Use of wire line logs for estimation of strength variability in cap-rock lithologies

Elizabeth S. Petrie  
Utah State University

Tamara Jeppson  
Utah State University

James P. Evans  
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/graduate_posters

Recommended Citation
Petrie, Elizabeth S.; Jeppson, Tamara; and Evans, James P., "Use of wire line logs for estimation of strength variability in cap-rock lithologies" (2011). Rocky Mountain (63rd annual) and Cordilleran (107th annual) Joint Meeting. Graduate Student Posters. Paper 12.  
https://digitalcommons.usu.edu/graduate_posters/12

This Presentation is brought to you for free and open access by the Browse all Graduate Research at DigitalCommons@USU. It has been accepted for inclusion in Graduate Student Posters by an authorized administrator of DigitalCommons@USU. For more information, please contact rebecca.nelson@usu.edu.
Use of wire line logs for estimation of strength variability in cap-rock lithologies

E. Petrie, T. Jeppson, & J. Evans
Introduction

- Characterization of cap-rock lithologies at reservoir-seal and intra-seal interface
- Examine lateral and vertical variability of Poisson’s Ratio and Young’s Modulus
- Field and sub-surface methods and results
• Pilot study – Jurassic Carmel Formation
• Located on western edge of San Rafael Swell along I-70
• 20 wells analyzed covering approximately 440 km²
Jurassic Carmel Formation

- Seal to the underlying Navajo Sandstone
- I-70 outcrop at western edge of San Rafael Swell
- Mineralized fractures (veins) and open fractures
- Mixed siliciclastic carbonate sedimentary sequence of shallow marine to peritidal origin
Shear Velocity Calculations

- Covert digitized sonic log travel times to velocity
- Vertical resolution limited by frequency and distance between transmitter and receiver ~ 2 ft or 61 cm

Utah D-8

<table>
<thead>
<tr>
<th>GR</th>
<th>VP</th>
<th>VS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

2.71 km

Utah D-7

<table>
<thead>
<tr>
<th>GR</th>
<th>VP</th>
<th>VS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

~ 2 ft or 61 cm
Well log analysis

Raster well log data from 20 wells used to derive Poisson’s Ratio and Young’s Modulus

- Dipole sonic logs not available for all wells – must derive shear velocity from compressional velocity
- Empirical – based on relationships established by previous workers and verified using dipole sonic logs from two wells
- Need bulk density to calculate Young’s Modulus
  - Density is often presented as density porosity must convert to bulk density

### Gamma Ray

<table>
<thead>
<tr>
<th>Gamma Ray</th>
<th>( \frac{V_p}{V_s} )</th>
<th>Cross plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR&lt;50, Carmel</td>
<td>1.9</td>
<td>A</td>
</tr>
<tr>
<td>150&gt;GR&gt;50</td>
<td>1.8</td>
<td>B</td>
</tr>
<tr>
<td>GR&lt;50, Navajo</td>
<td>1.6</td>
<td>C</td>
</tr>
<tr>
<td>GR&gt;150</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>
Shear Velocity Calculations
Vs from Vp and observed lithology relationship

- Control wells show a 3.1-3.8% difference between measured and calculated shear velocity

- Vp/Vs log shows the relationship used for Vp to Vs calculation based on GR value

Utah D-8

Utah D-7
Poisson’s Ratio

Published Poisson's ratio for various lithologies (from BP)

Poisson’s Ratio – calculated values fit with published values for sandstone, muddy limestone and mudstone

Young’s Modulus GPa
Young's Modulus Calculations

Utah D-8

<table>
<thead>
<tr>
<th>GR</th>
<th>0.00</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>VD(M)</td>
<td>0.18</td>
<td>5.00</td>
</tr>
<tr>
<td>E(T)</td>
<td>0.35</td>
<td>5.00</td>
</tr>
<tr>
<td>FI</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

Utah D-7

<table>
<thead>
<tr>
<th>GR</th>
<th>0.00</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>VD(M)</td>
<td>0.18</td>
<td>5.00</td>
</tr>
<tr>
<td>E(M)</td>
<td>0.35</td>
<td>5.00</td>
</tr>
<tr>
<td>FI</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

Percent difference
Carmel 1.3% Navajo 13%

Percent difference
Carmel 1.5% Navajo 2.3%
Results

Poisson's ratio and Young's modulus calculated 20 wells

- Poisson's ratio reflects an average of expected values over a defined by GR lithologic zones.
Variability in calculated $E_d$

CARMEL SEAL

NAVAJO
Lateral variability exists within the Carmel Seal across the study area.

Average Young's modulus ranges from 17.3 to 39.7 GPa.

Variability in Young's Modulus observed across short distances in offset wells.
• Difference map average $E_d$ – Carmel/Navajo Interface
• Most wells show a decrease across the interface
• Average change is 5 GPa
Reservoir Seal interface

Inset shows deformation band in Navajo & associated small normal fault in overlying Carmel

- GR log
- Calculated Young’s Modulus
- Measured strat column
- Fracture density histogram compiled from scanlines and ortho-image analysis

Scanline lithology:
- Mixed
- Sandstone/limestone
- Shale/siltstone

Reduction of 4 GPa
Intra-seal bedding interface

Fracture density histogram
Compiled from scanlines and ortho-image analysis

Discontinuities within the Carmel seal
inset shows fracture pattern changes
across bed interface

Intra-Carmel variations in $E_d$ of 5-19 GPa
Conclusions

- Shear velocity values can be estimated from compressional velocity – providing estimates of elastic moduli
- Variations in elastic moduli are observed laterally and across interfaces
- Fracture density in outcrop shows a relationship to lithology and bed thickness – this relationship is also observed in the calculated rock strength in the well bore
- $E_d$ shifts average 5 GPa across Navajo Carmel interface, larger shifts of up to 19 GPa observed within the Carmel
- Establishing a link between outcrop discontinuity distributions and well log data will be useful in constraining risk during design and implementation of CO2 sequestration projects and provides data for modeling scenarios
Acknowledgements and Questions

Tamara Jeppson
Jim Evans
DOE Grant # DE-FC26-0xNT4 FE0001786
GDL Foundation Fellowship
SMT Kingdom Software – University Grant
Sirovision Software – University Grant
Going forward

- Outcrop correlation across lateral sedimentologic changes and offset wells
- Burial history – are the subsurface rock strength values observed associated with burial history – deepest burial of paradox sediments around Green River
- Interface (reservoir/seal and within seal) modeling of fracture propagation
Outcrop analysis – Outcomes

Lithologic heterogeneity results in assorted fracture patterns

Fracture swarms observed at changes in lithology; these units lack shale inter-beds and occur in limestone-dominated facies.

Bifurcation of fractures across lithologic boundaries

Mineralized fractures in resistant medium bedded sandy limestone experience deflection and arrest in the inter-bedded shale.