

An Automated Approach to Wellbore Stability Analysis

Petroleum Engineering Senior Design II

GROUP L:

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Introduction

Wellbore stability is an essential element of determining the viability of a well and a field.

Mud Weight is an important part of wellbore stability analysis.

The process to find ranges of mud weight involves intense calculations and long iterative processes.

Objectives

The objective of this project was to study wellbore stability analysis and determine a quicker and simpler way to conduct the process.

We determined the best way to accomplish this would be to create a computer program.

In an effort to use pre-drill data the purpose of the program is to intake seismic data from field and determine the optimal mud weight ranges required for drilling.

The program is most useful in overpressure zones.

It can also be used to evaluate hydraulic fracturing criteria.

Detailed Evaluation Criteria

The overall requirement for all aspects of the program was simple:

- 1. Ensure equations and methods used for calculations provide the most accurate and representative model of real conditions.
- 2. Ensure the program is time effective to use and greatly reduces the amount of effort required to evaluate wellbore stability.
- 3. Ensure the program is capable of performing with pre-drill data.

Using the Mohr-Coulomb failure criteria, we created a program that will be most useful to drilling and reservoir engineers, and aids evaluations in the planning of well locations, drilling methods, and completions methods.

Assumptions Made for Program

Used data from a well in Wyoming to test our program because it was easy to obtain.

Used sonic logs to simulate seismic data.

- Eliminated need for stacking methods.

Used Gardner's correlation to estimate densities.

- Assumed a generalized constant for the equation.

Comparisons

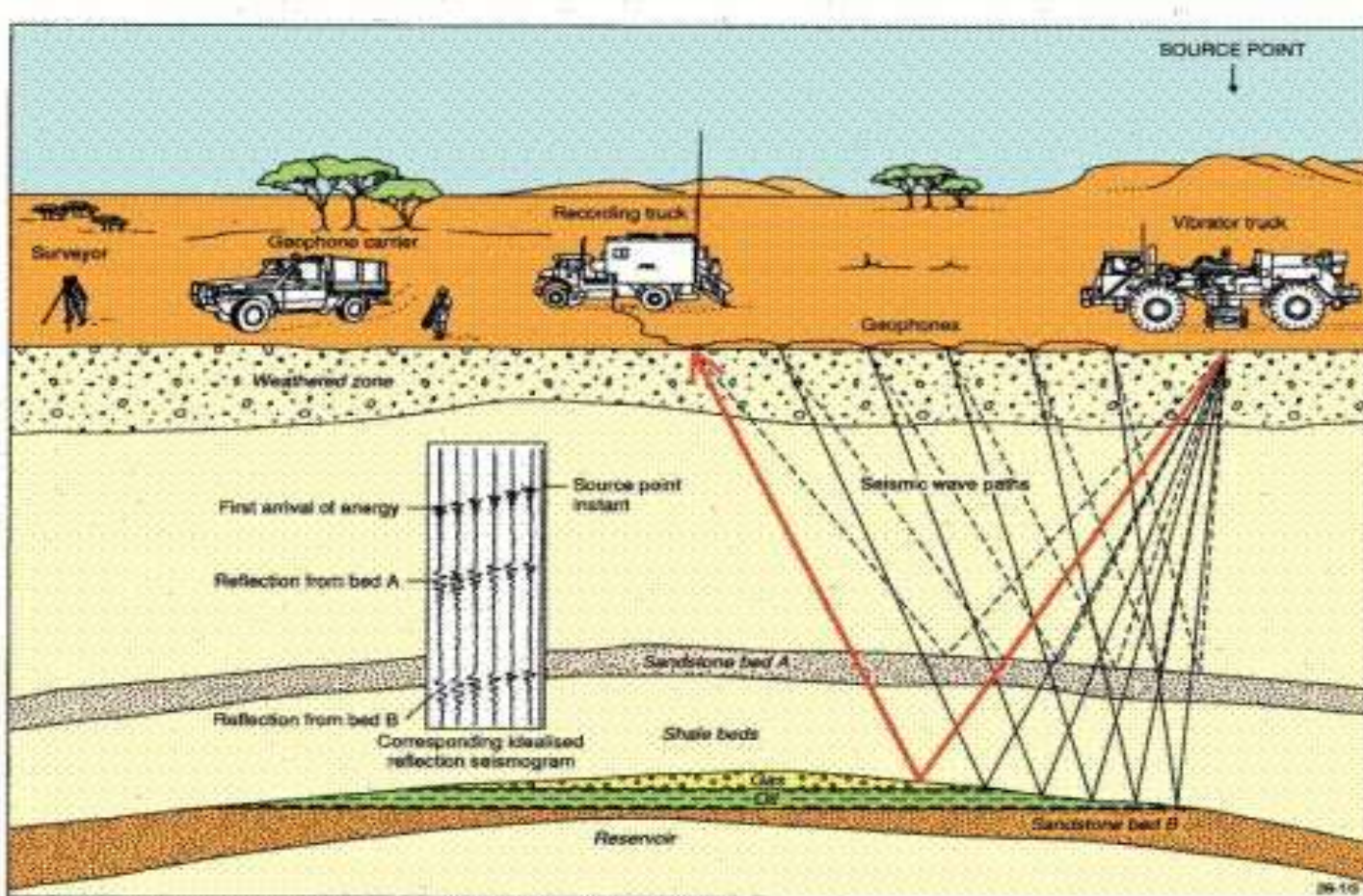
Used program to calculate effects and properties.

