Geothermal Resources in Colorado's Oil and Gas Basins

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Colorado Geological Survey

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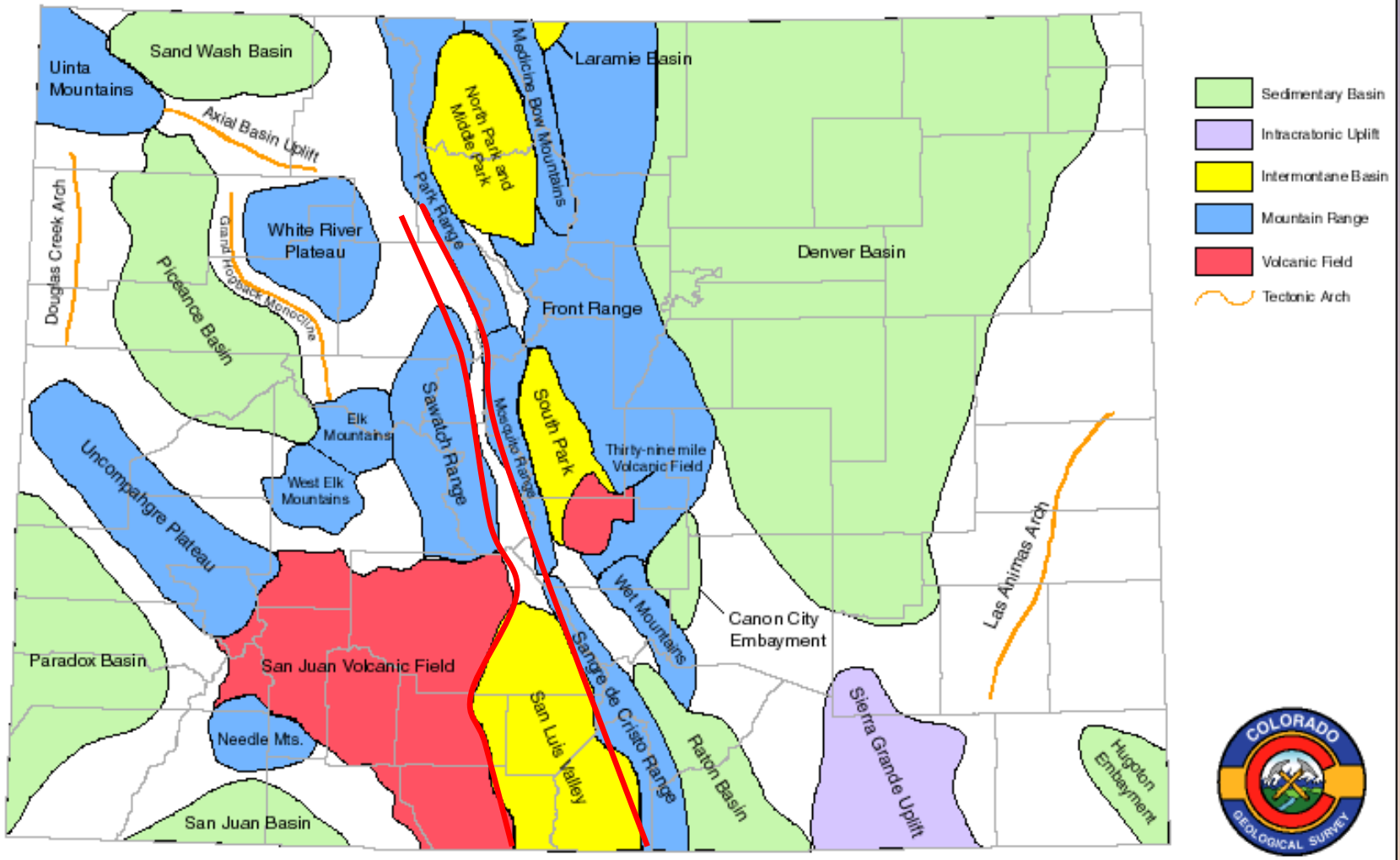
Presentation:

- Sedimentary Basins: 3 vignettes from Colorado
  - Underdeveloped geothermal resources
- The Paradox Basin in Colorado
  - Thermal refraction by salt diapirs
- The Wattenberg Field, Denver Basin
  - The data set that (almost) wouldn't
- The Raton Basin in Colorado:
  - High heat flow, BHT data target a drilling site: Why is EGS still wasting money drilling crystalline rock?

Major Tectonic and Geographic Features of Colorado

modified from Tweto, 1979



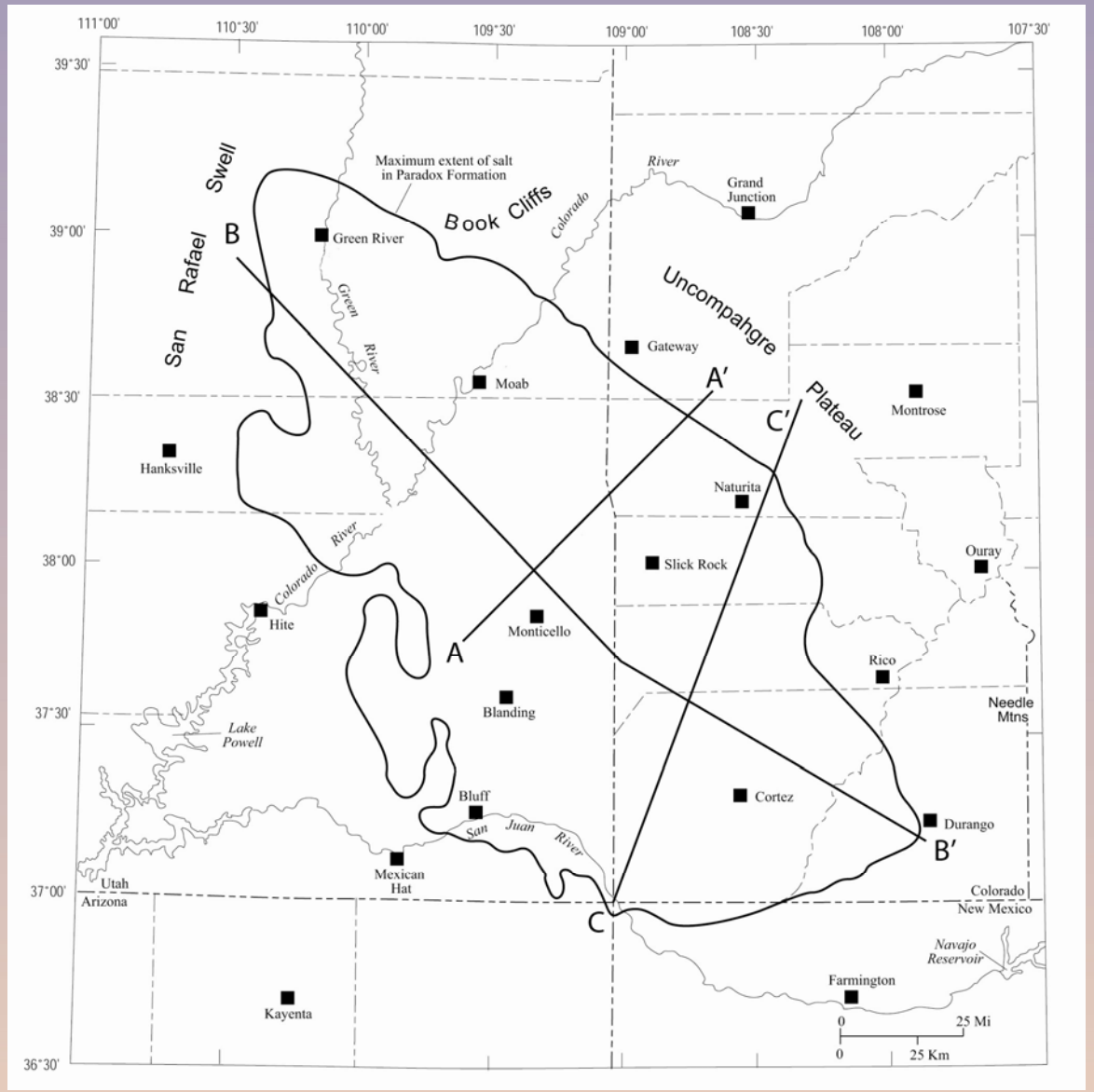
Paradox Basin, Utah and Colorado

Approximately Oval Basin

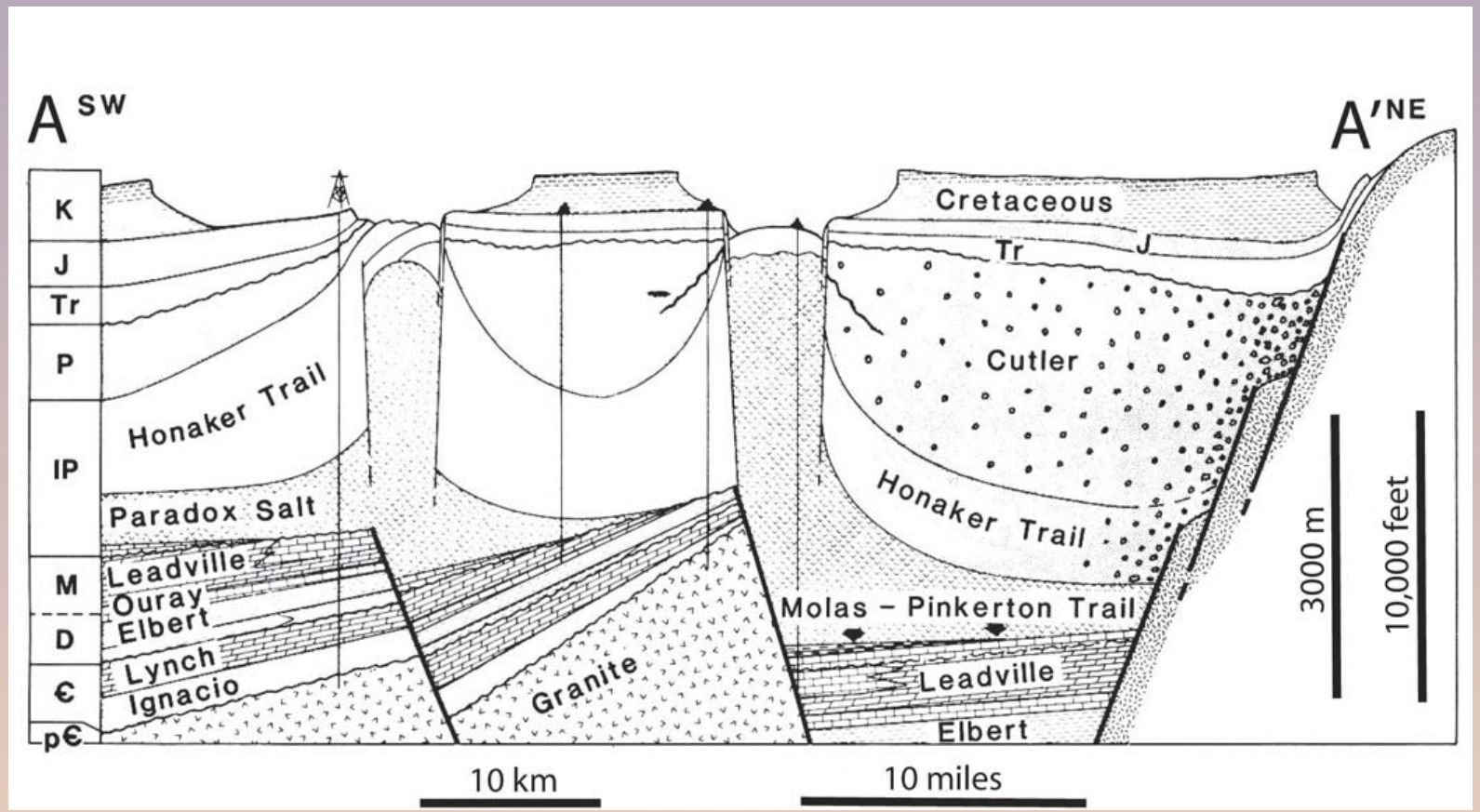
Maximum NW-SW length
~300 km (~190 miles)

