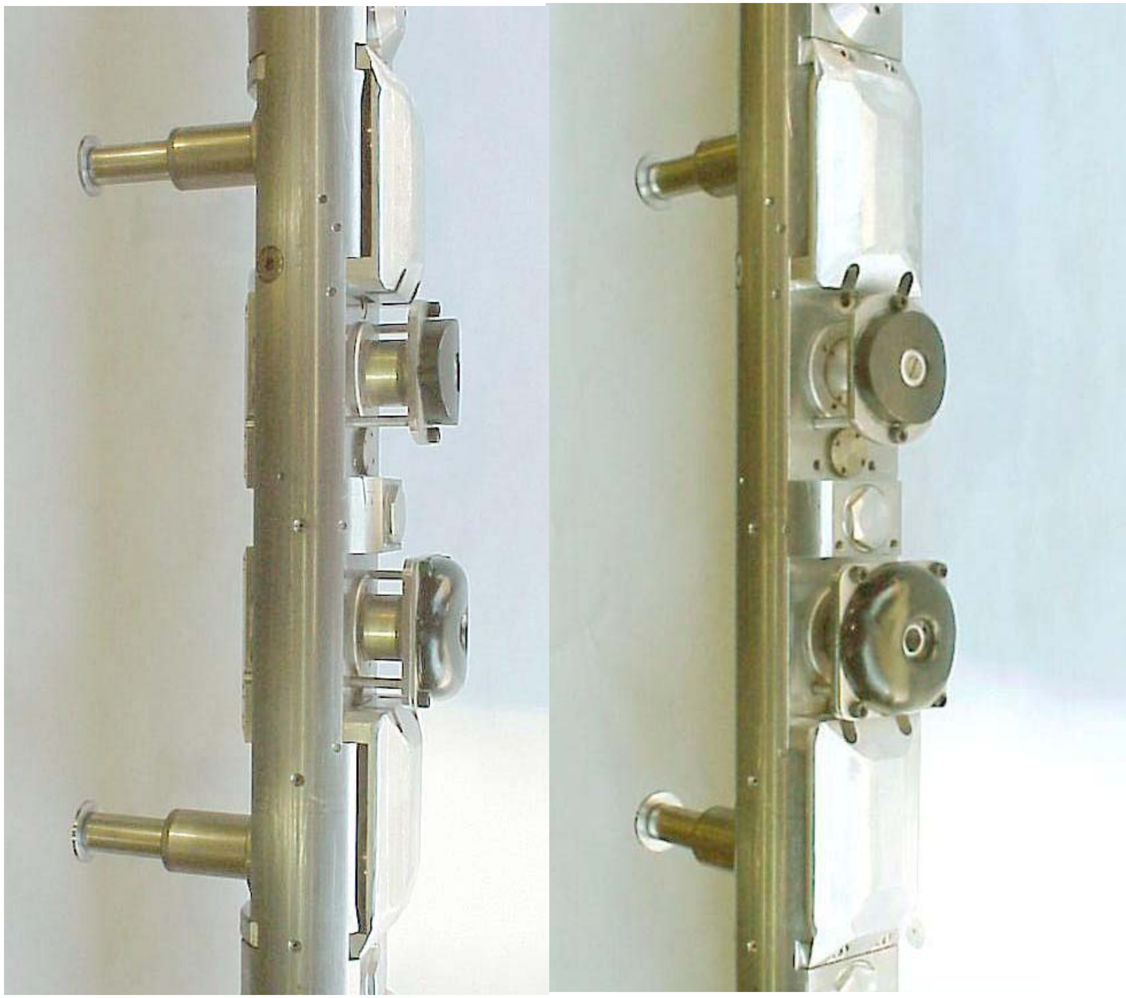
GeoTap™ Formation Tester



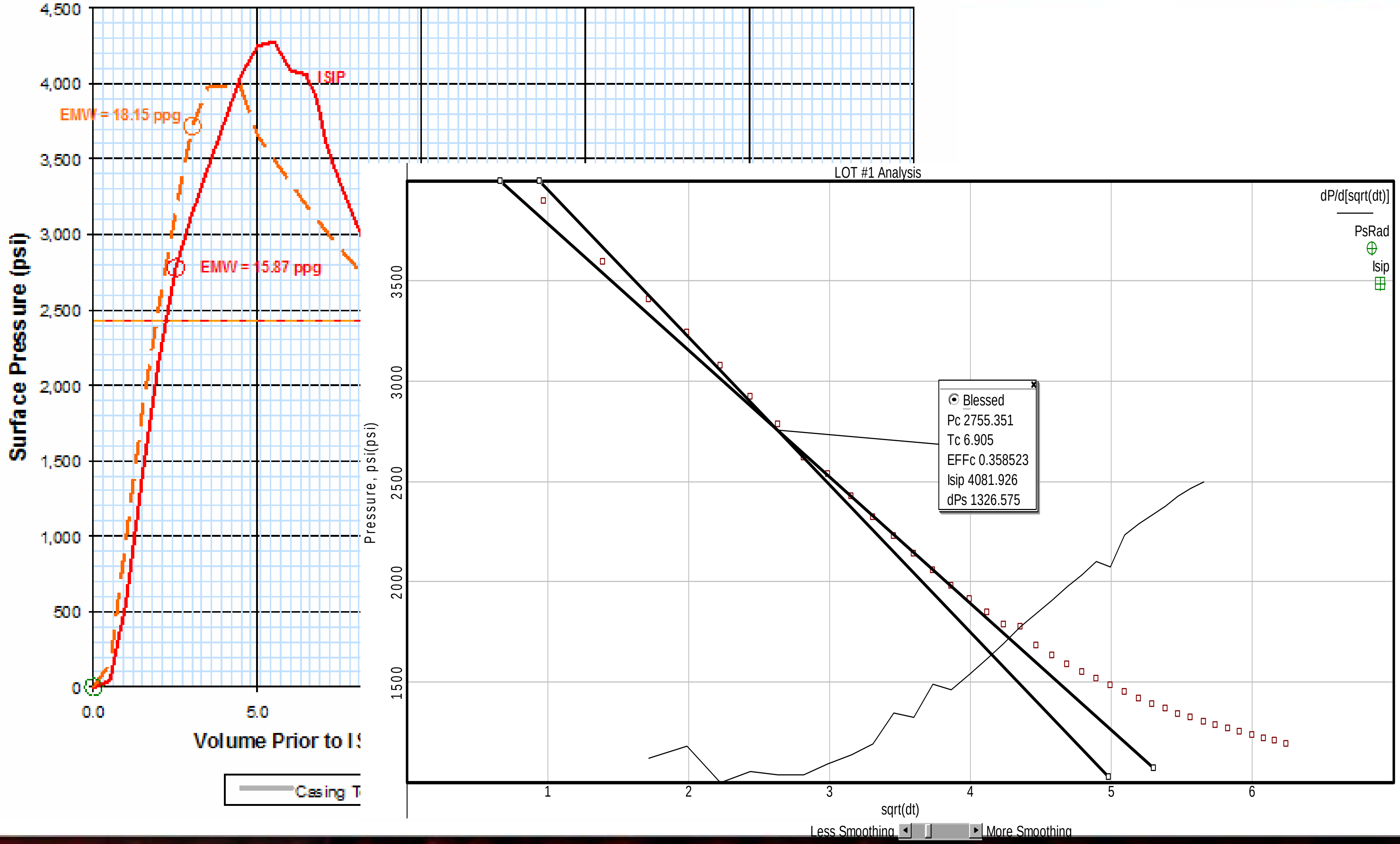
Applications

- Formation pore pressure for fluid type, fluid contacts, and reservoir connectivity / isolation determination
- Formation/fluid mobility (permeability / viscosity) indicator
- Precise overbalance determination
- Improved well control and drilling safety
- Improved borehole stability
- Cost savings (rig time and wireline costs)
- Doubles as pressure-while-drilling tool