Compared predicted models to data from well logs to determine accuracy.

Also can use program to compare results from different situations.

- No pore pressure effects
- With pore pressure effects
- With thermal effects
- With both effects

Seismic Exploration



Rock Mechanics

Failures from an instable wellbore

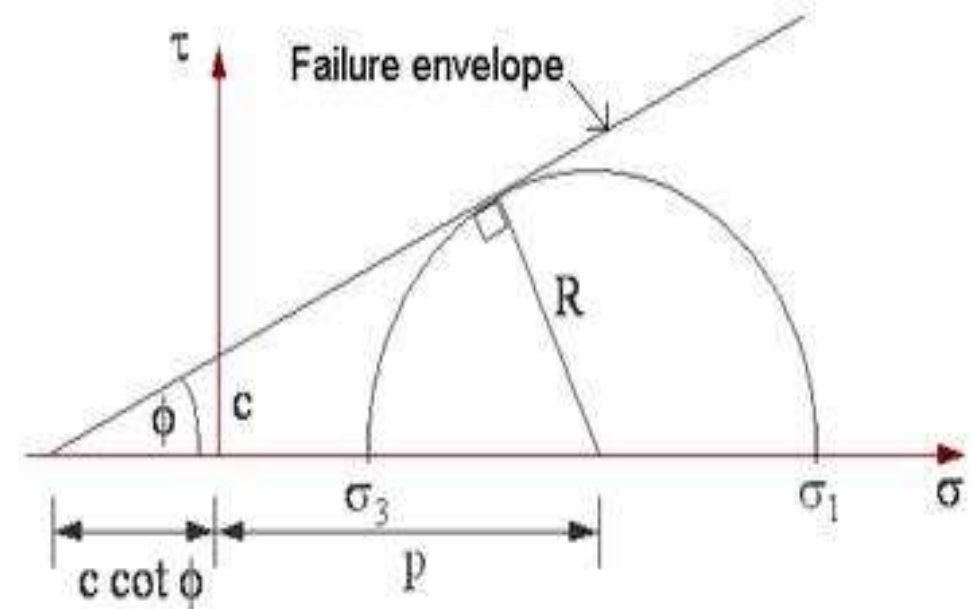
- Collapse
- Fracturing

Mohr-Coulomb failure criterion

- Mohr's circle
- Max stress (σ_1)
- Min stress (σ_3)
- Shear envelope
- Internal friction angle (ϕ)
- Half of Unconfined compressive Strength or Apparent Cohesion (c)

Kirsch's Solution

- At 0° and 90°
 - $\sigma_r = MW * depth$
 - $\sigma_\theta = 3\sigma_h - \sigma_H - \sigma_r$
 - $\sigma_z = \sigma_v - 2\nu(\sigma_H - \sigma_h)$