Maximum NE-SW width
~150 km (~95 miles)

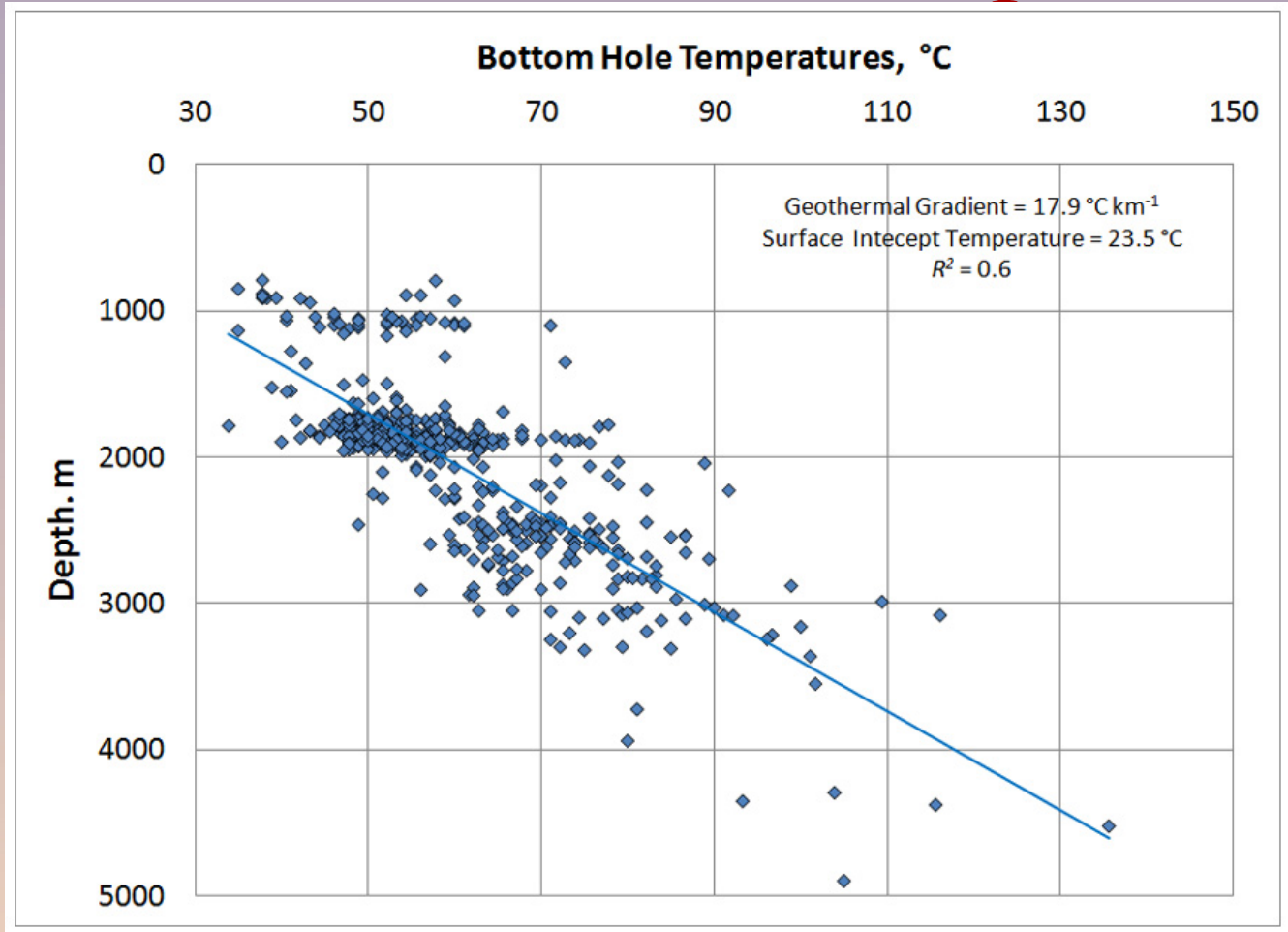
Pennsylvanian evaporite sequence



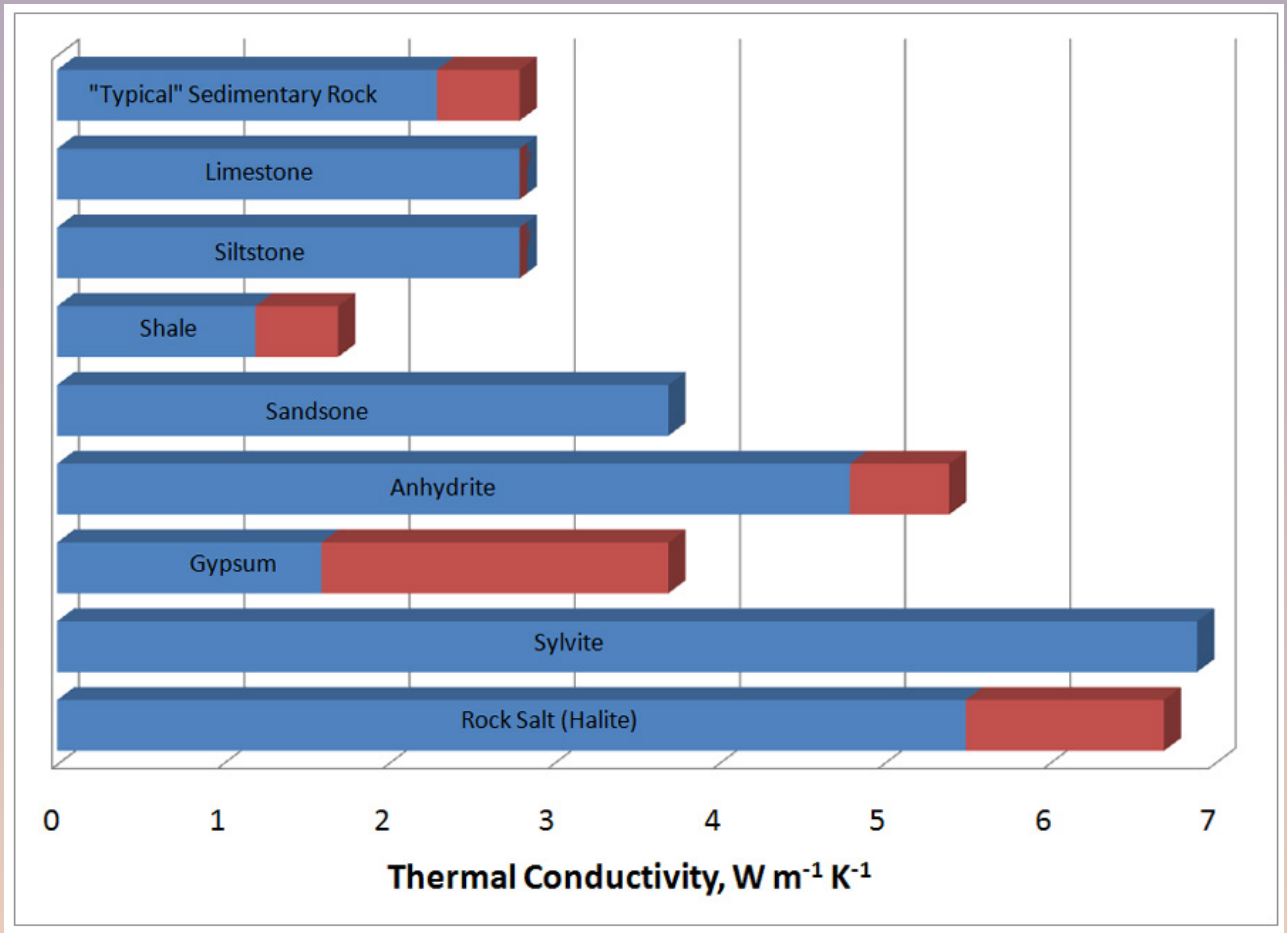
Paradox Basin Cross-Section Showing Salt Diapirism



