A Preliminary Analysis of Geothermal Resources in the Central Raton Basin, Colorado, from Bottom-Hole Temperature Data*

Paul Morgan[1]

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Please refer to companion article, "Stratigraphic Control of Temperatures in the Wattenberg Field, Denver Basin, Colorado," Search and Discovery Article #80066 (2009).

[1]Colorado Geological Survey, Denver, CO (morgan.pablo@gmail.com)

Abstract

The Raton Basin is the southernmost classical Laramide basin in the Rocky Mountain region and straddles the New Mexico-Colorado state line. As an asymmetric basin, deeper to the west, its central portion lies at the western end of Las Animas County, Colorado. Over 1900 bottom-hole temperatures (BHTs) were compiled from the logs of 1886 wells in Las Animas County, most of which were drilled over the past fifteen years, and are associated with the extraction of coalbed methane, primarily from Upper Cretaceous and Paleocene formations. Most of the wells from which the BHT data were collected were drilled in about a day using air percussion rotary rigs, and to depths of less than 1100 m (3600 ft). The exclusive use of air in drilling many of the shallower holes and short drilling times deviates from conditions for which general temperature corrections for the effects of drilling were derived. However, even before correction, the data show significant coherent trends, with higher gradients, in general, in the western portions of the study area. BHT data from 54 wells in the depth range of 1128 to 2253 m (3700 to 7400 ft) were corrected by standard correction techniques. These corrections were checked and found to be consistent with extrapolated equilibrium temperatures at two depths in a deep well in which temperature data were available at four different times. Data from these deeper wells and tentative data from the shallower wells allow general conclusions to be made concerning geothermal resources in Las Animas County and, in particular, the central Raton Basin. Geothermal gradients in Las Animas county west of the Raton Basin are typically <40°C km-1 (22°F/1000 ft) and do not indicate significant geothermal resources. Much of the Raton Basin has gradients in the range of 40-60°C km-1 (22-33°F/1000 ft), and locally gradients exceed 60°C km-1 (33°F/1000 ft) and continue to depths of at least 2000 m (6550 ft). The corrected BHT temperature at this depth is 113°C (235°F), which is hot enough for electricity generation, using binary power-plant technology. Water is abundant at shallower depths in the basin. If sufficient natural permeability exists, or if stimulated permeability can be generated, at depths of 2000-2500 m (6500-8200 ft) for hot-water production and reinjection, the central Raton Basin is a good candidate for binary power-plant electricity generation.

Reference

Geothermal Energy Worldwide, 2000, Geothermal Education Office: Web accessed 6 October 2006 http://geothermal.marin.org/geomap_1.html

Reiter, M.A., C.L. Edwards, H. Hartman, and C. Weidman, 1975, Terrestrial heat flow along the Rio Grande Rift, New Mexico and southern Colorado: GSA Bulletin, v. 86/6, p. 811-818.

A Preliminary Analysis of Geothermal Resources in the Central Raton Basin, Colorado, from Bottom-Hole Temperature Data

Paul Morgan

Colorado Geological Survey

COLORADO GEOLOGICAL SURVEY

Presenter's Notes:

Introduction

Oil and gas basins are a somewhat ignored area in the search for geothermal resources. During the past nine months we have examined data from three Colorado oil and gas basins--the Denver, Raton, and San Juan basins, and found that there is a high potential for finding geothermal resources in this type of basin, and wells commonly exist to the depth of the resource.

Presentation Outline:

- Sedimentary Basins, an unconventional geothermal target
- The Raton Basin
- BHT Data from the Raton Basin
- Interpretation and Implications for a Geothermal Resource