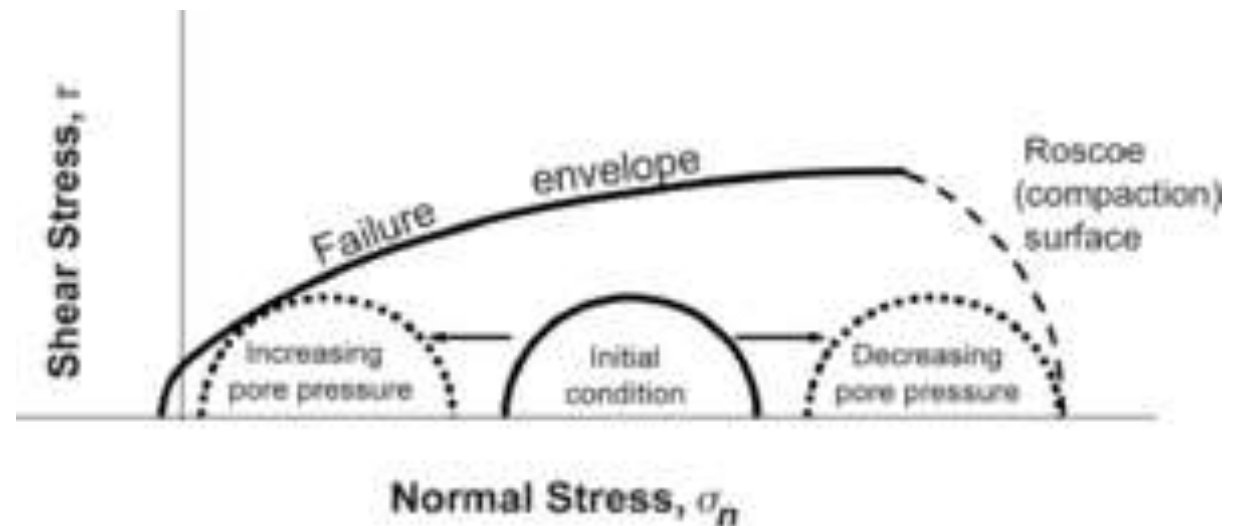


Effects of Pore Pressure

As stated before we took into account pore pressure and thermal effects.

Pore fluid pressures will reduce the effective stress supported by the rock mineral frame.

If pore pressure is increased, the effective stresses decrease, and the Mohr circle is shifted left until eventually the envelope may be contacted and the rock fails.

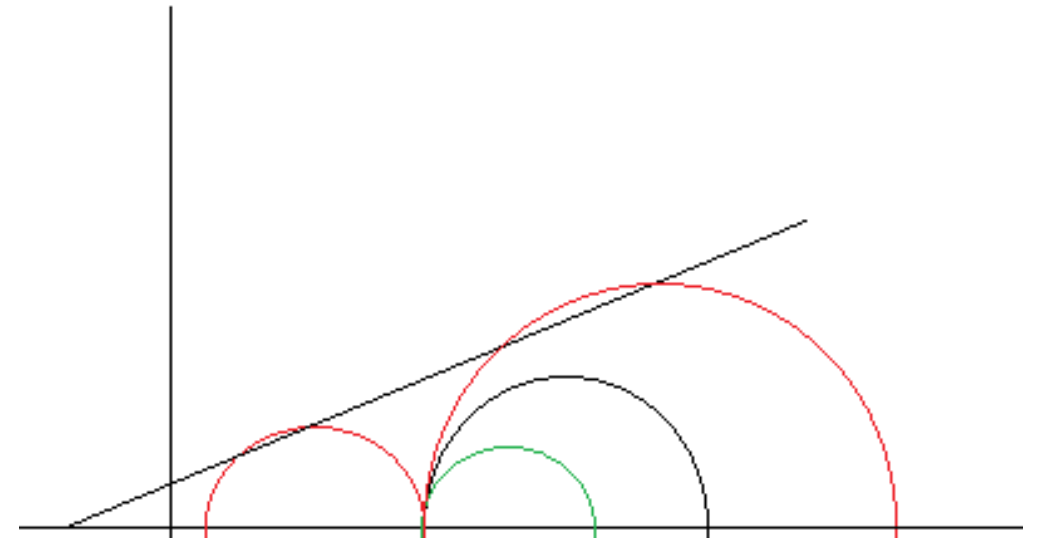


Thermal Effects

When adding thermal effects it is not as clear as pore pressure how it will effect the stresses.

If the mud temperature was to exceed the formation temperature we would likely see the large red circle.

If the mud temperature stayed under the formation temperature the circles would initially shrink, but could have a change in principle stresses and then fail by tension or shear.