Colorado Paradox Basin Uncorrected BHT vs. Depth Data

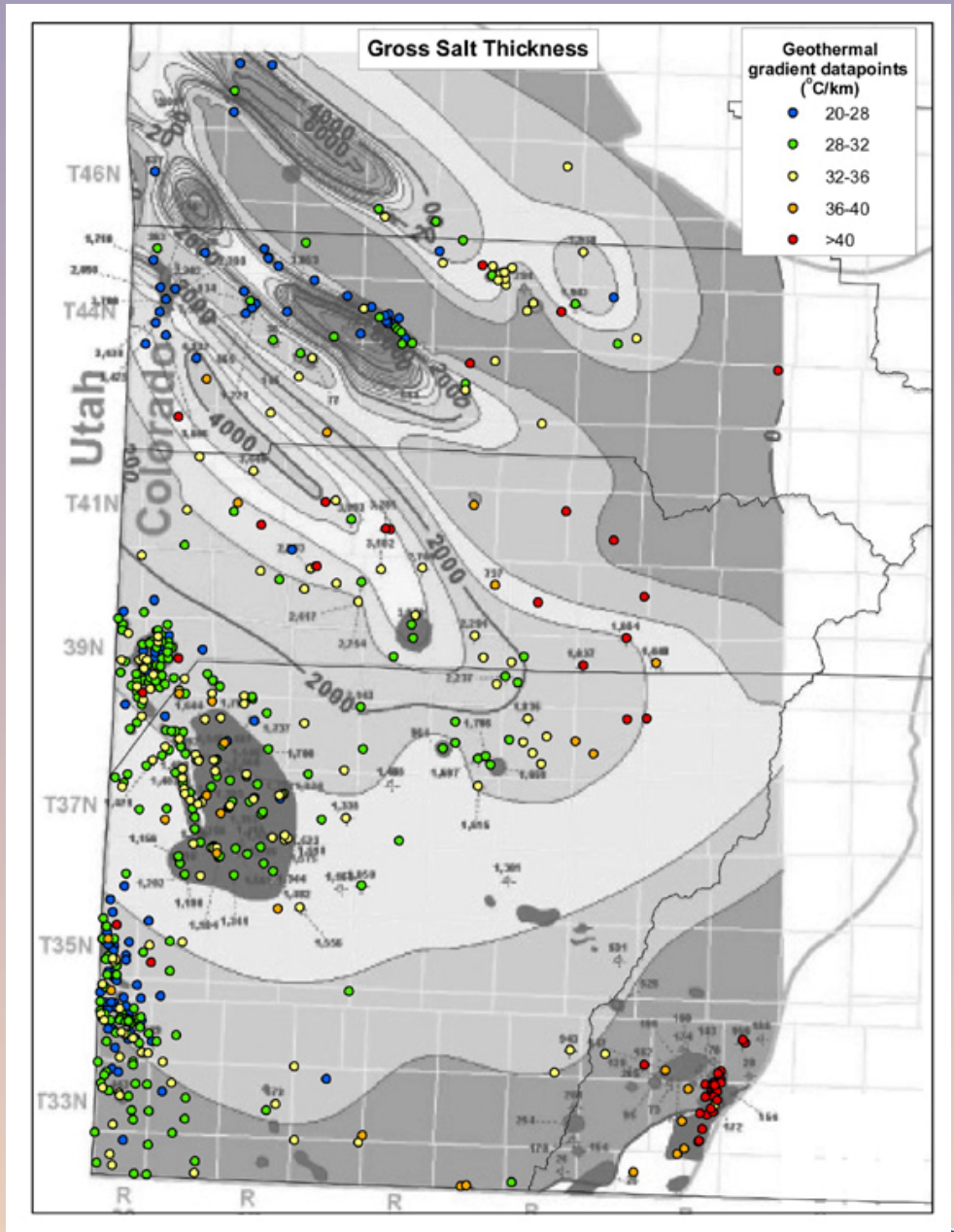


Probable Range in Thermal Conductivities in Paradox Basin



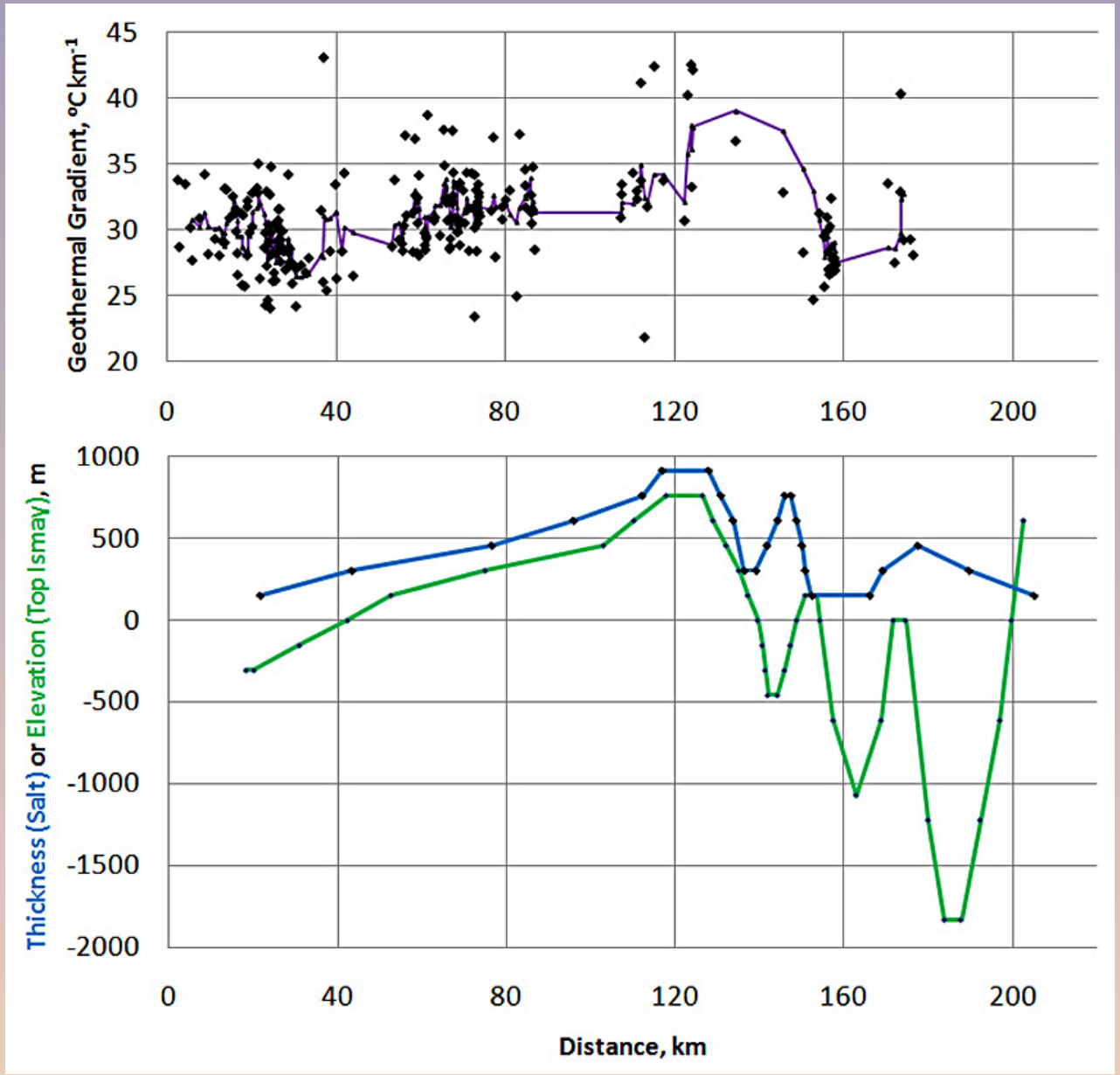
Colorado Paradox Basin: Corrected Geothermal Gradients plotted on Salt Thickness

Geothermal Gradients calculated from Corrected BHT Data



Colorado Paradox Basin: Profiles of Geothermal Gradient Data, Salt Thickness, and Elevation of Top of Salt Formation