Halliburton RDT - Dual Probe Section

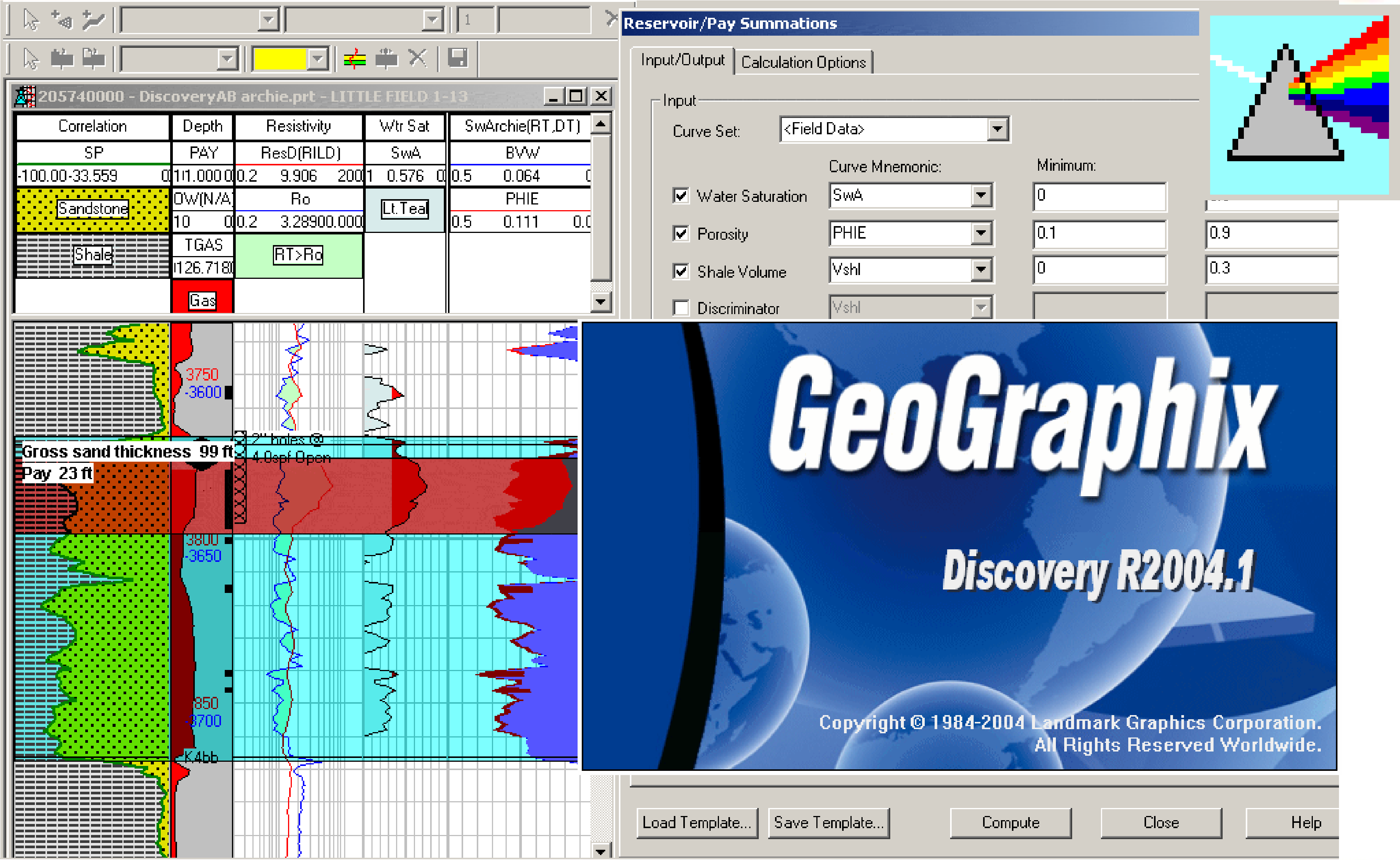


S_h Obtained from LOT and PDA



● Blessed
Pc 2755.351
Tc 6.905
EFFc 0.358523
Isip 4081.926
dPs 1326.575

Log Based Geomechanical Modeling with PRIZM



Reservoir/Pay Summations

Input

Curve Set: <Field Data>

	Curve Mnemonic:	Minimum:	
☑ Water Saturation	SwA	0	
☑ Porosity	PHIE	0.1	0.9
☑ Shale Volume	Vshl	0	0.3
☐ Discriminator	Vshl		