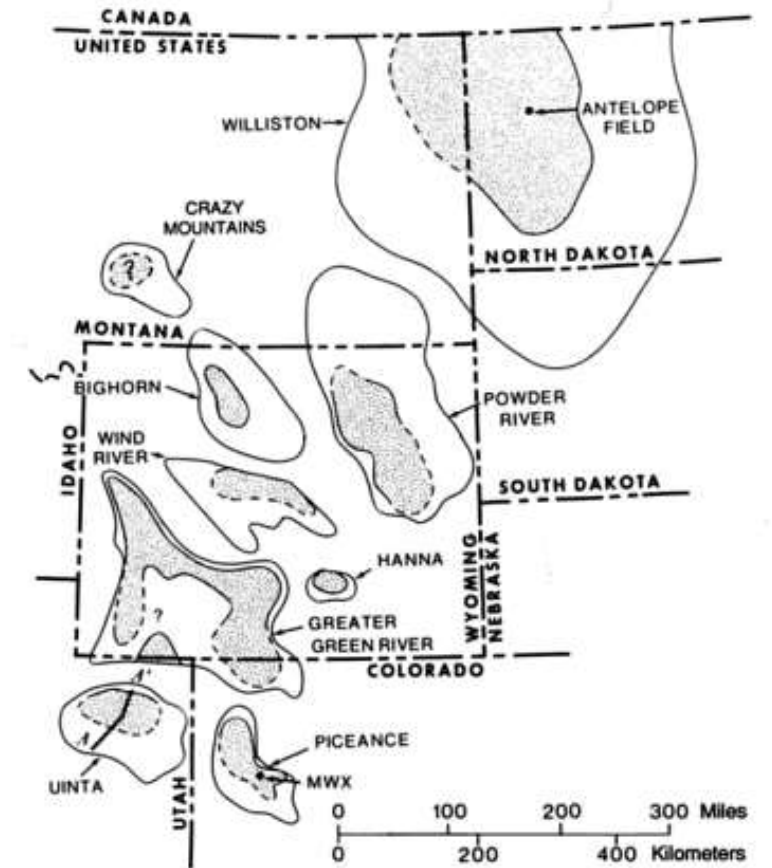


Common Overpressure Areas

Our program becomes useful for predicting stability issues so that pre-emptive measures can be taken an account for safety issues.

Aqua-thermal pressuring- Caused from compaction disequilibrium.
Aqua-thermal pressuring caused by thermal expansion. (Gulf Coast)

Tectonic Movement – Tectonic uplifting and compaction to form over-pressured areas. Obviously common in the Rocky mountain Region. Common overpressure areas seen in map to the right.



Location of Test Well

24 miles East of Rock Springs

Along the Rock Springs uplift

TD = 12,747 ft

- Target Madison and Weber Formations
- Secondary Target Phosphoria Formation



Well Lithology

The Left plot shows the formations encountered while drilling the well.

We should be able to assume our well is sandstone/shale since the plot on the right shows basically all formations made up of shale and many different kinds of sandstone.