A 5-point moving average is also plotted with the geothermal gradient data

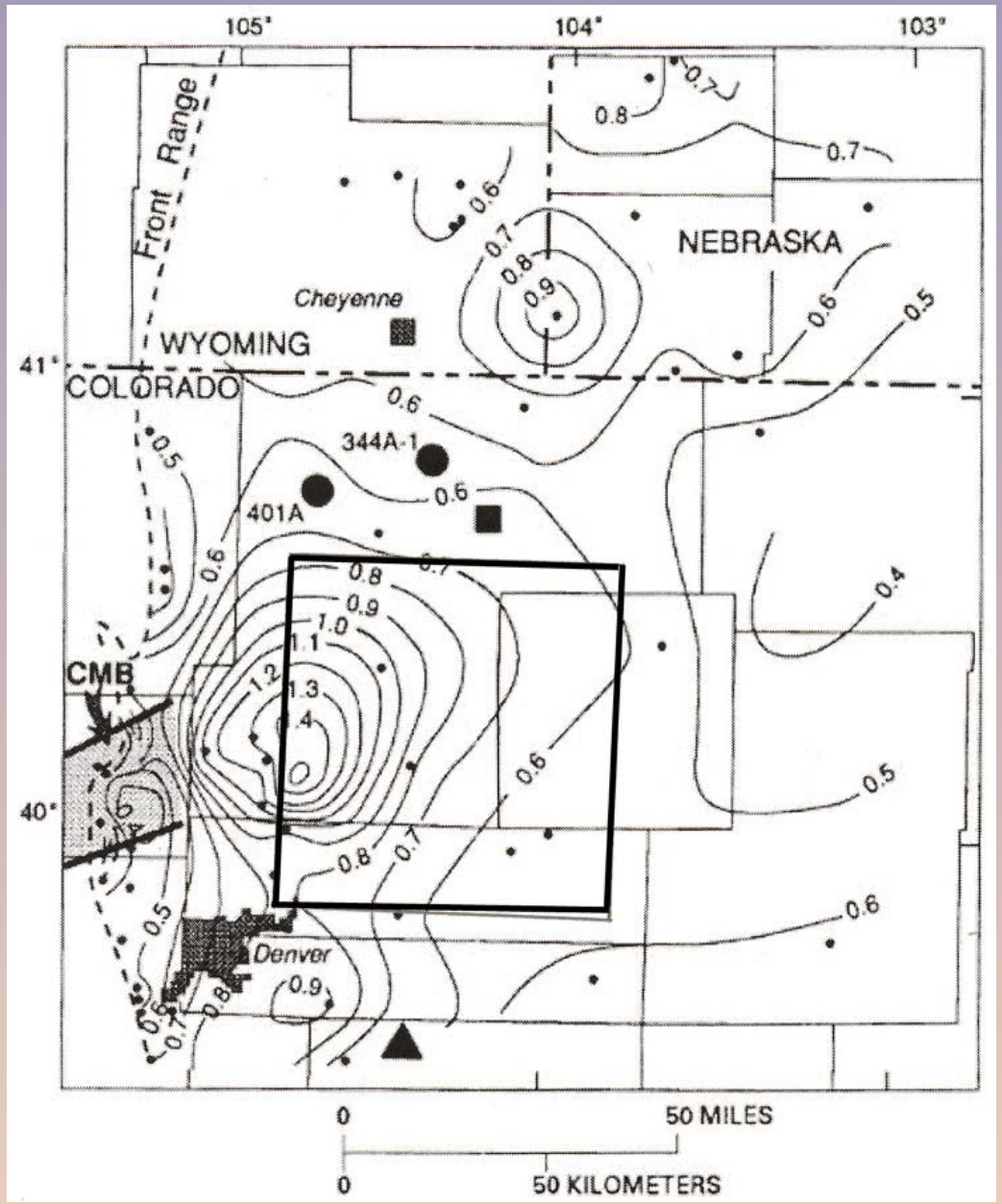


Wattenberg Field
Denver Basin

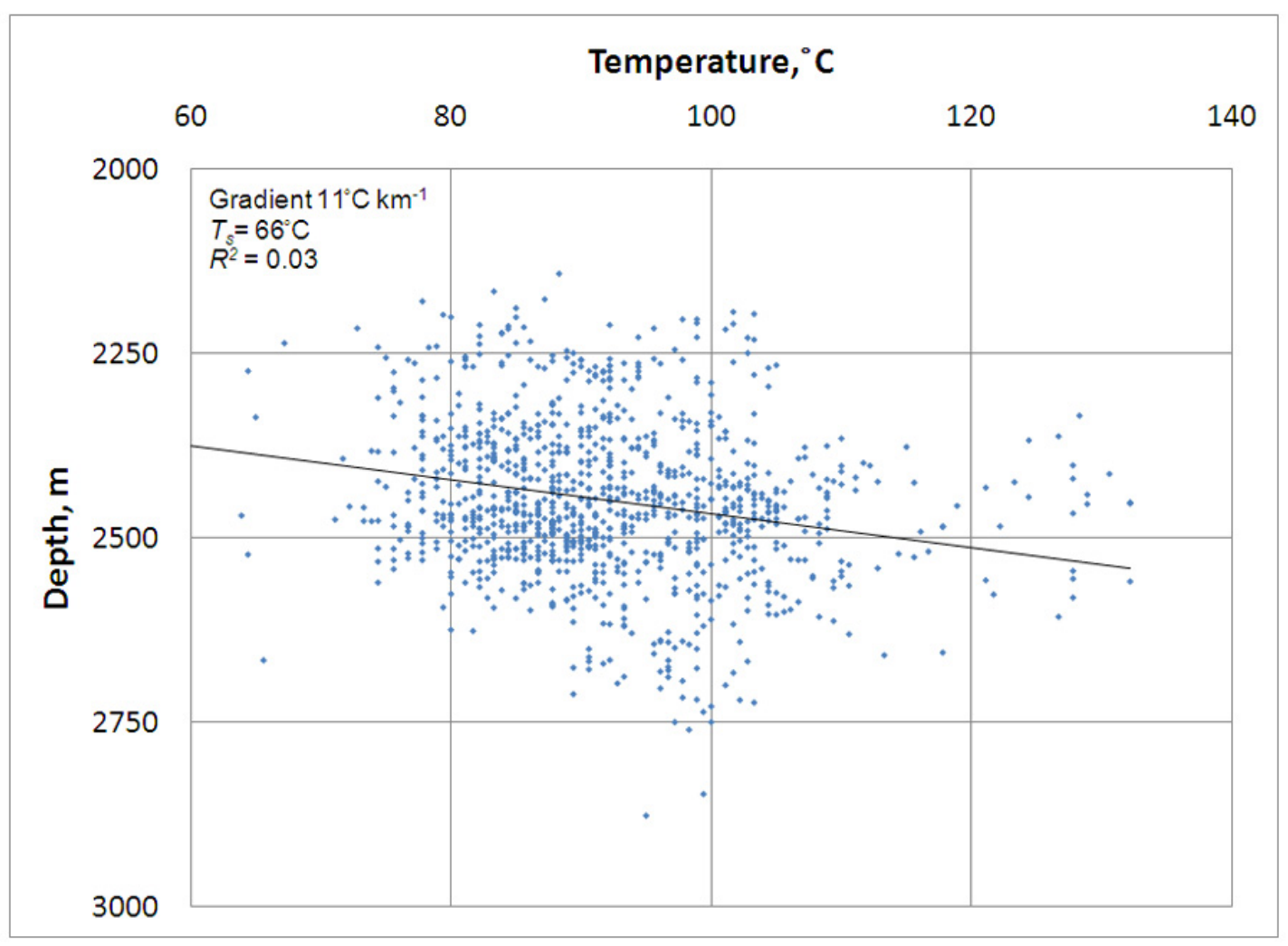
Box shows location of study area
(approximately 80 km by 80 km)
50 by 50 miles)

Contours are vitrinite isoreflectance
(after Higley *et al.*, 1992)

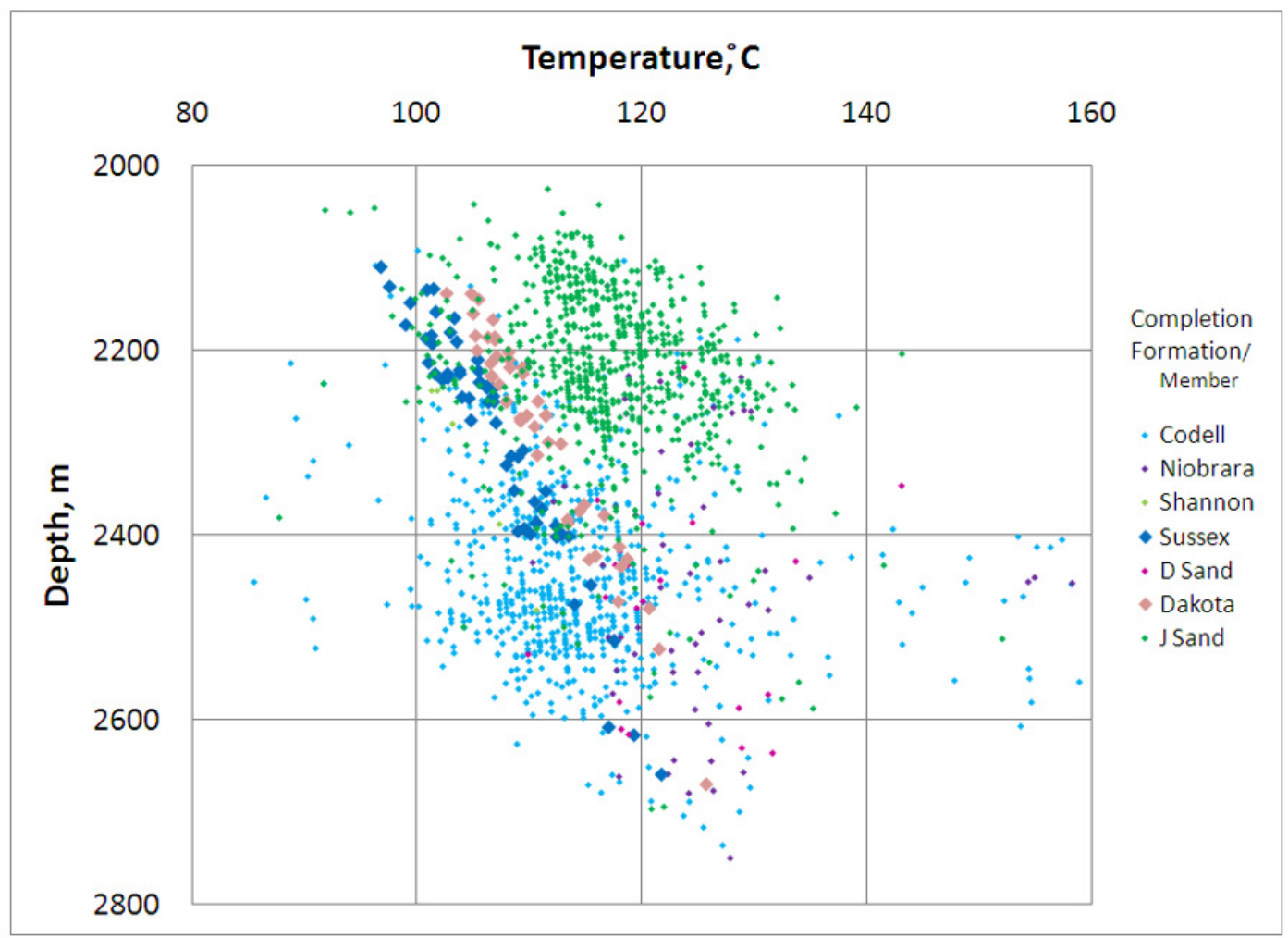
CMB indicate the northeastern termination of the hypothesized Colorado Mineral Belt