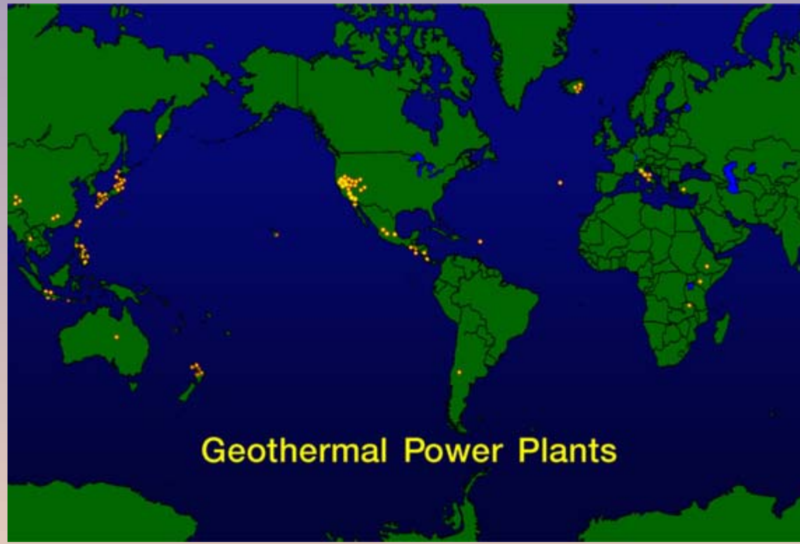
COLORADO GEOLOGICAL SURVEY

Presenter's Notes: This presentation first briefly discusses the collection of bottom-hole-temperature or BHT data, the primary data source for this study. Data from the Central Raton Basin are presented and discussed, along with some information from western Colorado.

“Traditional” Geothermal Sites

- Plate Margins & other areas of young volcanism
- North American Geothermal Power Plants:
  - California
  - Nevada
  - Utah
  - Alaska
  - Western Mexico
  - (Hawaii)

Locations of Geothermal Power Plants

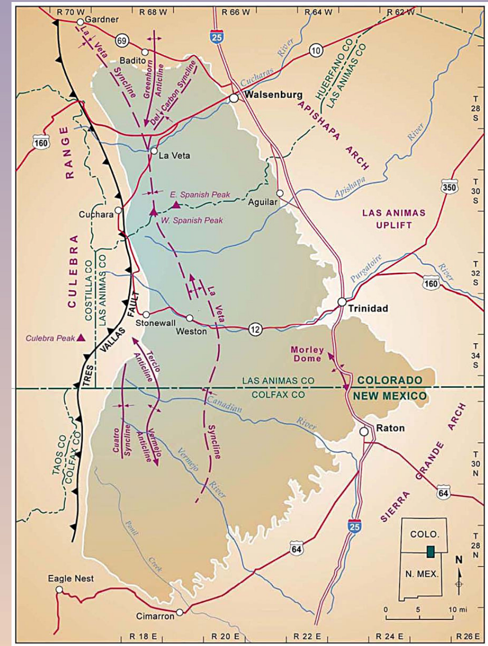


Source: Geothermal Education Office: 2000

Raton Basin

Laramide Basin

Long history of coal mining. Last 15 years, primarily drilling for coalbed methane. In Colorado most activity is in the Las Animal County portion of the basin.



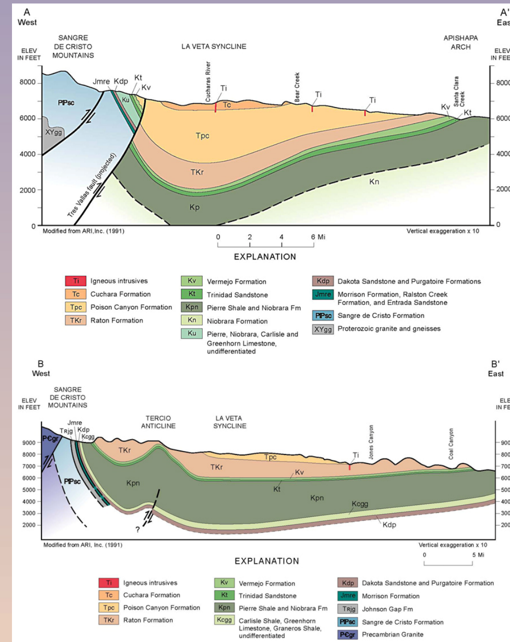
COLORADO GEOLOGICAL SURVEY

Presenter's Notes: The Raton Basin straddles the Colorado-New Mexico state line. After more than a century of coal mining, since 1998 most geological activity in the basin has been drilling for coalbed methane. In Colorado, the most active producing area is the central basin in Las Animas county.

Asymmetric basin

West-to-east cross-sections, just north and just south of Las Animal County.

Note: west-to-east topographic gradient and west-to-east shallowing of basin.