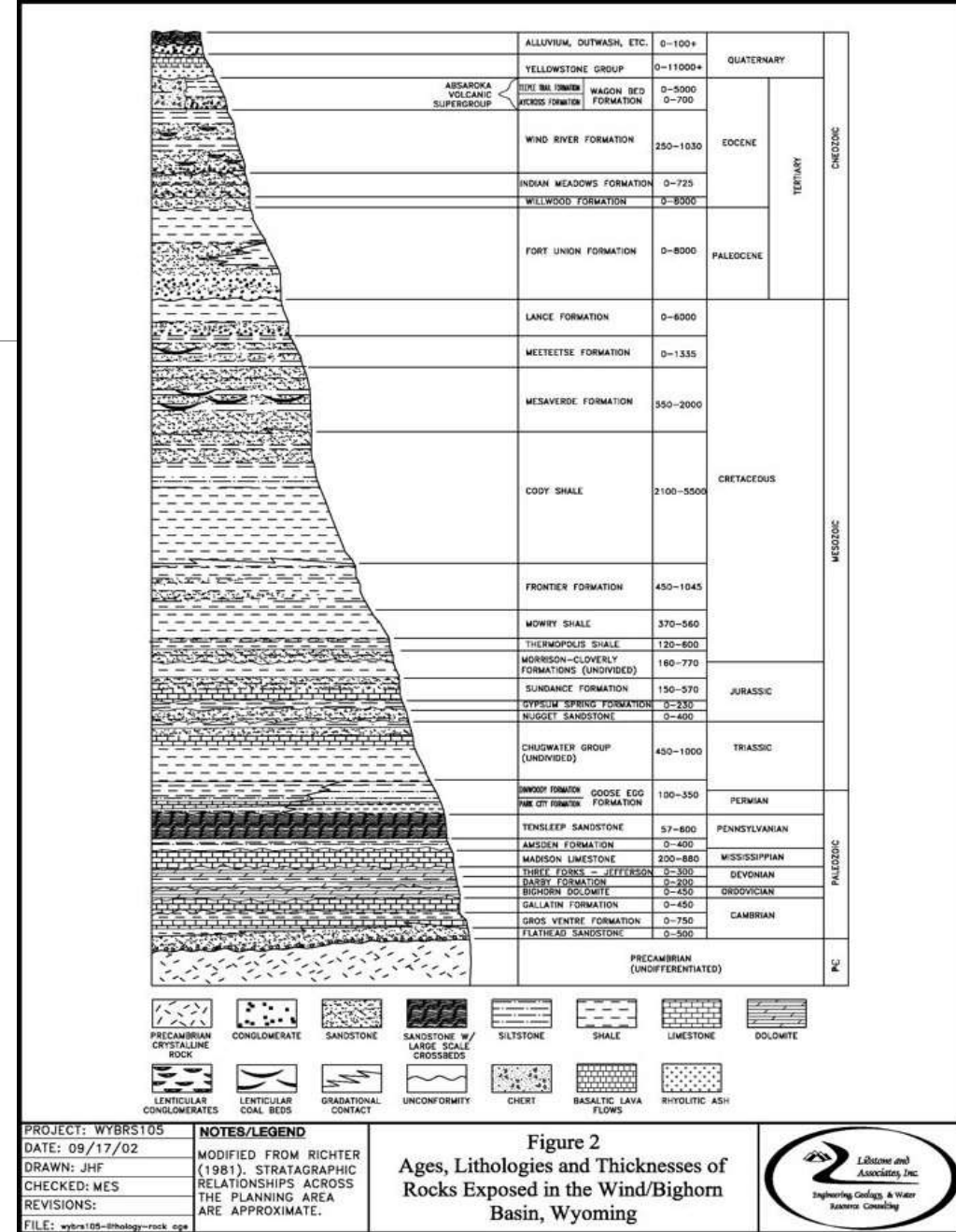


Figure 2
Ages, Lithologies and Thicknesses of Rocks Exposed in the Wind/Bighorn Basin, Wyoming

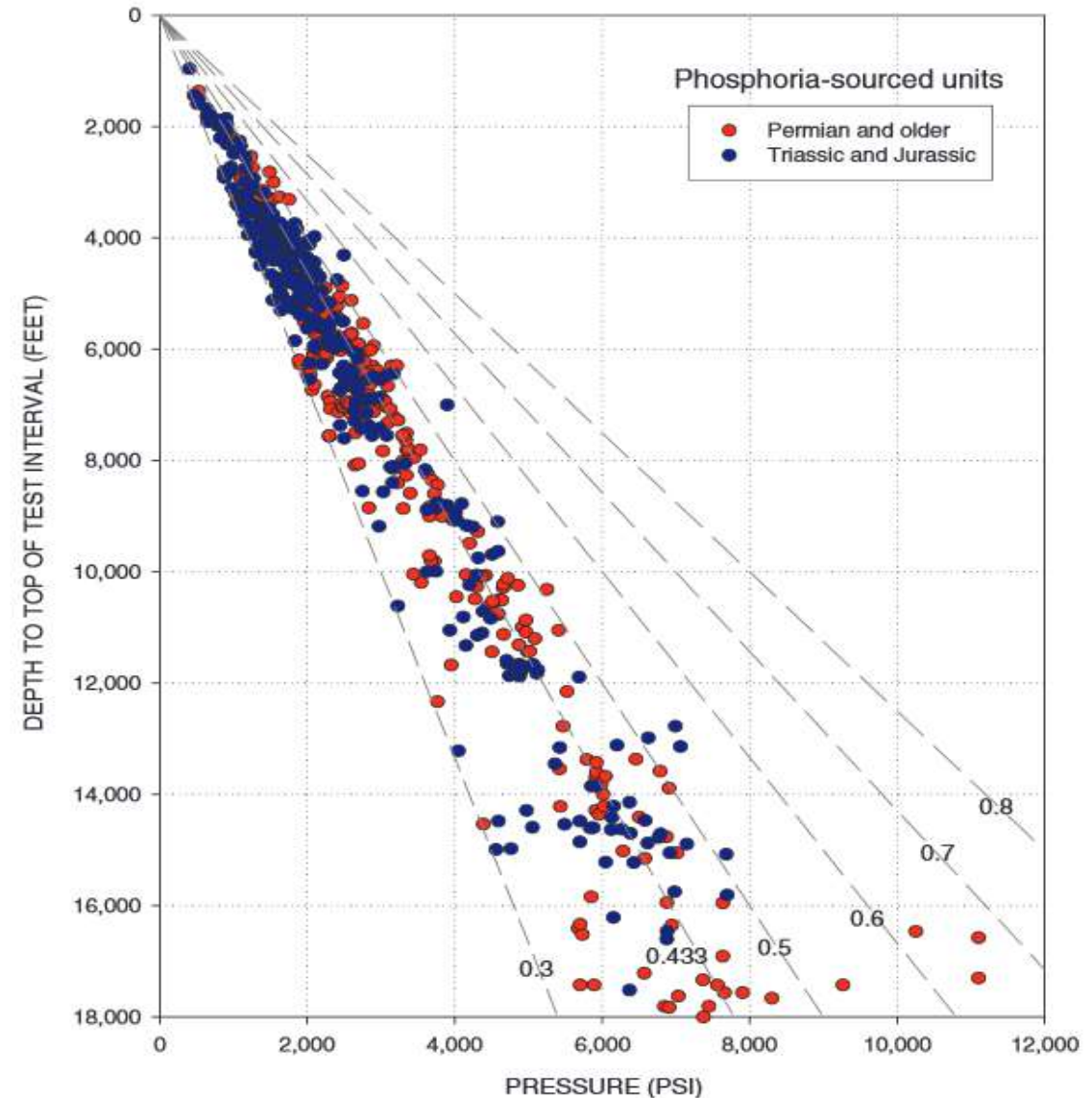


Pressure Assumptions

Originally expected overpressure due to the uplifting, but from different well information in the area we should be able to assume a normal pressure gradient (0.433-0.5psi/ft).