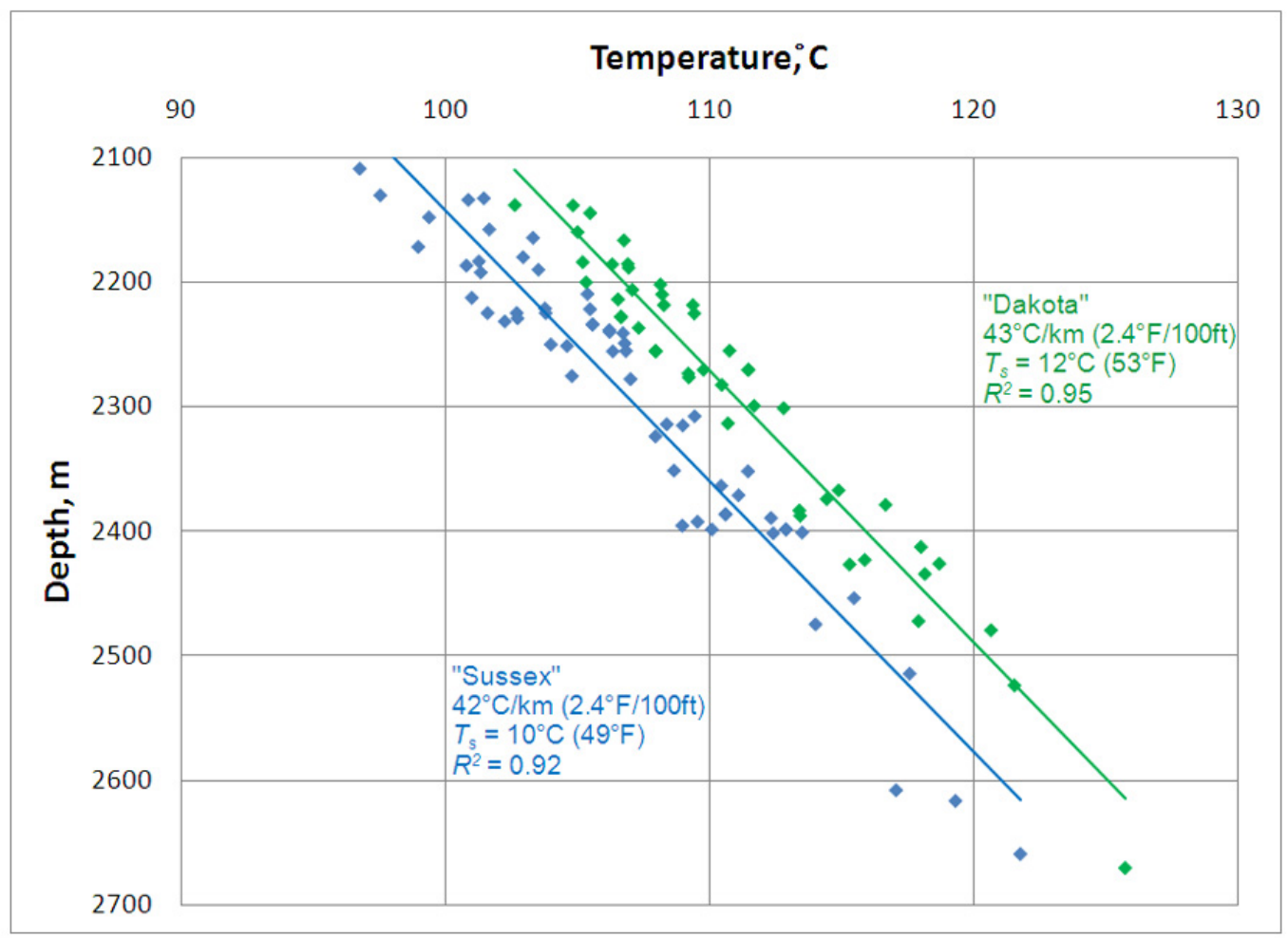
Wattenberg Field BHT vs. Depth Data



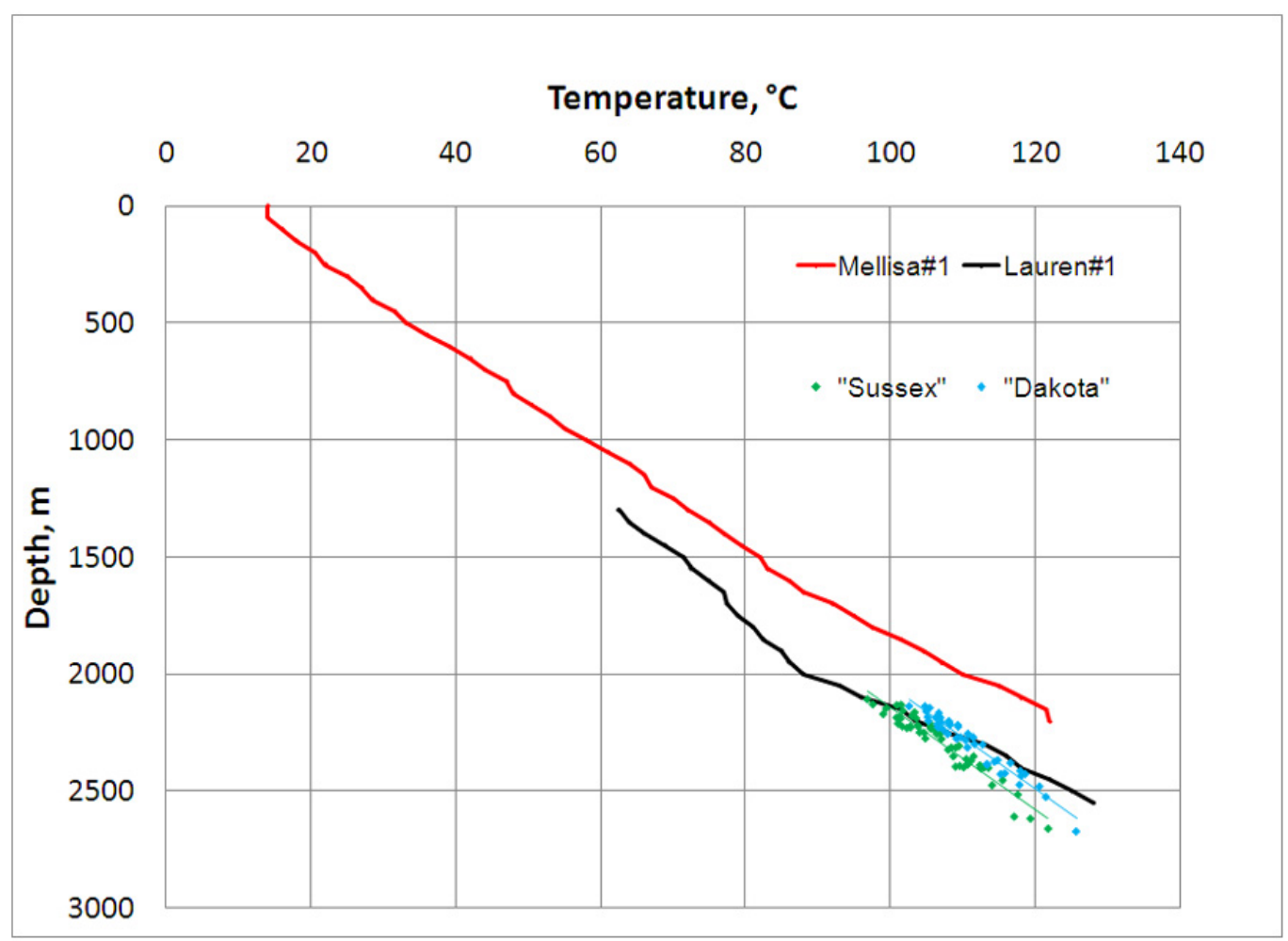
Wattenberg Field BHT vs. Depth, Identified by Completion Formation



Wattenberg Field, "Sussex" & "Dakota" BHT vs. Depth Data



Denver Basin Precision Temperature Logs with BHT Data

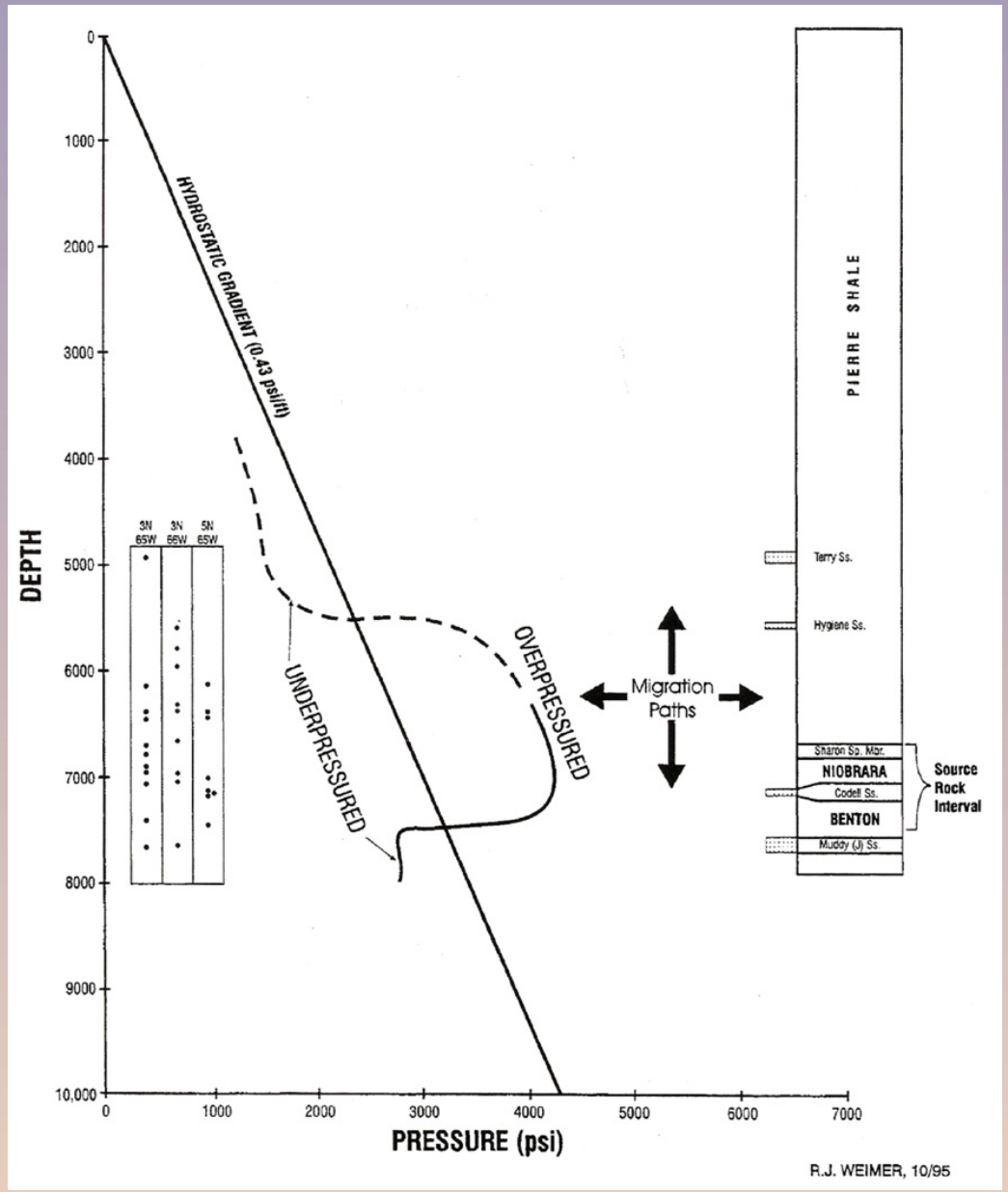


Wattenberg Field
Pressure vs. Depth

BHT data from the overpressured zone do not yield useful geothermal gradient results

BHT data from above and below the overpressured zone yield useful geothermal gradient results

Are the temperatures in the overpressured zone disturbed, or are the data unreliable?