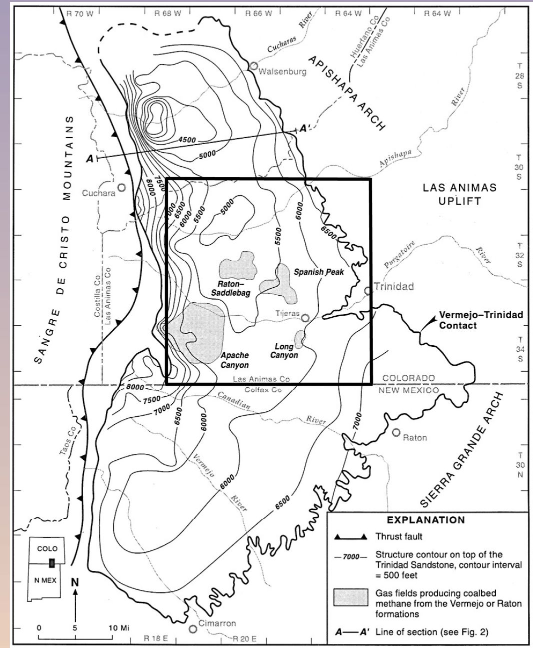


COLORADO GEOLOGICAL SURVEY

Presenter's Notes: These two roughly west-to-east cross-sections are from just north of (top) and just south of (bottom) the central Raton Basin. The main structure of the basin was formed approximately 60-70 million years ago by east-west compression, causing faulting and steep eastward dips on the west side of the basin, and gentle westward dips on the east side of the basin. Today the general topographic gradient is down to the east from the Sangre de Cristo Mountains in the west.

Location of Study Area

Detailed study area is a square approximately 45 x 45 km (28 x 28 miles)

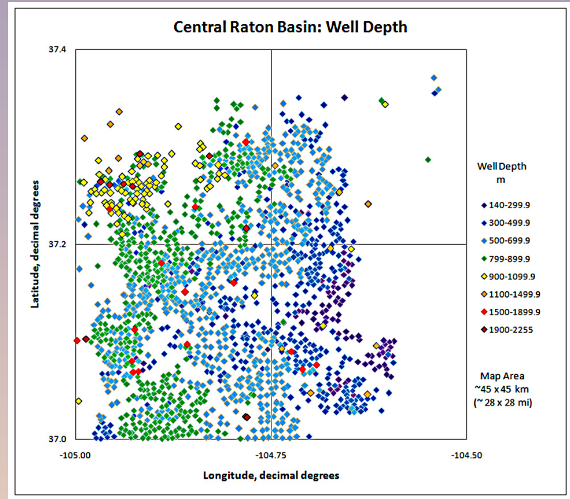


COLORADO GEOLOGICAL SURVEY

Presenter's Notes: The location of the study area is shown by the black box here and is approximately square, 45 km (28 miles) on a side.

Well Depths

Well depths range from less than 150 m to approximately 2255 m (490 to 7400 feet), and in general wells were shallower in the east and deeper in the west, although the deepest wells were scattered throughout the basin.



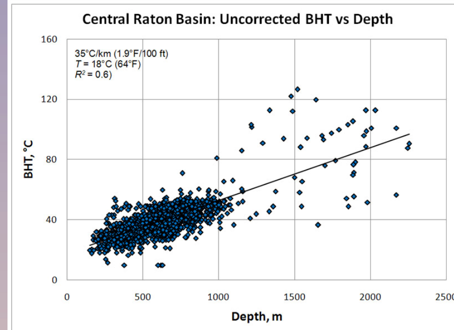
Presenter's Notes: Bottom-hole-temperature (BHT) data were collected from more than 1800 wells in the study area with depth ranging from 150 to 2255 m (490 to 7500 ft). Most of the wells were less than 1100 (3,600 ft) in depth, but data were collected from deeper wells scattered throughout the basin. In general, shallower wells were on the eastern side of the basin and deeper wells to the west.

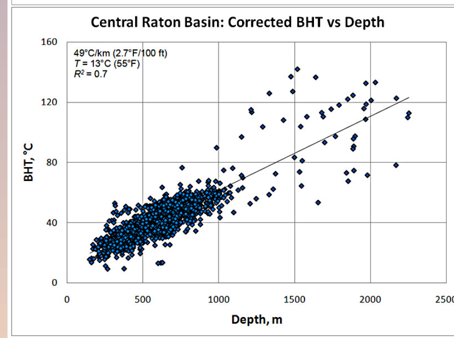
BHTs versus Depth

There was reasonable coherence in the BHTs when plotted against depth.

