Temperatures and Potential Geothermal Resources in the Piceance Basin, Colorado

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Temperatures in Colorado Sedimentary Basins

- Bottom-hole-temperatures from oil and gas wells, recorded during routine logging runs, are being compiled as part of a National Geothermal Data System.

- In Colorado the temperatures are generally higher than average for their depth (high geothermal gradients) – we are interested in the possibility of using the heat (geothermal energy) in these sedimentary basins.

Thermal Spring Rico, Colorado
Use of geothermal energy in oil extraction from oil sands is under study in Alberta.

Geothermal energy could be used as a sort of “preheater” for major oil sands mines, which use 40-degree Celsius water to separate oil from sand. A new research project is exploring this option. Today most of that heat comes from natural gas.

Outline

• Brief introduction to the Piceance Basin
• Bottom-hole temperatures from the basin and correction for drilling disturbance.
• Calculation of geothermal gradients and distribution of geothermal gradients in the basin
• Possible causes of variations in gradient across the basin
• Is there a usable geothermal resource?
Piceance Basin
Major Drainages

Component drainage basins are shown

Modified from Taylor, 1987
Generalized Stratigraphic Column for the Piceance Basin

Modified from Colorado Geological Survey (unpublished)
Depth to Base of Cameo Coal

Modified from EPA, 2004
Bottom-Hole-Temperatures vs. Depth

Piceance Basin: BHT vs. Depth

- $y = 0.038x + 2.3777$, $R^2 = 0.3028$
- $y = 0.0336x + 11.776$, $R^2 = 0.7214$
- $y = 0.0375x + 3.9623$, $R^2 = 0.4787$
- $y = 0.0151x + 25.96$, $R^2 = 0.108$
- $y = 0.012x + 79.702$, $R^2 = 0.0742$

Depth Range:
- <1000
- 1000-2000
- 2000-3000
- >3000
# Temperature Statistics by Unit/Formation

<table>
<thead>
<tr>
<th>Stratigraphic Age</th>
<th>Name</th>
<th>Average Depth, m</th>
<th>Average Temperature, °C</th>
<th>Geothermal Gradient, °C/km</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleocene/Eocene</td>
<td>WASATCH</td>
<td>917 ± 471</td>
<td>44 ± 15</td>
<td>39 ± 15</td>
<td>181</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>WILLIAMS FORK</td>
<td>2183 ± 549</td>
<td>89 ± 24</td>
<td>36 ± 12</td>
<td>664</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>MESA VERDE</td>
<td>1756 ± 772</td>
<td>65 ± 25</td>
<td>33 ± 11</td>
<td>238</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>CAMEO</td>
<td>2320 ± 432</td>
<td>93 ± 19</td>
<td>35 ± 6</td>
<td>477</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>ROLLINS</td>
<td>2367 ± 401</td>
<td>99 ± 19</td>
<td>37 ± 6</td>
<td>4605</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>COZZETTE</td>
<td>2139 ± 568</td>
<td>89 ± 23</td>
<td>38 ± 7</td>
<td>68</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>CORCORAN</td>
<td>2287 ± 745</td>
<td>88 ± 24</td>
<td>35 ± 6</td>
<td>956</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>MANCOS</td>
<td>1353 ± 589</td>
<td>55 ± 25</td>
<td>34 ± 8</td>
<td>563</td>
</tr>
<tr>
<td>Upper Jurassic</td>
<td>MORRISON</td>
<td>1622 ± 642</td>
<td>63 ± 20</td>
<td>34 ± 7</td>
<td>255</td>
</tr>
<tr>
<td>Lower Permian/Upper Pennsylvanian</td>
<td>WEBER</td>
<td>1985 ± 213</td>
<td>64 ± 9</td>
<td>26 ± 3</td>
<td>464</td>
</tr>
</tbody>
</table>
Drilling Disturbance Correction

Piceance Basin: Data from Wells with 2nd Cement Bond Logs and Drill Stem Tests

Temperature, °C vs. Depth, m

Data Sources:
- CBLT
- CBL BHT
- DST T
- DST BHT

Equations and R² values:
- \( y = 0.0302x + 20.514 \)  
  \( R^2 = 0.6071 \)
- \( y = 0.0273x + 17.607 \)  
  \( R^2 = 0.7094 \)
- \( y = 0.0264x + 21.015 \)  
  \( R^2 = 0.8387 \)
- \( y = 0.0258x + 13.392 \)  
  \( R^2 = 0.7418 \)
Corrected Bottom-Hole-Temperatures vs. Depth

Piceance Basin: Corrected BHT vs. Depth

- $y = 0.0398x + 7.4462$, $R^2 = 0.3221$
- $y = 0.0353x + 16.845$, $R^2 = 0.7414$
- $y = 0.0392x + 9.0308$, $R^2 = 0.5015$
- $y = 0.0168x + 31.028$, $R^2 = 0.131$
- $y = 0.0138x + 84.77$, $R^2 = 0.0951$

Depth Range
- <1000
- 1000-2000
- 2000-3000
- >3000

Depth, m

Corrected BHT, °C

0 50 100 150 200 250

0 1000 2000 3000 4000 5000 6000
Average Geothermal Gradients

Piceance Basin: BHT Average Gradients

Latitude, decimal degrees

Longitude, decimal degrees

-109.2-108.8-108.4 -108 -107.6-107.2-106.8

Average Gradient °C/km
- 22.5-25.0
- 25.0-27.5
- 27.5-30.0
- 30.0-32.5
- 32.5-35.0
- 35.0-37.5
- 37.5-40.0
- 40.0-42.5

(Values in parentheses represent data points.)
Average Well Depths

Piceance Basin: BHT Average Well Depths

Latitude, decimal degrees

Longitude, decimal degrees

Average Well Depth, m
- <1000
- 1000-1250
- 1250-1500
- 1500-1750
- 1750-2000
- 2000-2250
- 2250-2500
- 2500-2750
Average Geothermal Gradient vs. Average Well Depth

Piceance Basin: Average Geothermal Gradient vs. Average Well Depth

\[ y = -0.004x + 39.114 \]

\[ R^2 = 0.1086 \]
Geothermal Gradient vs. Well Collar Elevation

Piceance Basin: Geothermal Gradient vs. Well Collar Elevation

\[ y = 0.0072x + 21.207 \]

\[ R^2 = 0.1574 \]
Topography, Quaternary Faults and Remnants of Lava Flow at Southern End of Basin
Leadville Limestone:
Karst/cavern-forming, frequently faulted/fractured.
Conclusions

• In the southern Piceance Basin, 100 °C at 2.5 to 3.3 km depth; 150 °C at 3.75 to 5.0 km.

• Temperatures are sufficient for binary power production or process heat.

• The Leadville Limestone may be found at depths with these temperatures and yield very high volumes of geothermal fluid.
Acknowledgements:
- Brian Scott, Colorado Geological Survey
- Matt Sares, Colorado Department of Water Resources

For Further Information
- [http://geosurvey.state.co.us/Pages/CGSHome.aspx](http://geosurvey.state.co.us/Pages/CGSHome.aspx)
- Energy Resources
  - Renewables
    - Geothermal
- [Paul.Morgan@state.co.us](mailto:Paul.Morgan@state.co.us)

THANK YOU