Raton Basin Colorado

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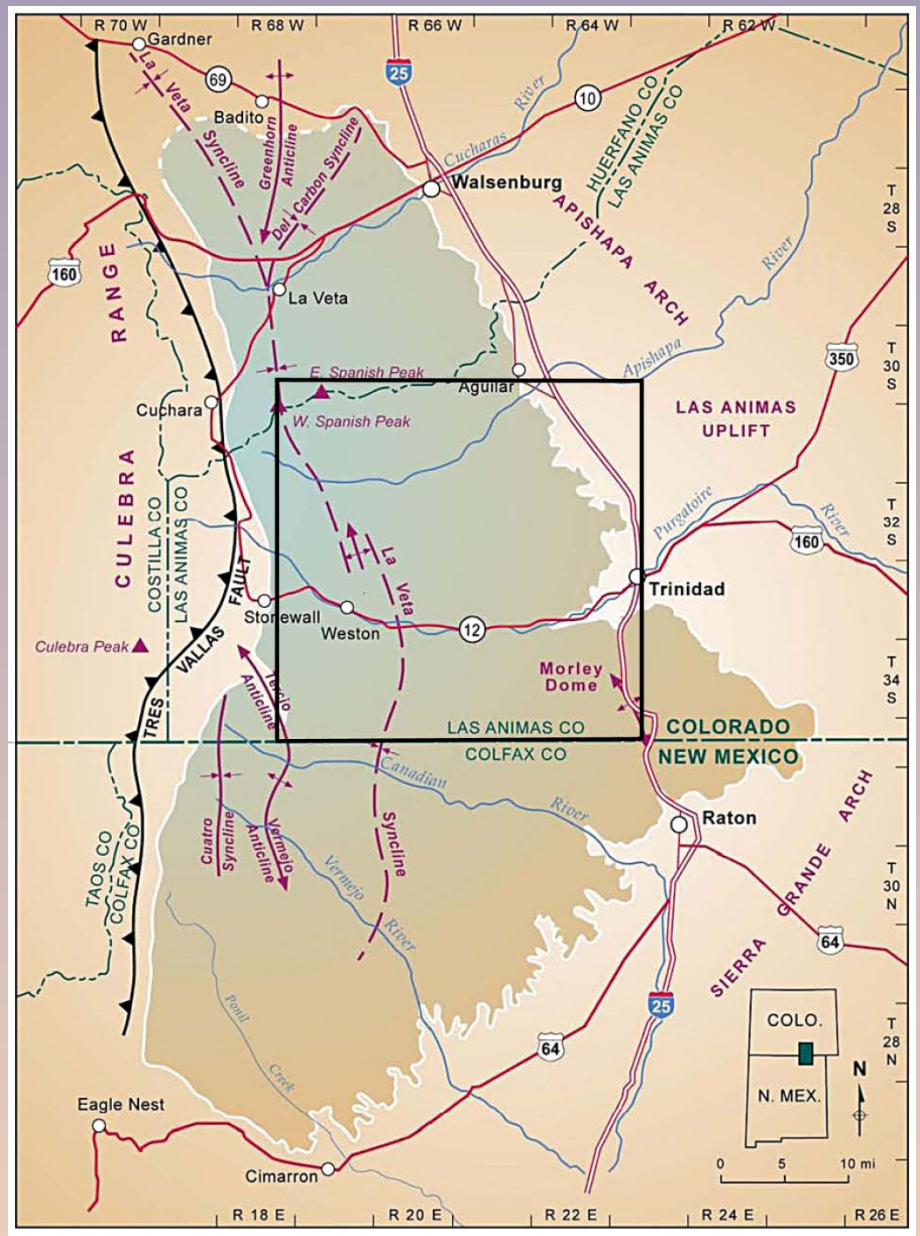
Long history of coal mining. Last 15 years, primarily drilling for coalbed methane

In Colorado most activity is in the Las Animas County portion of the basin.

Study Area ~45 by 45 km

(~28 by 28 miles)

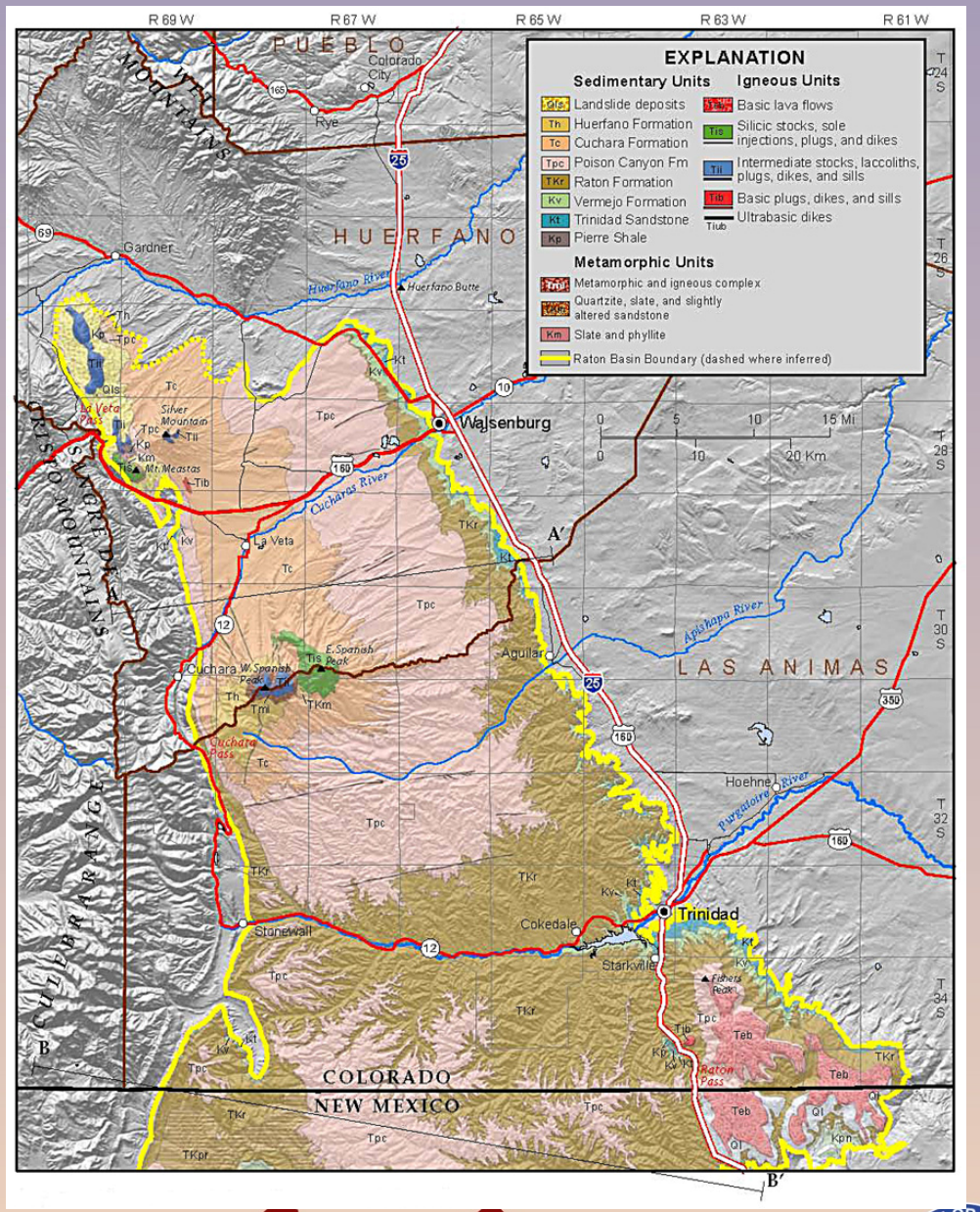


Raton Basin Geology

Southernmost classical Laramide (~80 to ~60 Ma) basin in the southern Rocky Mountain region.

Covers about 13,000 km^2 (4,000 miles^2), and is bounded on the west by the Sangre de Cristo Mts.

Regional slope is from west to east.

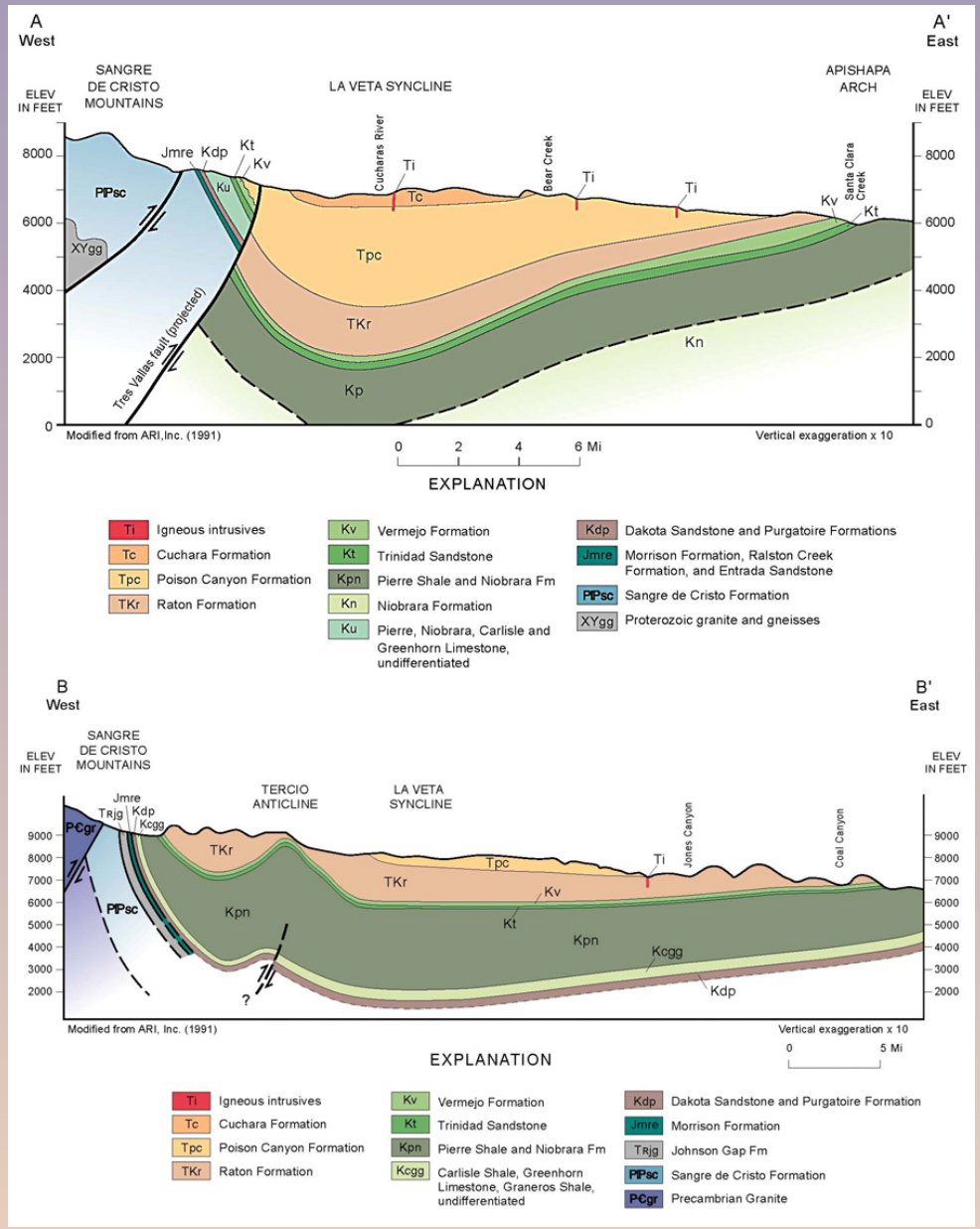


Asymmetric basin

Basin fill ranges in age from Devonian through Plio-Pleistocene.