The Phosphoria formation (pressure info to the right) is the well's secondary target sitting immediately above the target formations Madison and Weber.

RSU #1 has a TD of 12,747 ft, so we should expect similar pressures as seen plotted to the right.



Drilling Mud Weight

Mud Weight is typically the most easily controllable parameter during drilling operations.

Too high of a mud weight leads to formation invasion, and causes tensile failure of the formation.

Too low of a mud weight allows shear failure of the rock, and may cause borehole breakout.

Rock strength criterion and a linear poro-elasticity stress model are combined to find the most optimal mud weight to provide wellbore stability.

The accuracy of these models in the particular formation being drilled govern how well the predicted mud weight controls the occurrence of instability issues.

Drilling Mud Weight and Economic Consequences

Encountering wellbore stability issues during the drilling operation leads to much higher costs on the drilling schedule.

These include loss of circulation, stuck pipe, side tracking, and reaming operations.

Every one of these issues raises the cost of drilling to a significant degree.

Depending on the drilling contract a rig on stand-by could cost as much as \$20,000/day.

It becomes optimal to use our program.

Drilling Mud Weight Safety Concerns

Maintaining a specific mud weight is essential to a safe drilling process.

Improper mud weights can lead to a blowout.

This is especially prevalent in over-pressured zones.

Applications of Hydraulic Fracturing to Increase Productivity

Hydraulic fracturing is among the most prominent types of well stimulation techniques to enhance the extraction of oil and gas.

It is now a standard practice in the production of various types of reservoir formations.

Hydraulic fracturing is vital in the development of low permeability strata including over-pressured zones such as those this program is useful for.

Perkins-Kern-Nordgren Model

The PKN model is a bi-wing fracture model used to compute the geometry of hydraulic fractures.

It is applied to optimize the effectiveness of hydraulic fracturing treatments and allows the fracturing process to be modeled mathematically.

The PKN model assumes constant height along fracture length and an elliptical shaped fracture cross section.

Additional assumptions: fracture geometry is a bi-wing shape symmetric to the wellbore, the ratio between length and height is large, and fluid flows in direction of fracture length.

Hydraulic Fracture Orientation

Fracture orientations, lengths, and widths are based on in-situ stresses present in the formation being fractured.

Propagation normally occurs in the direction of the minor principle stress.

The seismic data used in the program for the stability analysis can also be used to guess the fracture heights.

Using data from the model it is possible to predict the fracture properties.

Results – Some Parameter Estimation

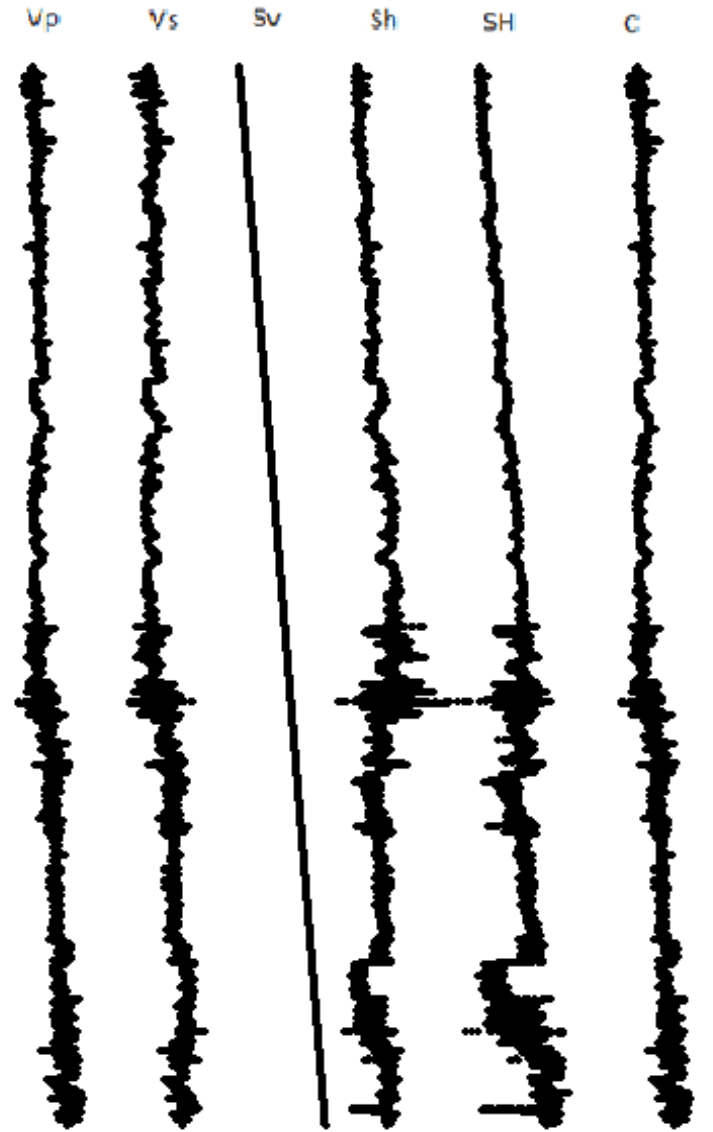
Prediction of Density and Temperature values gives reasonable values.