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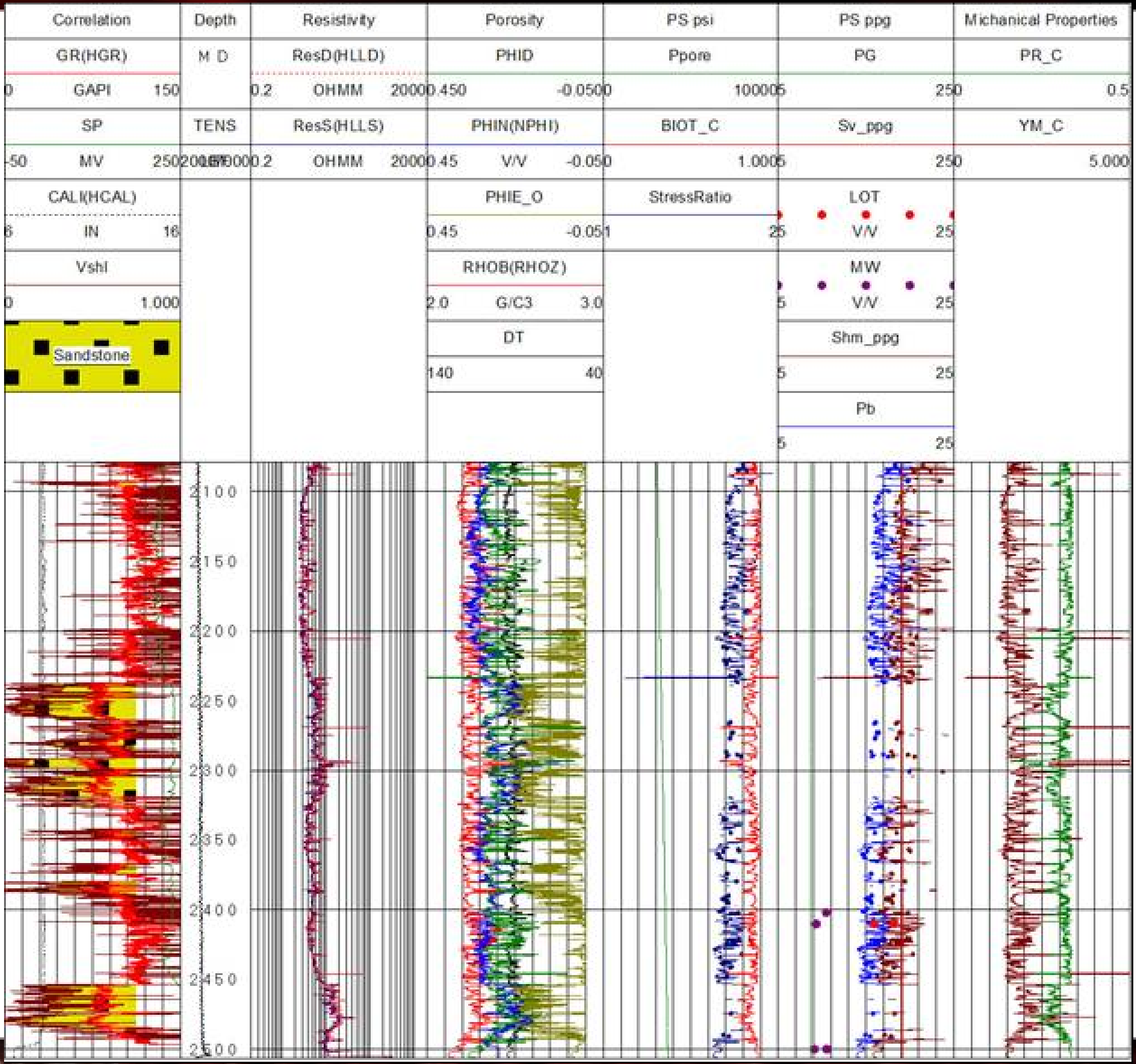
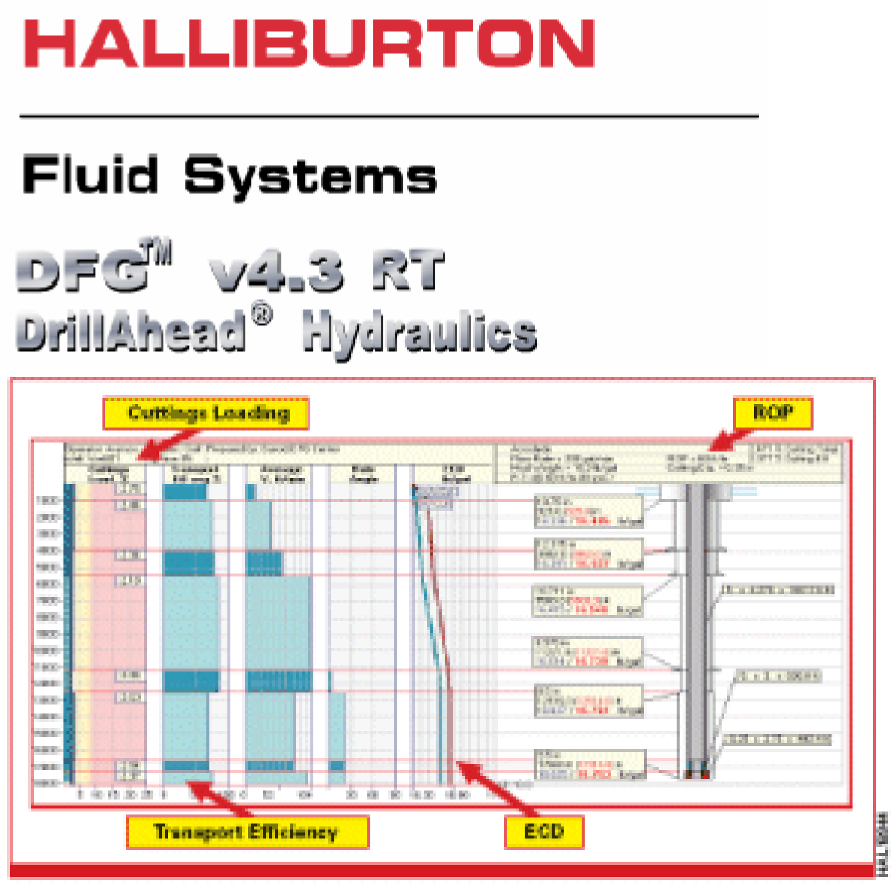
Log Based Geomechanical Modeling