Late Oligocene and Miocene igneous rocks occur as stocks, laccoliths, flows, plugs, dikes, and sills: gabbroic to rhyolitic.

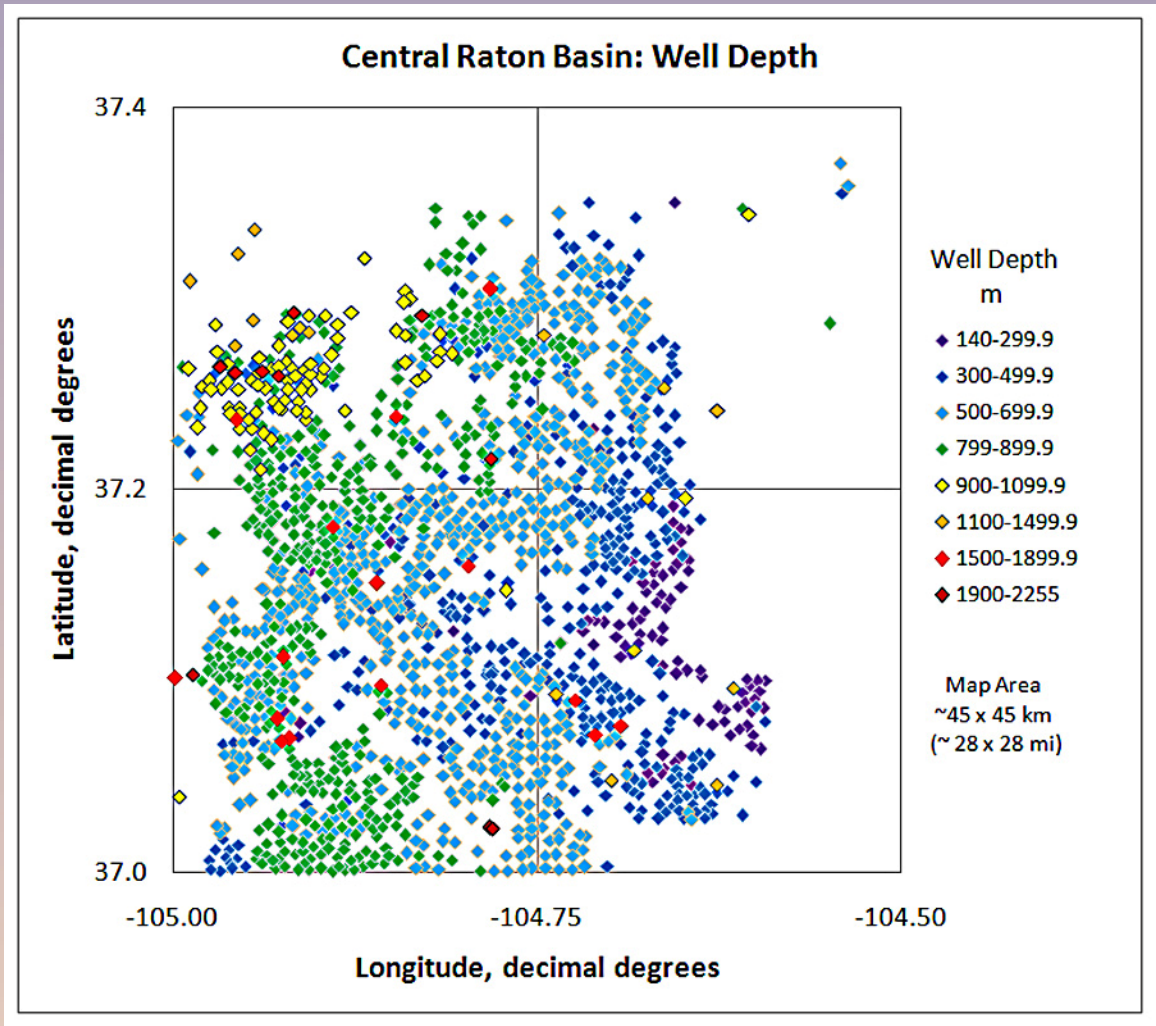
Steep dips on west, gentle (1° to 5°) on east.



Well Depths

Well depths ranged from less than 150 m to approximately 2255 m (490 to 7400 feet) .

In general wells shallower in east and deeper in west, although the deepest wells are scatted throughout the basin.

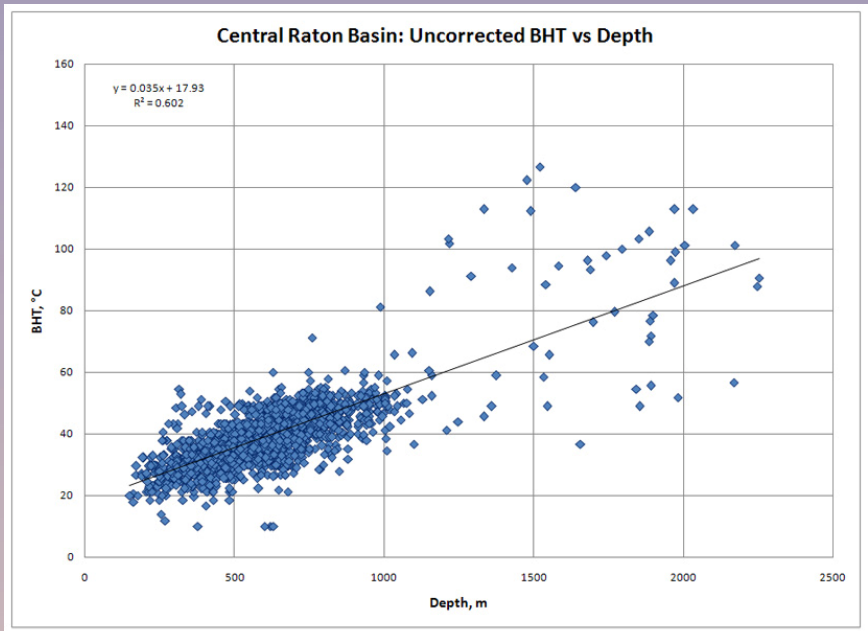


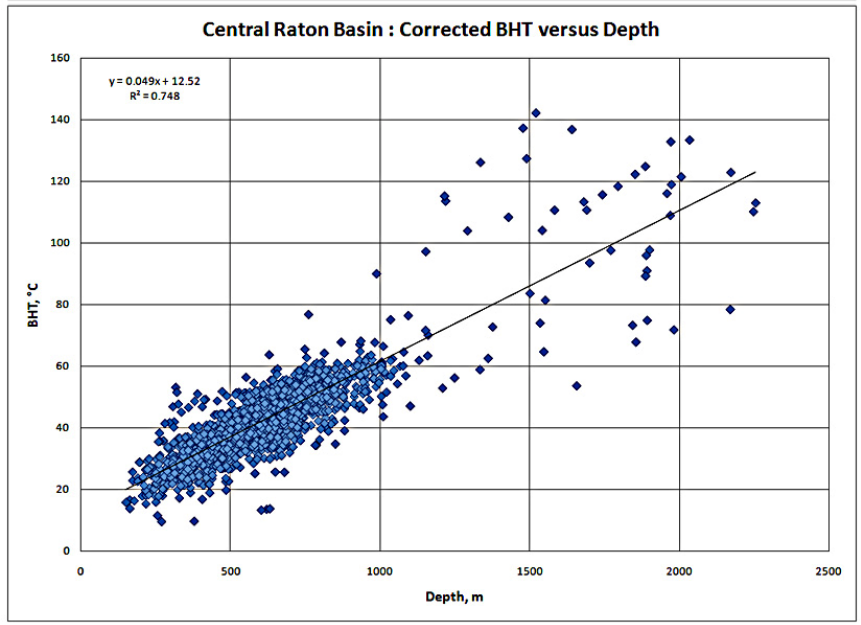
BHT's versus Depth

Reasonable coherence in BHT's when plotted against depth.

Corrected BHT's give more realistic surface intercept than the uncorrected data.

High heat flow in basin.