Density and Thermal Verifications



Parameter Investigation

Replace trig-function with ratio-metric estimation.



Mud Weight Basic Curve

```
Wellbore Stability Parameter Results
Maximum MW [ppg], Min: 23 Max: 172 Avg: 59
Minimum MW [ppg], Min: 0 Max: 1 Avg: 0
Sigma_v [psi], Min: 298.51792492093386 Max: 1962.257826480272 Avg: 1130.38787570
06023
Sigma_h [psi], Min: -9.566925336329425e-12 Max: 1.2202701326143715e-10 Avg: 3.91
0084737833344e-11
Sigma_H [psi], Min: -114.76845886500878 Max: 657.8016707316402 Avg: 294.57036479
77011
c [psi], Min: 11334.998703926094 Max: 33502.48963204788 Avg: 20884.45551320909
ifa [degree], Min: 26.6 Max: 26.6 Avg: 26.599999999989137
```



With Pore Pressure

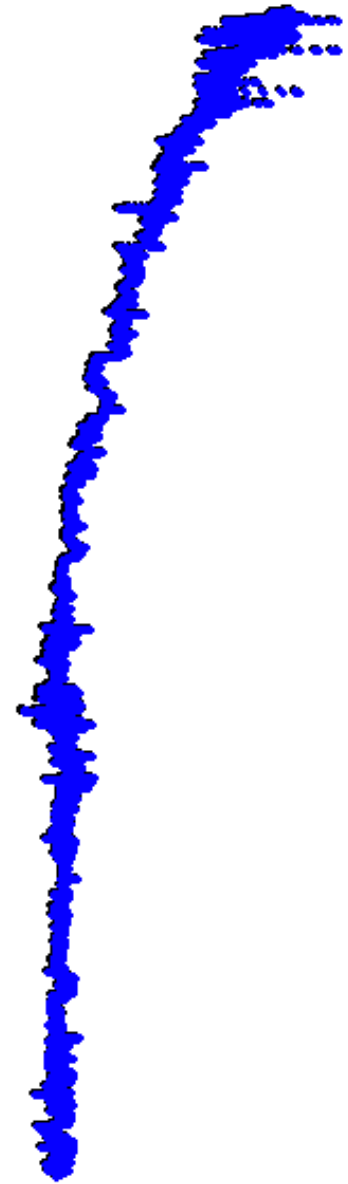
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Comparison

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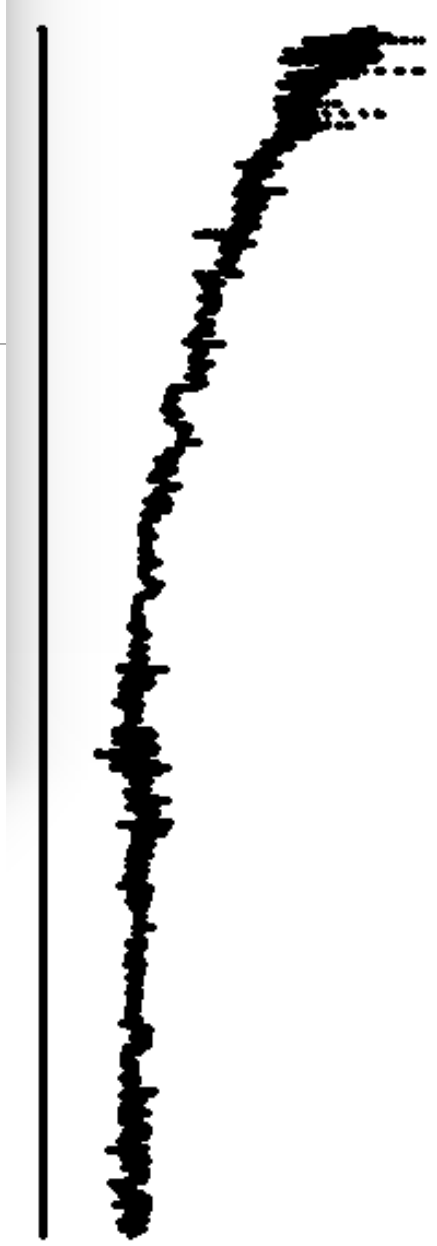
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With Temperature