ECD Predictions



HALLIBURTON

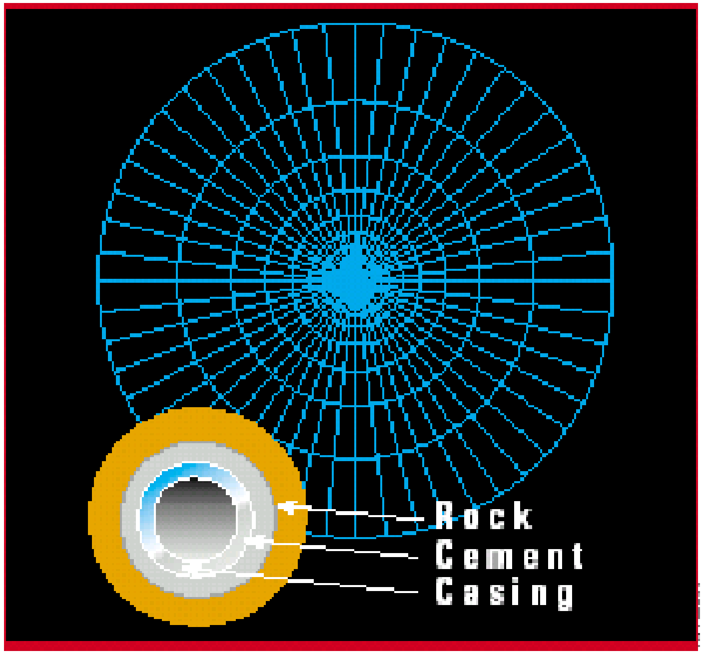
Fluid Systems

DFG™ v4.3 RT
DrillAhead® Hydraulics

DFG Software with DrillAhead Hydraulics Planning Service
Drill Well On Paper (DWoP)

OptiCem™ Software

Wellbore simulation program for all cementing jobs



Questions?