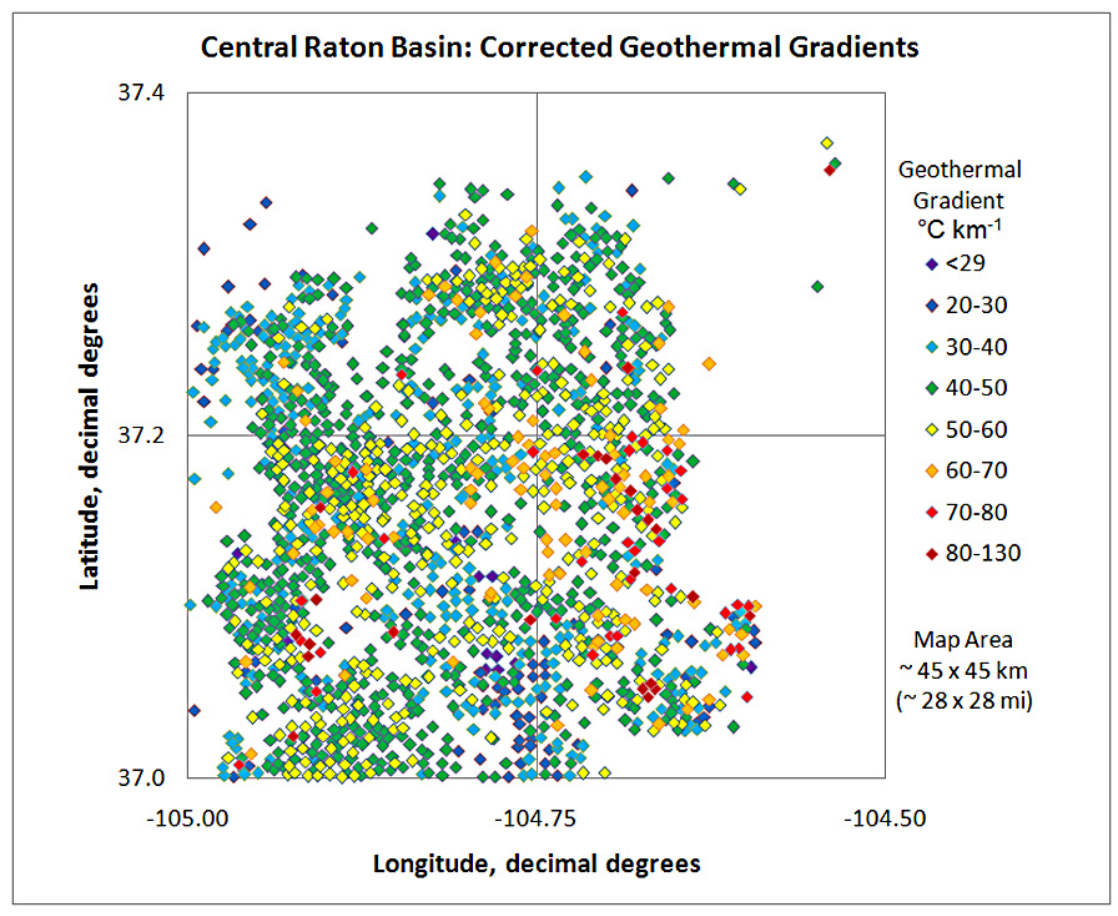




Geothermal Gradients

Uncorrected geothermal gradients from individual wells range from <20 to >100°C/km, and this range is increase by 10-30°C/km for corrected geothermal gradients.

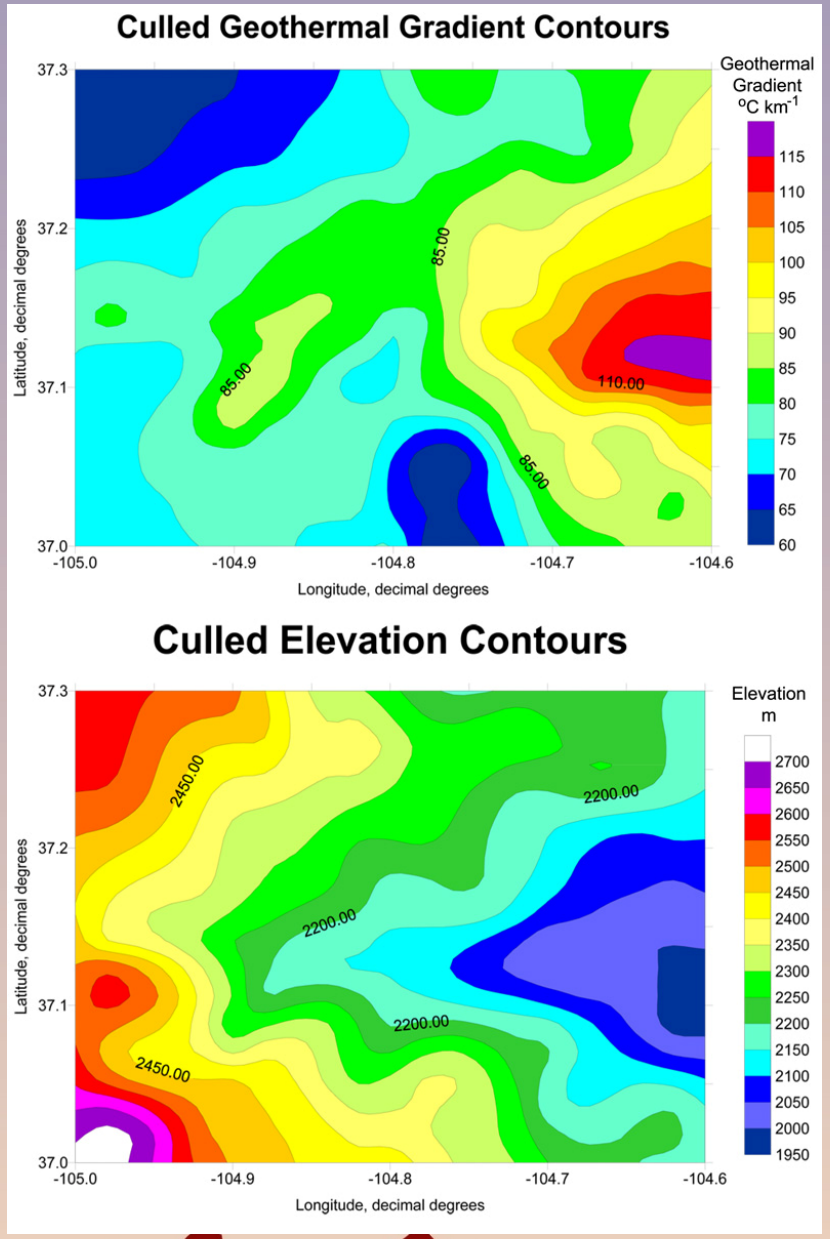
General trend of higher gradients to the east, but large scatter in data.



Contoured Smoothed Gradient and Elevation Data

General negative correlation between geothermal gradients and elevation.

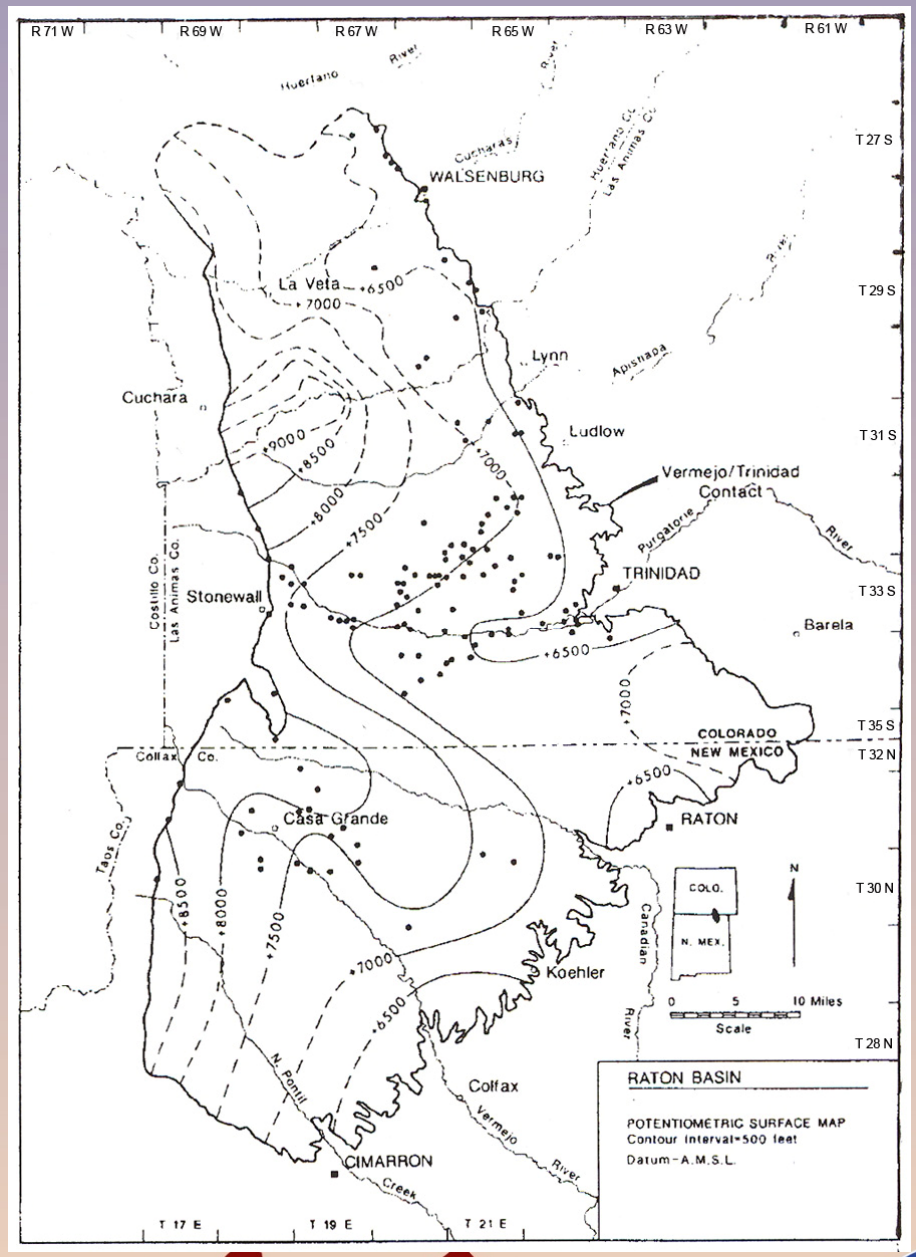
The prominent elevation feature at the center right is the drainage of the Purgatoire River.



Raton Basin Potentiometric Surface

Slope in water table potentiometric surface indicates subsurface water flow toward area beneath Purgatoire River Drainage.

Combined with geologic structure suggests down-dip flow in west and focused up-dip flow beneath Purgatoire River to east.



Concluding Remarks I

- Sedimentary basins can make attractive exploration targets, but need to be selective.
- Abundant “free” BHT data: noisy, but useful.
- Paradox Basin demonstrates thermal refraction, low geothermal gradients
- Wattenberg Field in Denver Basin high noise to signal ratio, but high gradients: Binary electricity generation

Concluding Remarks II

- Pattern of geothermal gradients in central Raton Basin consistent with heat transport by very slow water movement → geothermal target.
- Measured temperatures as high as 127°C (261°F) at 1500-2000 m (4900-6500 feet)
- Conservatively extrapolated temperatures of 150°C (300°F) at 1800-2500 m (6000-8200 feet)
- Formations probably "tight" at 1800-2500 m, but extensive experience of hydrofracking these formations
- Excellent prospect for sedimentary EGS and binary electricity production (better than any crystalline rock site currently under study)