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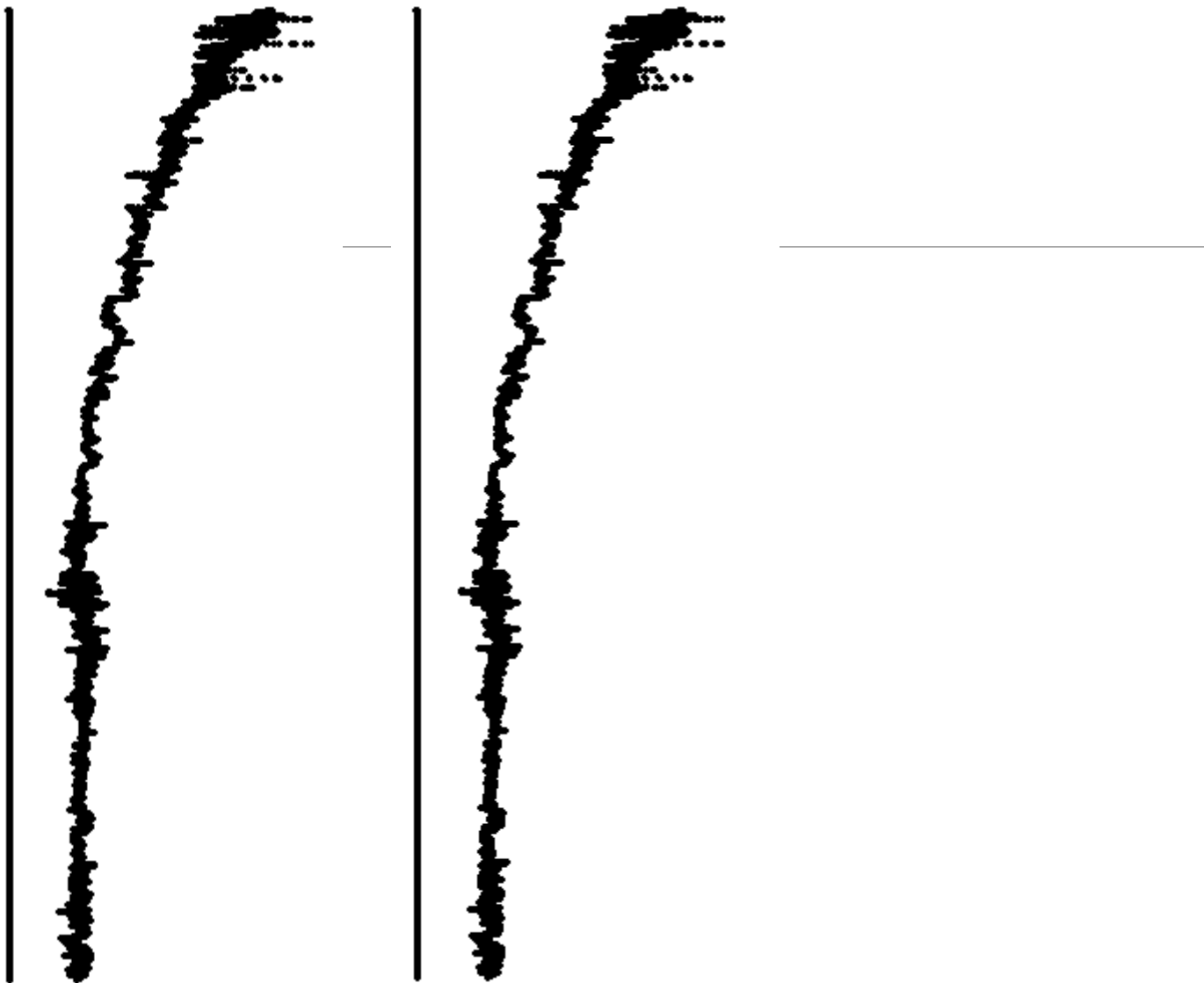


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□
```

Comparison



Fracture Results

Fracture lengths are too high.

Reason due to leak-off and soft formation.

```
Fracture Simulation Inputs
Q [cu-m/s]: 10    mu [cP]: 0.5    t [hr]: 1    Pw [psi]: 1.30
Fracture Simulation Results
Fracture Length Range [m]: 703246.4399791321 to 1156513.9830023847
```

Fracture Curve



Thank You

Questions?