The corrected BHTs give a more reasonable extrapolated surface *T* than the uncorrected data.

High heat flow in basin.





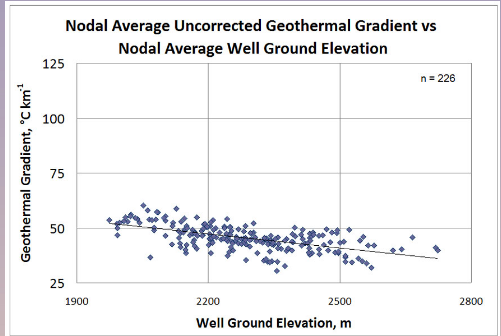
COLORADO GEOLOGICAL SURVEY

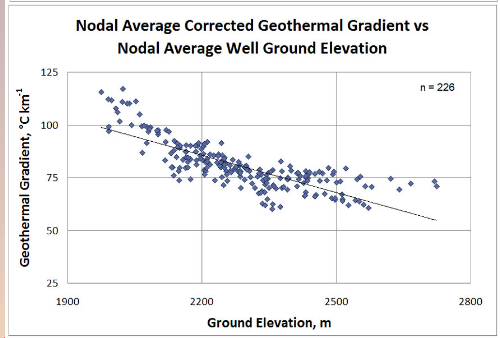
Presenter's Notes: BHT data, both uncorrected (upper) and corrected (lower) for the effects of the drilling disturbance, are plotted against depth here. Both sets of data show a reasonable cluster at shallower depths, and the scatter at greater depths is mostly associated with different positions in the basin. The extrapolated surface intercept from the corrected BHTs is more consistent with the mean annual ground surface temperature estimated from local weather stations than that extrapolated from the uncorrected data; this suggests that the drilling disturbance corrections used are reasonable. The geothermal gradients calculated from the trend lines to these data are 49.2 ± 11.9°C km^{-1} (2.70 ± 0.65°F/100 ft, n=1842) and 45.3 ± 12.5°C km^{-1} (2.49 ± 0.69°F/100 ft, n=1842) for the corrected and uncorrected BHTs, respectively. A single heat flow value published from the Central Raton Basin is 196 ± 40 mW m^{-2} (Reiter et al., 1975), which is significantly higher than other published values from the High Plains.

Geothermal Gradient versus Surface Elevation

Data were passed through a “boxcar” filter to give a uniform distribution of data on nodal points.

The resulting gradients show a negative correlation with elevation.

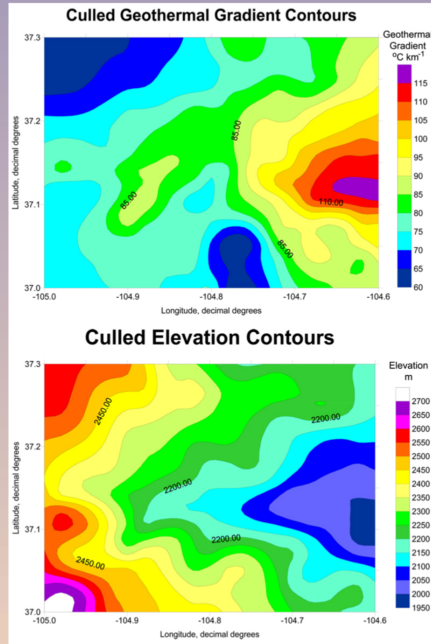




Contoured Data from Previous Slide

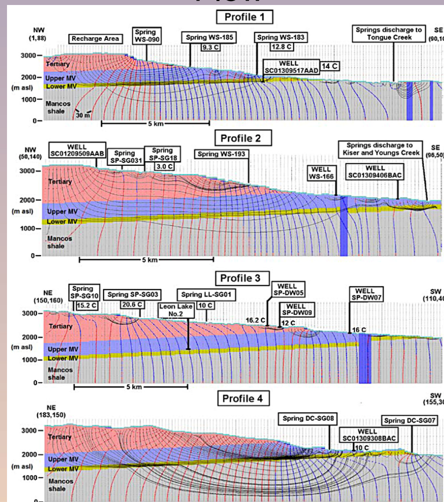
Note approximate spatial correlation in negative correlation between geothermal gradients and surface elevation.

The prominent feature at the center right is the drainage of the Purgatoire River.

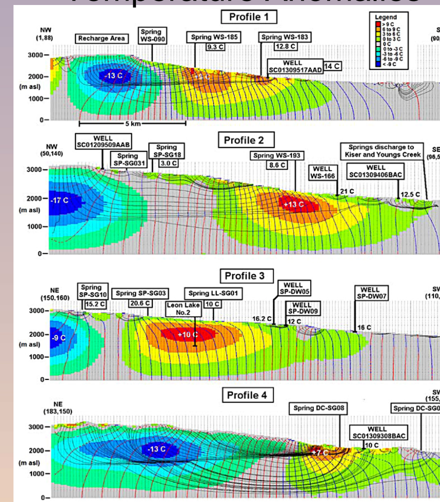


Models Fitting Data of Tongue Creek Watershed, Grand Mesa, western CO

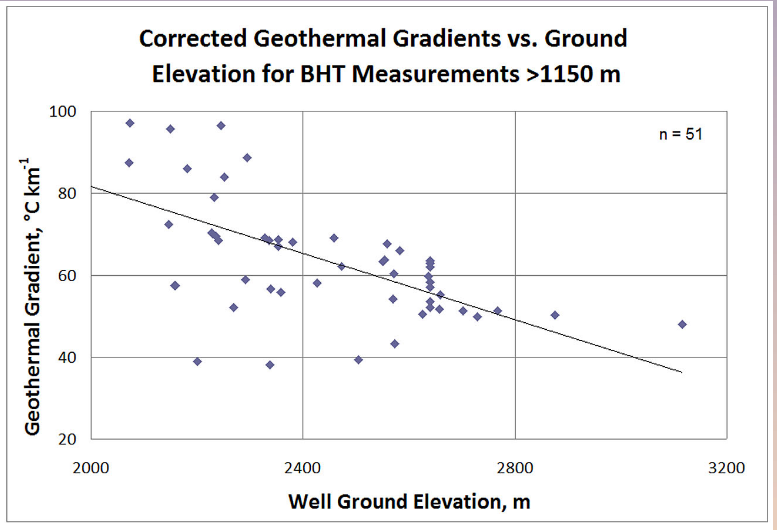
Flow



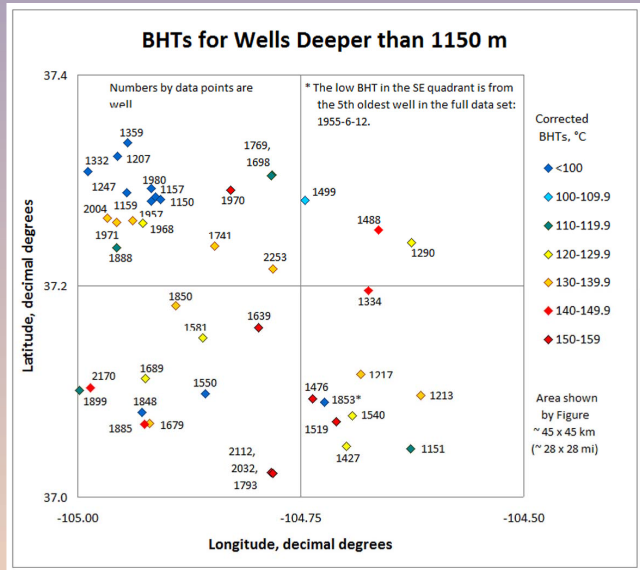
Temperature Anomalies



Gradient vs Elevation Inverse Correlation Includes Deep Wells



Corrected Deep Temperatures



Raton Basin Conclusions

- Deeper BHTs confirm trends of shallower data – highest gradients and subsurface temperature beneath Purgatoire River drainage.
- Temperatures as high as 130°C (265°F) at 1500-2000 m (4900-6500 feet)
- Extrapolated temperatures of ~150°C (300°F) at 1800-2500 m (6000-8000 feet)
- Good Potential for Geothermal Electric Power Production

Next Steps

- Pioneer Natural Resources actively investigating potential resource, with assistance from Colorado School of Mines and Colorado Geological Survey
- Actively reviewing available temperature data other than BHTs to confirm resource temperatures
- Formations at 1800-2500 m (6000-8000 feet) probably tight, and insufficient available water (~10,000 gallons/minute/well) from natural reservoirs for hydrothermal system – therefore investigating an engineered or enhanced geothermal system.